*Moore's almanac; * FUTURE SHOCK RESHAPE I.T.*

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Byline: PETER LEYDEN

Body

Doubling, superchips, quantum leaps; PETER LEYDEN talks to Gordon Moore, Intel's board chair emeritus.

FOR more than 30 years, Moore's Law has governed Silicon Valley like an immutable force of nature. The idea that processing power will double every 18 months has been treated as an axiom - rather than the rule of thumb it actually is.

No-one knows this better than Gordon Moore (pictured right). In an obscure 1965 magazine article, Moore, then R&D director at Fairchild Semiconductor, reluctantly predicted the expected increase in the power of integrated circuits over 10 years.

By the 1970s, Moore was a co-founder of Intel, and his tenuous "law" was well on its way to becoming a self-fulfilling prophecy among researchers, manufacturers, and vendors.

Now, at 68, Moore will serve as Intel's board chair emeritus. Moore is asked to look towards the next 30 years and, again, make some predictions about the future of computing power.

LEYDEN: How long will Moore's Law hold?

MOORE: It'll go for at least a few more generations of technology.

Then, in about a decade, we're going to see a distinct slowing in the rate at which the doubling occurs. I haven't tried to estimate what the rate will be, but it might be half as fast - three years instead of 18 months.

What will cause the slowdown?

We're running into a barrier that we've run up against several times before: the limits of optical lithography.

We use light to print the patterns of circuits, and we're reaching a point where the wavelengths are getting into a range where you can't build lenses anymore. You have to switch to something like X-rays.

Would X-rays open a whole new round of doubling?

Theoretically, they keep us on this curve for a longer time. Practically, they have a lot of problems. If we get away from optical lithography, somehow we have to get the subsequent technique up to the same level of sophistication to keep making progress rapidly.

X-rays represent a sufficiently dramatic change that it will be difficult to build on what we've done in the past. We'll have to start over, and it's going to take a long time to get traction.

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Obviously, the industry is worried about this. We're looking at a $US200 billion industry that typically invests 10 per cent of its revenues into research and development.

A significant fraction of that will be aimed at solving this problem. Maybe something will come out that will make this transition a lot less onerous than I believe.

Are the costs getting prohibitive?

Recently somebody gave me Moore's Second Law: The cost of manufacturing facilities doubles every generation.

In the late 1980s, billiondollar plants seemed like something a long way in the future. They seemed almost inconceivable.

But now, Intel has two plants that will cost more than $2.5 billion apiece.

And the cost of each generation after that will double?

That's where you get into numbers that sound impossible again.

If we double it for a couple of generations, we're looking at $10 billion plants. I don't think there's any industry in the world that builds $10 billion plants, although oil refineries probably come close.

Obviously, our first reaction is to see what we can do to keep the technology moving but the costs down. For example, we used to build a completely new set of equipment each generation. Now our development people try to reutilise as much of the previous generation's equipment as possible. And they've been pretty successful.

We may bring a $10 billion plant down to the $5 billion range. But these are still huge numbers.

What will we be able to do with these superchips?

Even with the level of technology that we can extrapolate fairly easily - a few more generations - we can imagine putting a billion transistors on a chip.

A billion transistors is mind-boggling. Exploiting that level of technology, even if we get hung up at a mere billion transistors, could keep us busy for a century.

How much more powerful than today's chips are billiontransistor chips?

Our most advanced chips in design today will have less than 10 million transistors. So, we're talking about a hundred times the complexity of today's chips.

We wouldn't have the foggiest idea what to do with a billion transistors right now, except to put more memory in a chip and speed it up. But as far as adding functionality, we don't know what can be done.

Do you think DNA computing, or organic semiconductors, could supersede microprocessors?

I'm sceptical about that stuff. You stir up a bunch of goo, and it's going to do something? I'm a chemist, so I can say this. The things we build don't happen that way. We're more deliberate in the way we do things.

I believe that the technology our industry has developed - this idea of building very complex structures layer by layer - is a fundamental technology.

It is as fundamental to the Digital Revolution as metalworking was to the Industrial Revolution. I don't believe it's going to be replaced. But I could be wrong; I could be too tied up in my own technology.

What about quantum computing or building computers with nanotechnology?

I'm sceptical about this, too, but it's closer to what we do than the DNA stuff. Quantum devices may be the ultimate transistors.

The transistor doesn't behave very well when you get down to very small dimensions, but that gets into the realm where things like quantum devices start working.

We may make the transition to a kind of quantum device that keeps this whole trend going. Quantum devices are pretty far out, and a lot of work has to be done. They're far enough away that they're beyond my tenure in this industry - a couple of decades from now.

Is there ever a point where you see so many problems ahead, you just want to give up?

Engineers thrive on problems. They are trained to solve problems. When they run out of problems, they become very frustrated.

I see. So you're just loving this?

Yeah, this is great stuff!

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