**Reflecting on 40 Years of Computing Innovation: What Does the Future Hold?**

*By Justin Rattner, Chief Technology Officer, Intel*

Intel introduced the first customer-programmable microprocessor in November 1971. Originally conceived as a software-defined alternative to a full custom chipset for a business calculator, the Intel 4004 microprocessor became the brains for a variety of products from gas pumps to traffic light controllers. Multiple generations of Intel microprocessors have followed including the Intel 8086 microprocessor in 1978, which powered the first IBM Personal Computer and quite literally changed the world.

Fueled by the relentless advancement of Moore's Law, computing has affected the lives of billions of people worldwide. It has revolutionized the productivity and efficiency of transportation, government, manufacturing, agriculture, communications, finance, and countless other aspects of society. Computing has played a critical role in some of the most profound events in the last 40 years, from space travel to radical medical research such as sequencing and analysis of the human genome. Computing is also the cornerstone of the Internet which has become the essential infrastructure for the global information economy, providing businesses, consumers, and governments with ubiquitous access to information, services, and applications. Most importantly, it has brought an unprecedented degree of social interaction on a planetary scale.

**Looking to the Future of Computing**

The dramatic evolution of computing over the past few decades has unleashed wave after wave of business and personal productivity and has provided billions of people with their first real opportunity to participate in the global economy. Yet, we are still at the very early stages in the evolution of computing. We've just begun to see its impact on the course of history. More importantly, the pace of technological innovation is, in fact, accelerating. The sheer number of advances in the next 40 years will equal or surpass all of the innovative activity that has taken place over the last 10,000 years of human history.

Such advances in chip technology are paving the way for many new applications, where Intel envisions billions of connected people, and trillions of connected electronic and electromechanical devices, creating the so-called "Internet of things." We are also approaching an age where computing systems will be "context aware". They will be aware of their

environment, what is happening around them, and the user's intent. This capability is poised to fundamentally change the nature of how we interact with and relate to information devices and the services they provide. Future context-aware devices, ranging from PCs to smartphones and automobiles to televisions, will anticipate your needs, advise you, and guide you through your day in a manner more akin to a personal assistant than a traditional computer.

One of the key technical challenges to realising the full potential of computing in the future is the reduction of energy consumption. If we fail to reduce the amount of energy per computation, the astonishing transistor budgets that will come with the steady advancement of Moore's Law will go unused or will operate at speeds far below their physical limits.

For example, imagine an end-of-the-decade smartphone with advanced sensing capabilities requiring 100 gigaFLOPS of computing power. If we simply scaled one of today's mobile processors to this level of performance, such a phone would need a battery many times the size and weight of the phone itself to deliver the 600 watts of continuous power. Think of a motorcycle battery and you have the idea. Even if we could somehow deliver that much power, it would be very unpleasant to hold the phone, not to mention the battery, in your hand.

Intel's long-term goal here is to achieve a 300X reduction in energy consumption per computation within the next ten years. If we are successful in developing such extreme-scale technology, 100GF would consume a mere two watts of power or even less. We're talking thin batteries and low case temperatures for one incredibly powerful phone. The required breakthroughs in energy efficiency represent both an enormous challenge and an enormous opportunity to rethink the way we've been building computing systems since the advent of the microprocessor.

**Inventing the Future**

While accurately predicting the future has proven to be extremely difficult, inventing the future is actually much more straightforward. It's that simple principal that guided Intel co-founder Robert Noyce and will guide our scientists and engineers for the next 40 years. When I step back to think about it, I realise we're at a very significant point in time. It's a time when technology is no longer the limiting factor. The limit today is that of our own imagination. As we reflect on the amazing progress that's been made since the advent of the microprocessor, I want to challenge everyone in the computing community to create your own vision of the future. If you can dream it, we can invent it, together.