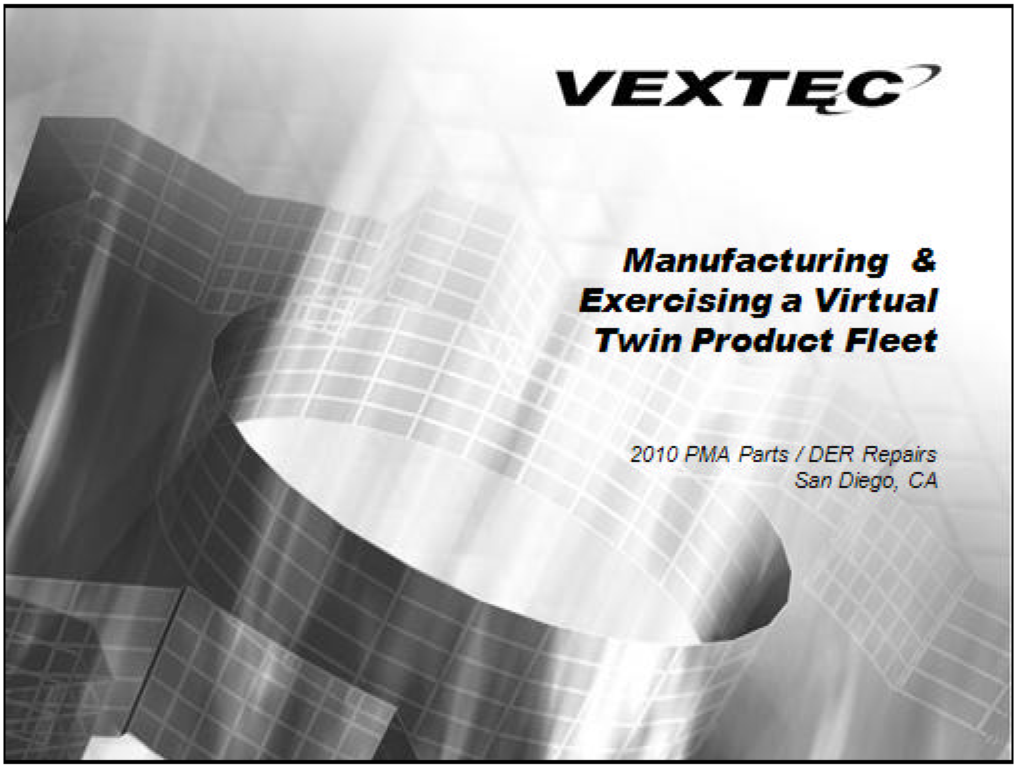
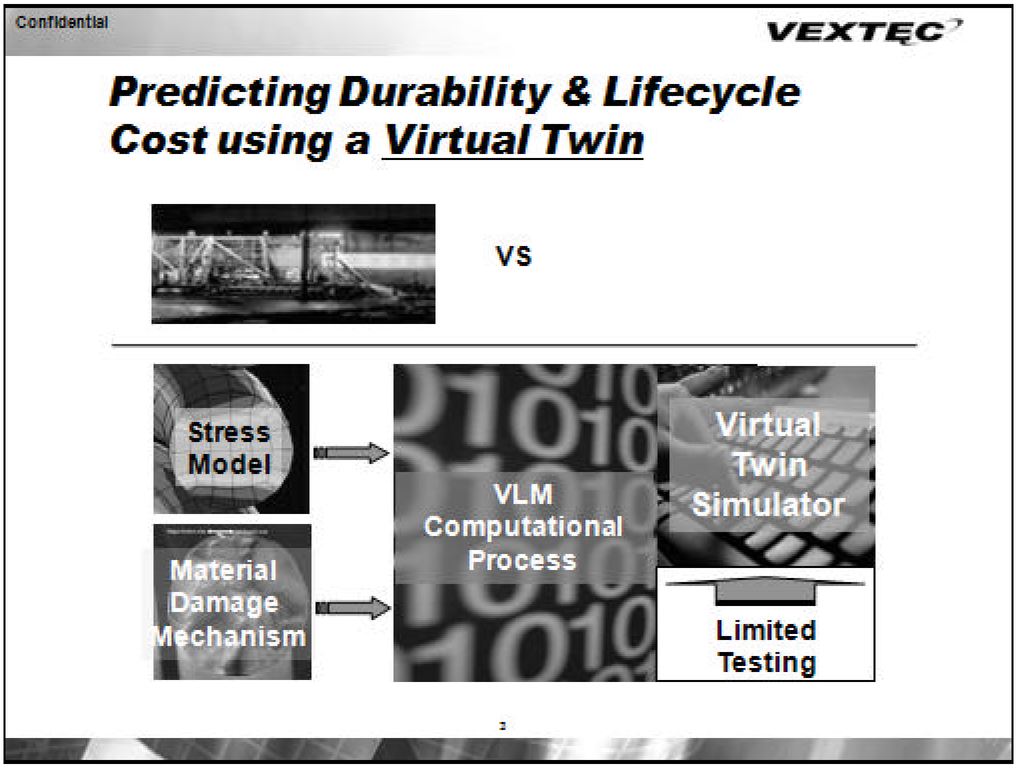

VEXTEC
Manufacturing &
Exercising a Virtual
Twin Product Fleet
2010 PMA Parts / DER Repairs
San Diego, CA

Confidential

VEXTEC

What's the barrier to lower cost replacement airline parts?

- The airlines know where the costs are (not a barrier)
- PMA parts cost less by factor 1-10 (not a barrier)
- PMA's (& repair companies) want to provide parts
  - Part size, shape, can be exactly replicated (not a barrier)
  - Clear understanding of functional need (not a barrier)
- PMA's ability to DEMONSTRATE their parts are as durable as OEM parts (given $/time – a Barrier)
- OEMs telling airlines/FAA that PMA parts aren't as durable – sometimes even subjectively (a Barrier)



Durability has been and continues to be derived from physical testing and a lot of trial and error

Yes there are computational tools – but they stop at the point of modeling component stress

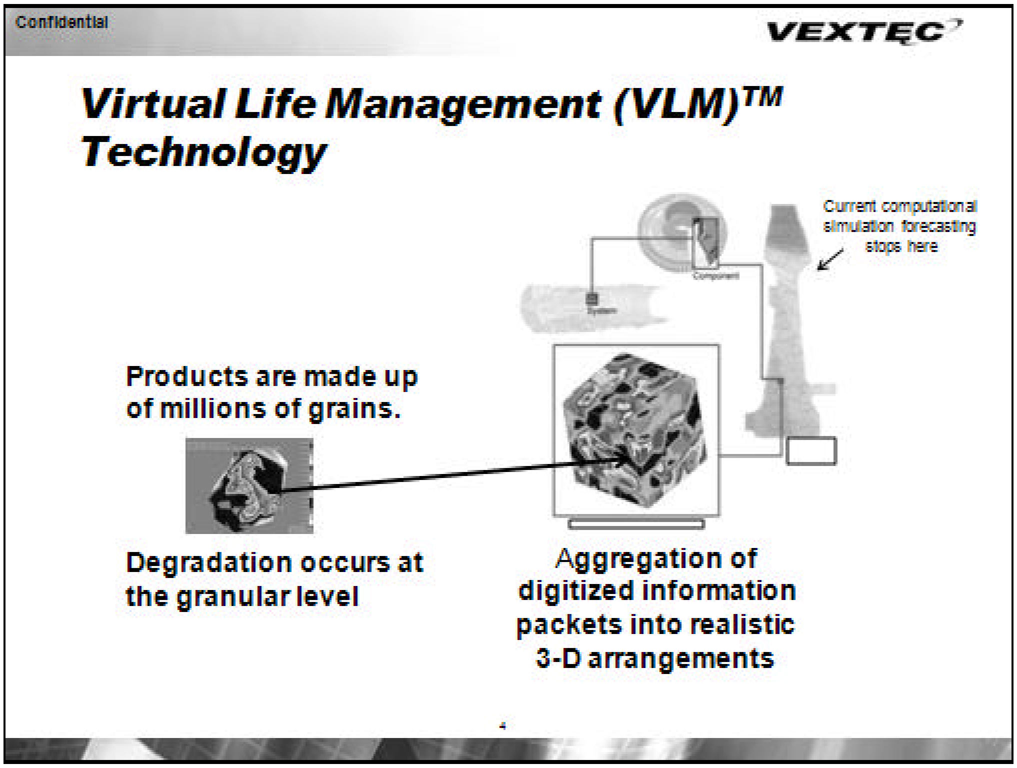
Durability can't be predicted based on stress alone – engineers have known this for decades – that's why when 10 laboratory tests are conducted at exactly the same stress level, all 10 will fail differently

So there has to be some other factor involved – that is the processed materials reaction to the application of stress

Before now – there hasn't been means for processing these two factors combined together with the computational efficiency of 1s and 0s ….until now that is

Its now possible to create a 3-D digital rendition of a product – a virtual twin – that can be exercised to fully understand durability trade-offs as never before

The idea of a virtual twin may seem new – but really its not – most of you use one every day



So how does virtual life management technology create a virtual twin?

The figure depicts an engine, component and conventional stress modeling in use today.

Uniquely VLM predicts the products reaction to the stress through the creation of a 3D representation of the material

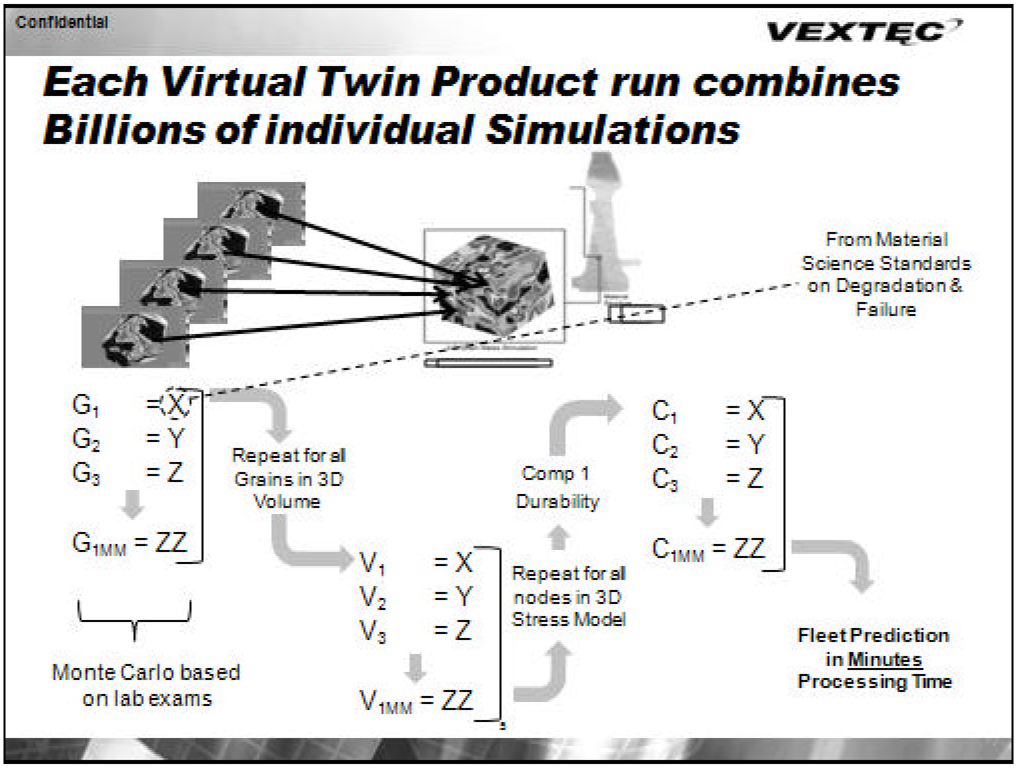
Manufactured products – like rotors, struts, etc – are really composites of tiny material grains – millions of them, sometimes hundreds of millions

Grains are combined into complex arrangements which are different for different areas of the component based on the manner of processing used

Failure doesn't occur at the level engineers are modeling stress at

Failure occurs at the grain level – material scientists have known this for decades

The computational horsepower didn't exist until now so there has been no way to efficiently process durability at this level of complexity



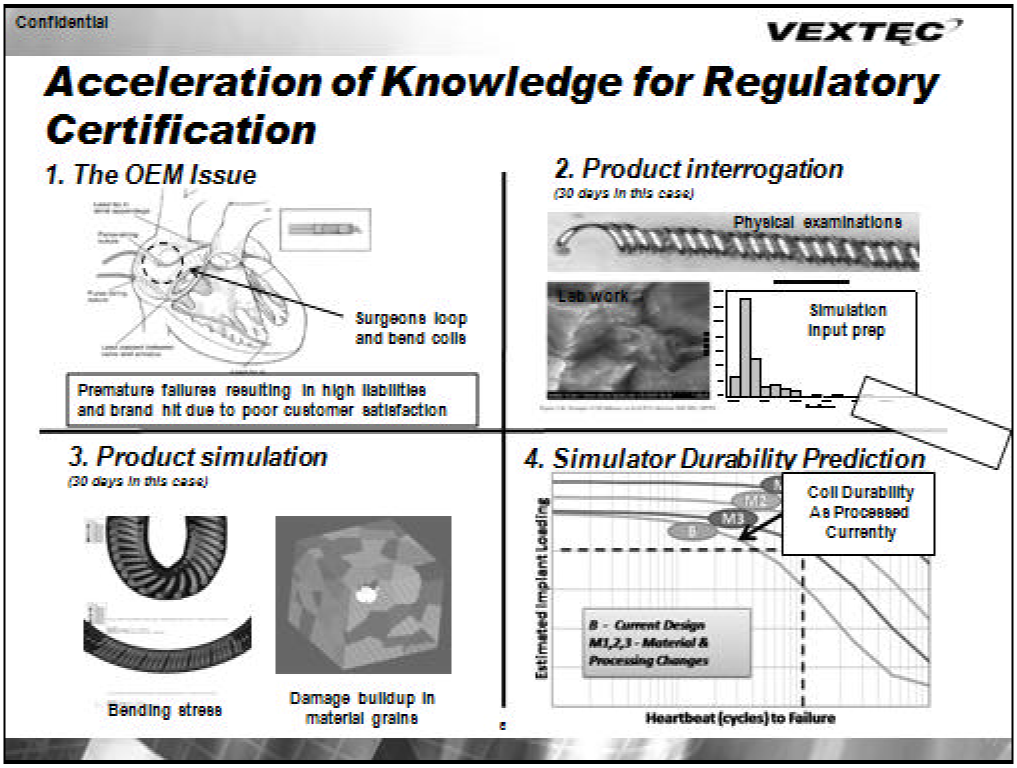
This looks complicated. But its really intended to convey that the key to predicting fleet durability is management of real world variability – variability starting at the grain level and ratcheting up to the variability that exists in-service application

The computational processing is really a brute force approach – the 3D representation includes many grains - stress is translated from the component to the first grain and well understood material physics predicts whether degradation occurs.

The information is digitized as 1's 0's and the processing moves to the next grain and so on.

All the digitized grain simulations are aggregated. The entire process is repeated for all the elements in the finite element model, and then all that information is aggregated to predict the durability of the first component.

So the magic behind the intellectual property is that the entire process is repeated for all the thousands of components in the fleet – hundreds or thousands of billions of individual simulations – with an average processing time of 30 minutes or less.



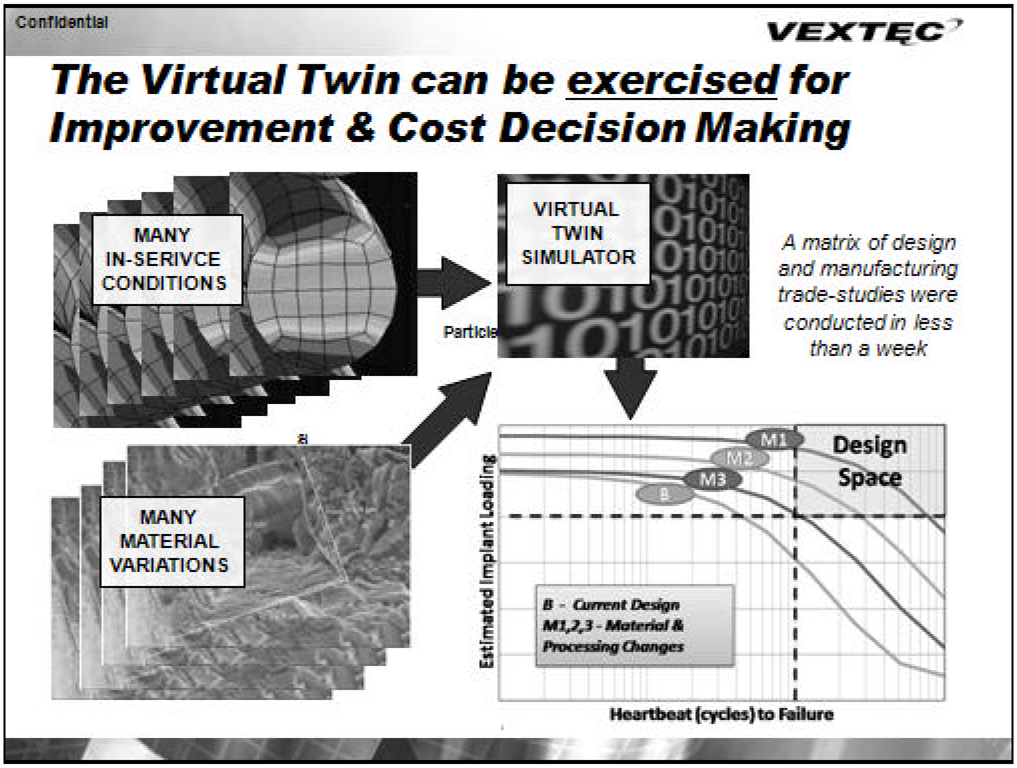
Wire implant issue…

Medical device makers need to go through a regulatory certification process like some FAA parts due – they are looking for anyway to accelerate their R&D….in the medical world time to market is everything!

The variability at the material grain level is a key to the computational processing and we get this information in the laboratory using high resolution imaging (30 days in this case)

Once the material parameters are setup then we bring in the geometric complexities and stress are brought in – in this case a coil is really 4 individual wires woven together

After 60 days setup, the virtual twin was exercised to predict fleet durability. In less than a day – we simulated a fleet of 20,000 coils. The virtual simulation results correlated exactly with the 20 physical test points the device maker had collected over the last 2 years.



Once set up the real power of the virtual twin is to rapidly generate a matrix of possible fleet durability outcomes by pertebating design, manufacturing or in-service conditions

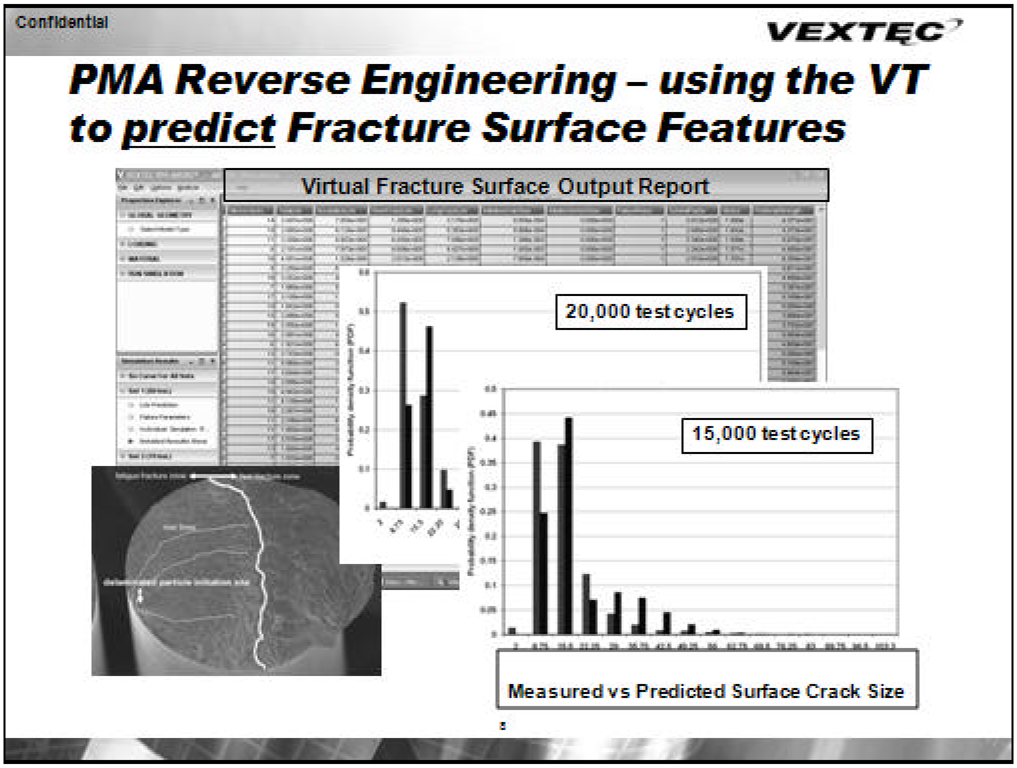
The device maker has an R&D program in place to achieve a new level of durability by 2012 (the box)

Product simulator was interrogated to determine what combinations of parameters would drive fleet durability into the box – two were material design parameters and 1 processing parameter

This figure shows 3 of the possibilities – M1 puts durability well into the target; M3 just gets it in.

So thereafter it’s a management decision as to which is most beneficial from a logistics and cost

The point is that management now has quantified metrics upon which to base its decisions on

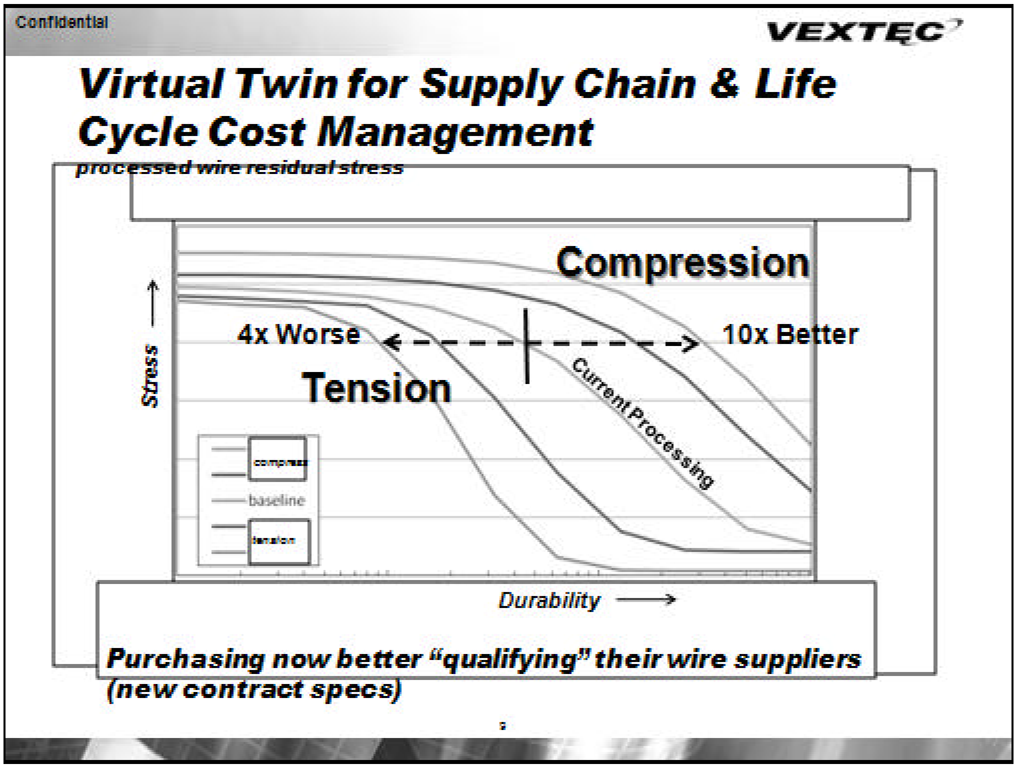


Key to the PMA world is knowing that you have reverse engineered the material physics correctly and now you can use the virtual twin simulation to do this

Let's look at an example of the medical wire reverse engineering – the VT catelogs which grains were simulated at the fracture surface – so all those individual simulations can be interrogated to determine which grains cracked and how large those simulated cracks were

The actual fracture surface of the physical part is then examined using high resolution imaging – the physical crack sizes are statistically counted

This figure shows that the predicted crack size statistics matched up with the measured statistics so the reverse engineering was correct



So I'm with an airline – what can I do with a product virtual twin? Well you can more effectively manage your supply chain for one

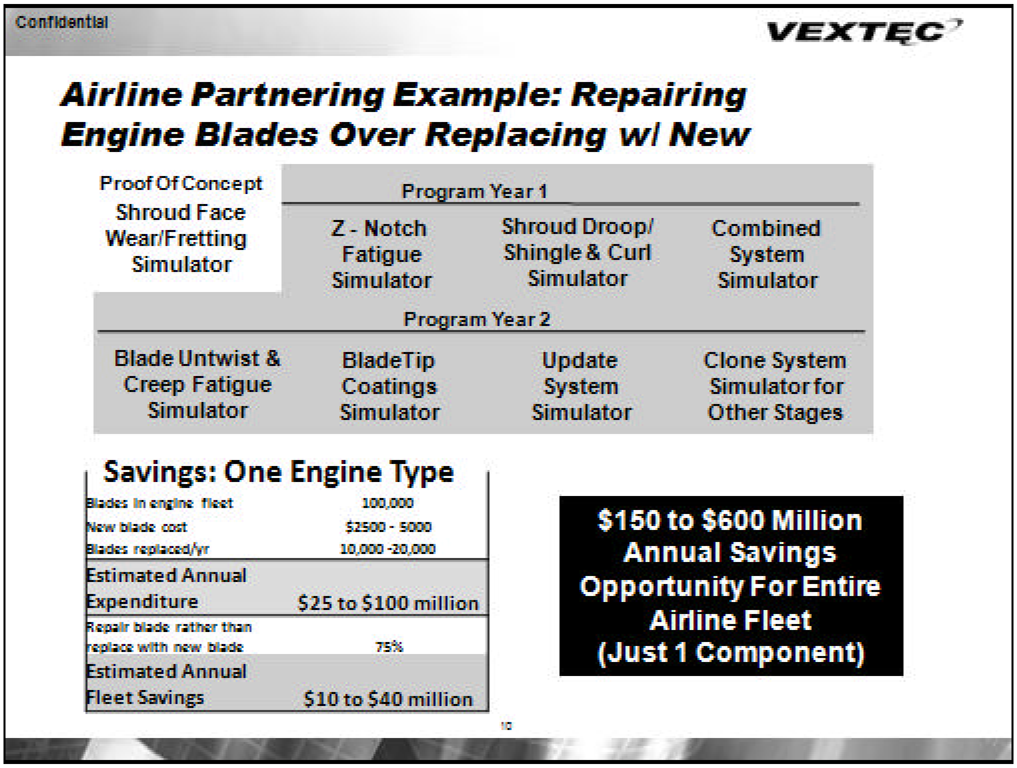
Referring back to the implant example – the device maker actually buys its wire from 8-10 different wire suppliers

One thing that came out of the simulator was the importance of wire processing to control the residual stress correctly

As figure indicates – you get a 10X durability improvement if the wire is processed with a compressive RS; process it with a tension RS and it's a disaster

None of the wire suppliers were attempting to control RS at all up to this point. So now the implant maker has mandated it

Some of the wire suppliers might say they can't – then that's a purchasing risk decision whether to buy from them



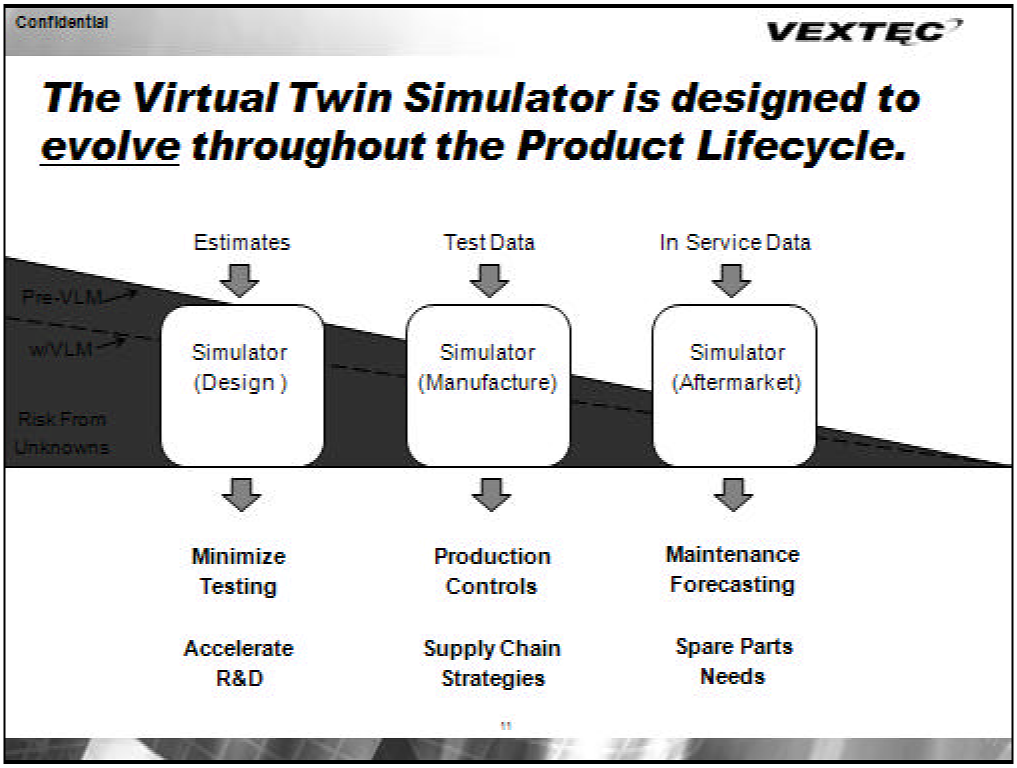
What are the economics driving airlines to start managing the product lifecycle using virtual twins and how does this process get implemented for a complex system?

This represents an example where an airline has been removing blades and replacing them with new (at high OEM pricing)

You can start the simulator activation process with a single failure mode and a single engine type and thereafter activate other failure mode simulators. At some point these can be integrated to produce a version 1.0 complex system simulator. Version 2.0 becomes a clone for another engine type and so on

The economics are a straightforward calculation. The airline knows how many blades are in the fleet, OEM price per blade, and how many they buy on an annual basis. In this case the cost is $25-100 million annually. Using the VT to implement a repair on 75% of the blades yields a $10-40MM for 1 engine type.

This airline flies RR, GE and P&W engines of many types – so the total possible savings number gets big

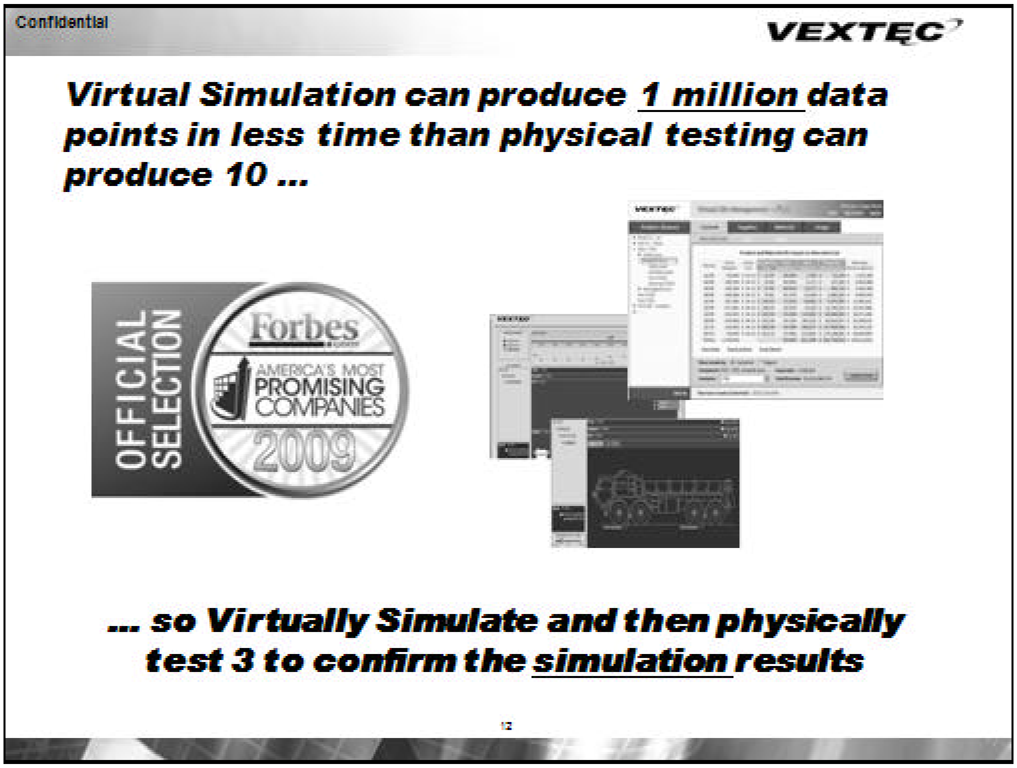


The airlines make money by keeping planes in the air. Keeping planes operational is a balance between cost and risk

Very little data exists on concept designs – but the durability simulation can be set up with estimates at this stage to bound the risk envelope and set budget and cost priorities

As knowledge is gained, the focus shifts to producing the parts as we intend for them to be produced

As the parts are fielded, the simulator can be seeded with actual in-service data and now the focus is on maintenance scheduling, spare parts needs, etc



The industry is so accustomed to collecting handfuls of physical test data points – its unrealistic to think that everything will change over night

My first job was as an aerospace test engineer so I understand the value of testing but you can never really afford enough data points to represent all the variability in materials, processing and in-service conditions –

one automotive company has a policy to run 22 tests on all their supplied components – I asked them how they came up with the number 22 and no one can tell me….now how ridiculous is that

Let me conclude by telling you a story –

…well thing of this as your new durability spreadsheet opportunity

We hope you've enjoyed our demonstration of VLM's capabilities. And we'd like to open up the floor for discussion.