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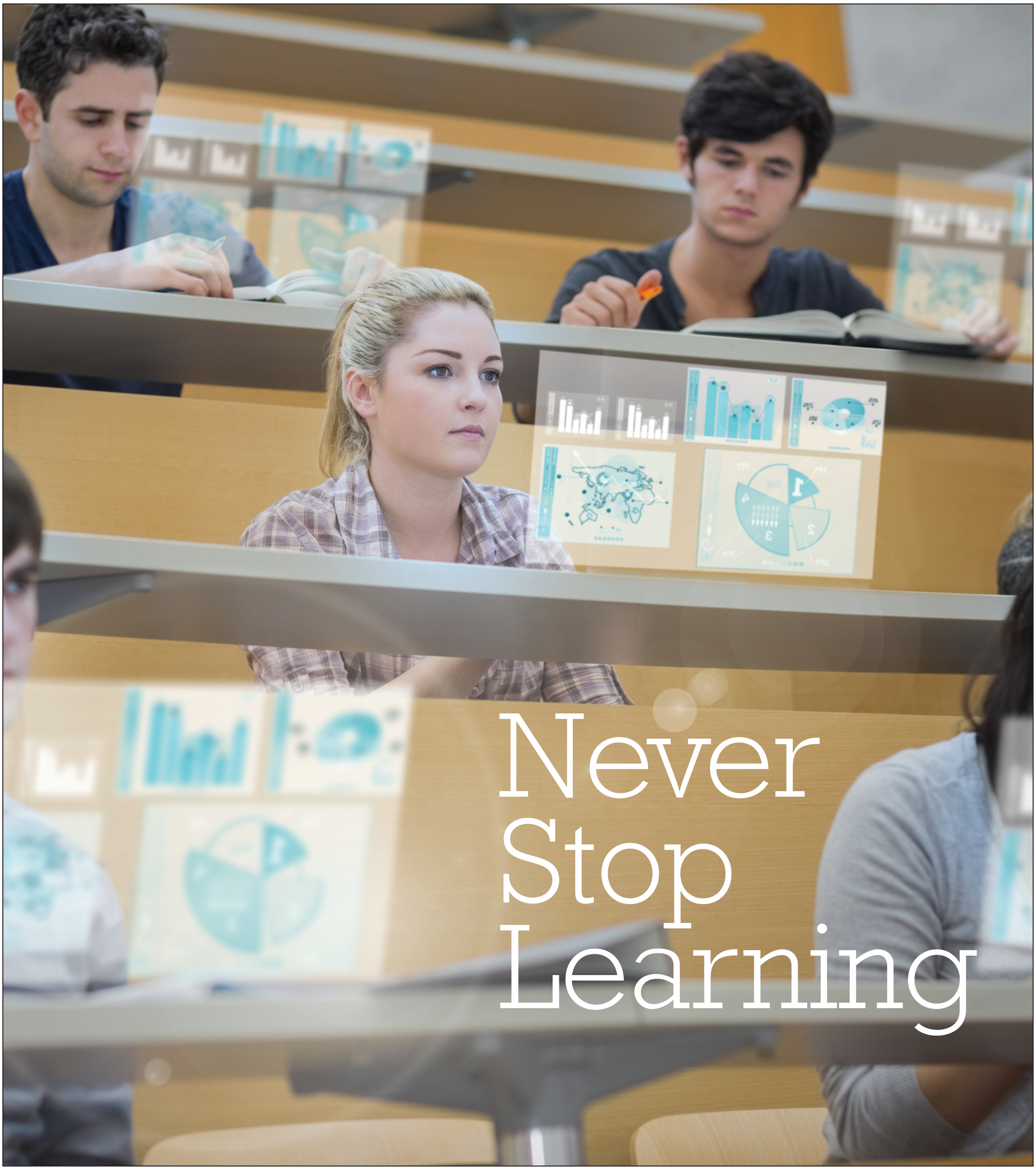
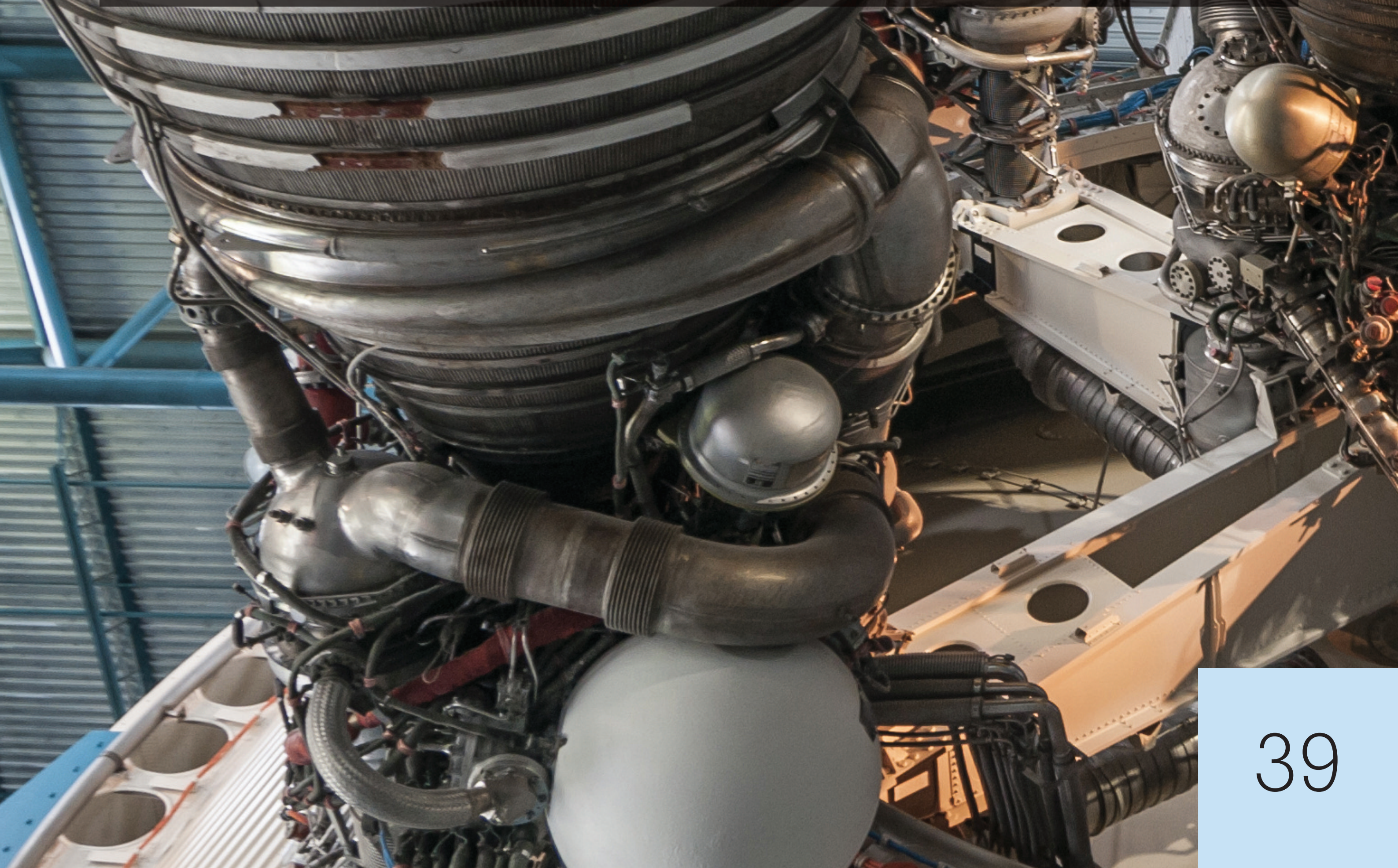


Massive Open Online Content – *A Hands-on Introduction to Engineering Simulation*

Dr Rajesh Bhaskaran is the Swanson Director of Engineering Simulation in the Sibley School of Mechanical and Aerospace Engineering at Cornell University. In this interview with Ian Symington, NAFEMS' Technical Officer, Rajesh discusses a novel approach to teaching engineering analysis and simulation that is seeing a huge level of interest.

Interested parties can enrol in the MOOC or find additional information at nafe.ms/2fOYaAV



Can you explain to our readers the basic principle behind a MOOC (Massive Open Online Course)?

I came across the MOOC phenomenon 4 or 5 years back when I saw a couple of courses, one from MIT and one from Stanford. They had opened up the enrolment to anyone who had internet access and an email account. They had around 150,000 people sign up. They basically recorded what they were doing in the classroom and set up some homework. This got people thinking, now 1 person can teach tens of thousands and this created a huge buzz. The Coursera MOOC platform was founded by professors at Stanford as a for Profit organisation while EdX was developed with funding from Harvard and MIT as a non-profit platform.

The MOOC movement was interesting to me and I thought it could be the ideal platform for teaching students about simulation. When I've surveyed students after they have taken a course, the feedback I receive is that the online tutorials are always the most useful part of the course. They find the online examples more useful than having me, in the computer lab, leading a hands-on session. In the lab, the computers can crash, I'm talking as they are trying to run through the example and the students are all working at different paces as some of them have used the tool before. I was putting a lot of effort into my lectures but the students were getting the most value from the homework and the online tutorials.

Was the course content developed specifically for the MOOC or was it adapted from existing classroom based material?

The course was developed from the start as an asynchronous course with students being able to work through the material at their own pace. Synchronous instruction works well on a small scale , especially when students have questions that they can take to me during my "office hours." With the MOOC we are moving from the lecturer being a sage on the stage to being a guide on the side. The MOOC also works well as I have a goal to get simulation embedded in other courses that are taught at Cornell.

The MOOC provides the opportunity for those involved in education to move from lecturing to mentoring. The key part of this is setting good homework exercises. For me the mentoring is the more enjoyable part of teaching. You have to be prepared to adapt the teaching style to the MOOC format, you can't just record a 1 hour lecture. I have split the MOOC content into short chunks separated by exercises that test the attendees understanding. The reason that a traditional classroom based approach does not work in this context is that the attendees are not in the classroom.

"…we are moving from the lecturer being a sage on the stage to being a guide on the side."

The course contains a number of worked examples but I was impressed on how much time was dedicated to discussing the problem prior to opening up the simulation package.

I'm not trying to teach what buttons to push in ANSYS but rather to teach conceptually what's under the hood so that what students do in ANSYS makes sense. In places like Cornell, students are exposed to maths and the physics through our regular courses. On the other side we have a program which exposes them to simulation, the problem was that these two sides are often disconnected.

I've developed a framework (See Figure 1) that I think really helps students to connect the two parts. In the "pre-analysis", I teach the students that they need to consider what mathematical model they are using, what are the assumptions and the physical principles that are inherent. The next point that I teach them to consider is "How is the tool solving that mathematical model?" One of the biggest misconceptions I see is that the students think they are solving the physical problem. They are rather solving a mathematical model of the physical problem. We want our students to be able to understand what is going on inside the "black box" that is a simulation tool. It is only by opening up the black box that we can prevent the garbage in – garbage out phenomenon from occurring. In parallel to discussing the mathematical model and numerical solution procedure we take the same physical problem and do hand calculations and look at how they compare to the mathematical model the tool is using. This often leads us to comparing the same physical problem using two different mathematical approaches. This approach is extremely robust and can be used across different disciplines. This approach sets you up perfectly for performing verification and validation. All of the problems in the MOOC are set up using this structure.

"With the MOOC we have one person teaching thousands on a one to one basis."

One aspect of the course that struck me is that the MOOC tackles, thermal, fluid, structural and even one way fluid structural coupling. This seemed very ambitious, I know very few simulation engineers in industry who are comfortable performing simulations across all these different disciplines.

This was a deliberate approach. I have a unique position at Cornell where I have to bring simulation into the mechanical and aerospace curriculum. As I was looking at different courses (fluid mechanics, solid mechanics, heat transfer) and looking at how I solve the problem using a classic approach and using ANSYS I felt like I was giving the students in each course a different story. I realised I was using the same tool to solve all these different problems and I thought there must be a common framework I can use to teach simulation. Almost all of these problems are boundary value problems (differential equations with boundary conditions). This type of mathematical model is independent of the physics and I think that getting the students using simulation across a range of domains helps to ensure they don't end up with a fragmentary view of engineering.

I noted that the example problems you use are quite complex, in the structural module you tackle a bolted joint, essentially a nonlinear contact problem. Did you have any concerns about using such complex examples?

No I don't have concerns about this. To be clear people are not going to be experts in performing nonlinear analysis after taking this course but it gives them an idea about how these problems can be approached. With the course I'm building the scaffolding, providing the foundation that will serve the course attendees in the future.

We need to push simulation down into the curriculum and I personally think it can be pushed down into the freshman year. Introducing simulation early can help to give relevance to some of the foundation topics that are being taught, like differential equations.

The course is also a good way of getting future engineers excited. The structural module contains interviews with a **SPACEX** engineer (Andy) which helps get the students excited. Andy talks about how the results of the simulation are used in his work to assess the bolted joint.

[Ed: In the course Andy uses the real world situation of analysing a bolted nozzle flange on the Saturn 5 engine (see Figure 3)]

"I have a good understanding of the mathematics but the way it is explained here would have made the acquisition of the understanding so so much quicker. I [greatly] appreciate this course of the big picture and practical frame it puts over a very complex and what for me at times past was a bewildering area."

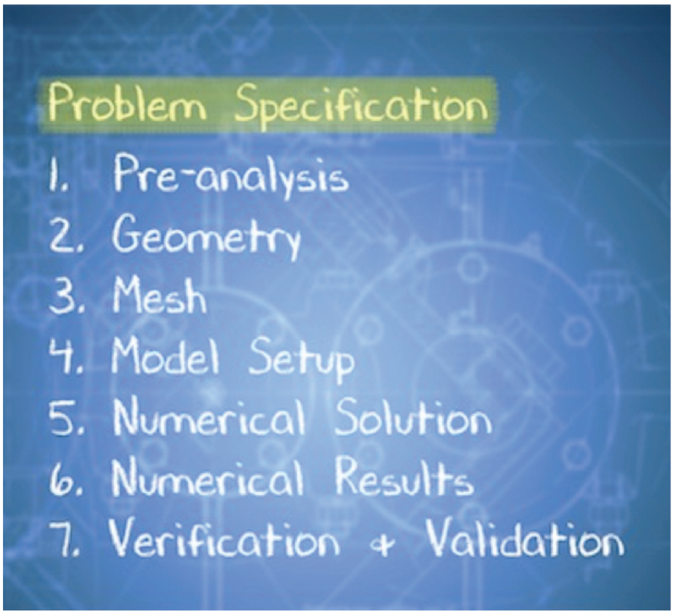


Figure 1 – Example Problem Framework

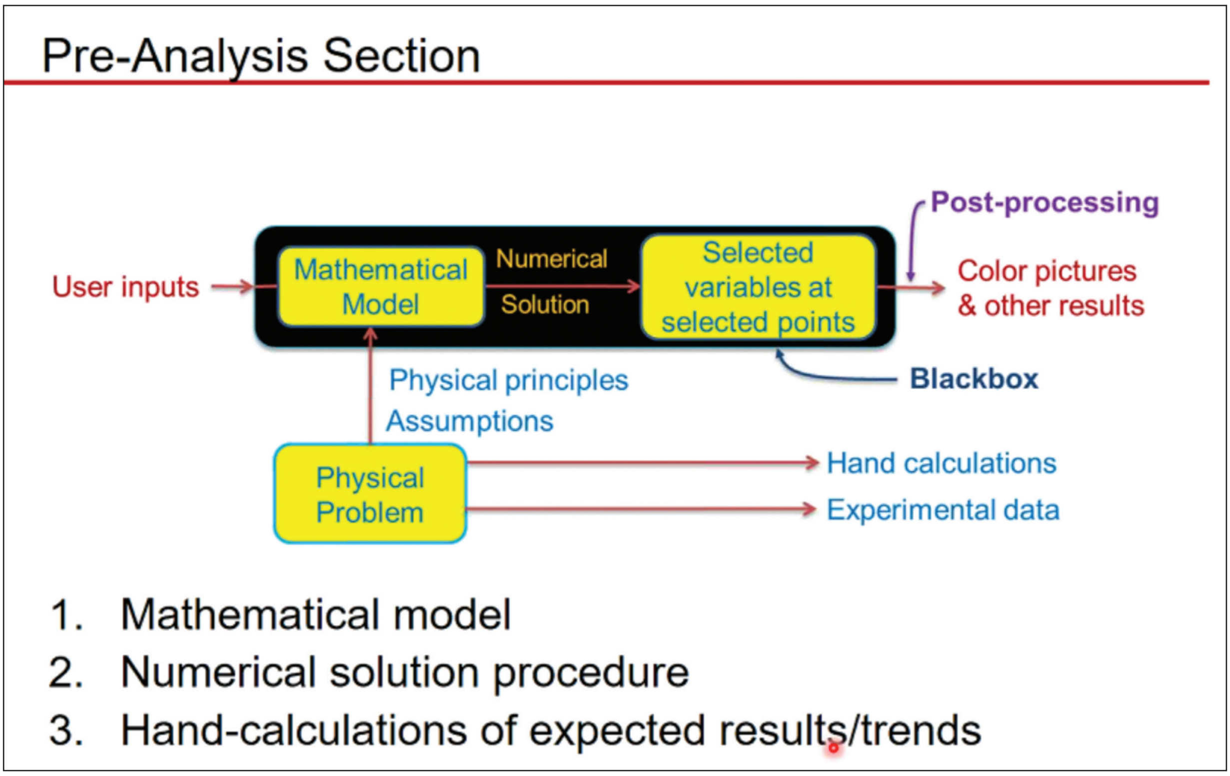


Figure 2 – How to get inside the "Black Box"

I liked how there was advice in one of the modules on what industry is looking for when they hire an engineer.

Absolutely this is the sort of information we can put in a MOOC. The MOOC provided a vehicle for the whole SpaceX example. In the module we have a discussion with Andy about how we take this complex problem and come up with something we can analyse. Without the MOOC we would have to bring Andy in as a guest lecturer. With the MOOC we can keep coming back to Andy at relevant parts of the example to get the industrial context. Here we have Andy acting in the role of "a guide on the side" which works well when teaching simulation. Andy was based in LA and I was based in Ithaca during the whole process.

When I was looking at the MOOC I noticed that there were sessions called Office Hours. Can you explain how these worked?

There are two ways for people enrolled on the Simulation MOOC to get help. The first is through the discussion forums, I have teaching assistants who monitor the forum and provide help but then we found that there were individuals with expert knowledge who are taking the time and helping people for free, they are effectively community teaching assistants. We have one person with over 650 responses most of which are very detailed. He clearly has a lot of knowledge and is very passionate about helping people.

There are a lot of questions posted on the forum but we find that a lot of them are on the same topic. There was one specific aspect of the boundary conditions in the heat transfer homework problem that came up often enough that I decided to record an "office hours" video. I created a video that provided clarification on the point that was causing confusion.

"The primary reason for people taking the course was relevance to employment."

There is a huge amount of content on the discussion forums which looks like a very valuable resource in itself.

For each module I had my Teaching Assistants comb through the discussion forum and create sets of frequently asked questions. I wanted to get to the point where the response to a large number of the questions is "Go check the FAQs". We are looking at providing another level of help which might be provided if an attendee is prepared to pay. This might be a method for providing the funding required to maintain the resource.

How much interest has there been in the course?

The figures to date for 2016 and 2017 are that 64,000 individuals have enrolled in the course and the content has had more than 1.2 million views on YouTube. Over 2000 individuals have paid $49 for a certificate verifying that they have taken the MOOC and passed the assessments. This is not an insignificant revenue considering it is 1 lecturer that is doing the teaching.

Your position is supported by a gift from ANSYS founder John Swanson. Can you tell me a bit about the progress that has been made by the Swanson Committee since it was set up?

The Swanson Committee was set up in 2002 and initiative has come a long way. Initially we had a modest sized room with 16 machines all running analysis tools including ANSYS. Now we have a pilot with Amazon App streams where students are running tools like ANSYS and Solid Works in a web browser and it is working amazingly well. We have come a long way with the technology but we have also come a long way with the pedagogy we are using to teach simulation.

How do you see MOOCs changing the academic landscape?

There was a lot of concern with people thinking that MOOCs will make Universities obsolete. Why would people pay so much money to attend a university when they can take courses from home for free. It will take a long time for the MOOC phenomena to find its place in the education system but first and foremost Cornell needs to be in the game, we can work out the revenue model at a later date.

Do you have any advice for NAFEMS and our readers on how education influences our industry?

I was reading the Democratisation of Simulation section of the Big Issues NAFEMS benchmark article and I noted that the article (nafe.ms/2fNu407) was mostly talking about how the expert can create customized interfaces for the non-expert. Simulation in the foreseeable future is not going to be pushbutton, the technological solutions will have to be coupled to educational solutions and that is an area that the MOOC addresses. ■

Figure 3 – Saturn V Engine

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