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Welcome to the Revolution:
Disruptive Technologies and 64-bit Computing

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One view of enterprise computing is of a landscape of robust 64-bit computing products including IBM's POWER-based eServer pSeries and iSeries servers, Sun's UltraSPARC solutions, and HP's PA-RISC and Alpha products, as well as the recent addition of Intel Itanium-based solutions from multiple vendors. The development of these 64-bit solutions followed an evolution similar to the previous jump from 16- to 32-bit processors and applications, with all vendors seeking benefits from the doubling of address space, as well as enhancements of integer operations and expansion of addressable RAM. But even the most familiar sights tend to change over time. During the past two years, enterprise IT has experienced tectonic shifts, some expected and others driven by the unexpected success of hybrid technologies such as AMD's Opteron processor. Consequentially, the most truly disruptive enterprise IT trends are occurring not in high-end solutions, where significant evolution is considered a matter of course, but rather in the low and middle ground, sparked by processors that can natively support mixed 32- and 64-bit computing processes.

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One view of enterprise computing is of a landscape of robust, mostly UNIX-based 64-bit computing solutions including IBM's POWER-based eServer pSeries and iSeries servers, Sun's UltraSPARC solutions, and HP's PA-RISC and Alpha products, as well as the recent addition of Intel Itanium-based solutions from multiple vendors. However, geographies tend to change over time and computing is no exception. During the past two years, enterprise IT has experienced tectonic shifts, some expected and others driven by the unexpected success of disruptive technologies, that are reshaping the 64-bit computing market for vendors, developers, and end users. In this report, we will consider the business and technological value of traditional 64-bit solutions and emerging trends affecting this market. In addition, we will discuss the current condition of some major 64-bit vendors, as well as future opportunities and challenges they are likely to face.

A Walk down 64-bit Memory Lane

In general, the development of 64-bit technologies followed an evolution similar to the previous jump from 16- to 32-bit processors and applications. While individual vendors pursued slightly different strategic efforts, all sought benefits from the doubling of address space 64-bit solutions offered over 32-bit. In addition, 64-bit processing provided considerable enhancements of integer operations and expansion of addressable RAM. Initially, 64-bit processor-based systems began appearing in the early 1990s, with IBM's RS4000 (though with a 32-bit OS) leading the way in early 1992, followed later that year by DEC's Alpha processor, and SGI's MIPS systems early in 1993. Though DEC pushed ahead of the pack in its 64-bit programming efforts, many vendors pursued mixed 32-/64-bit environments to better support customer and developer transitions. At the end of the day, all of these systems resulted in today's notion of 64-bit technologies as muscular solutions suitable for demanding high-end business and scientific computing environments. These systems became the platforms of choice for 64-bit UNIX operating environments, inspired ongoing developments including IBM's RISC, Sun's UltraSPARC, and HP's PA-RISC architectures, and provided the means for leveraging complex solutions including scientific and technical applications, computer-aided design (CAD), and increasingly robust databases.

In 1994, Intel and HP announced the co-development of a new processor architecture code-named Merced that they said would eventually become an industry standard platform for 64-bit computing. Initial speculation was so positive that HP (PA-RISC) and Compaq (Alpha) announced plans to discontinue their own 64-bit development efforts in favor of the new architecture. While Intel insisted that work was proceeding apace, the company announced delays on delivering the new chip in mid-1998 (as originally planned), mid-2000, and January 2001. The new Intel Itanium (i.e., IA-64) finally arrived in May 2001, but performed less impressively than what the market expected. To Intel's credit, the company corrected many of Itanium's shortcomings over the following eighteen months, but this further delayed Itanium's market adoption. Despite these problems, a goodly number of OEMs now deliver Itanium-based servers and IA-64 is the lone platform supporting Microsoft's 64-bit server and datacenter solutions. However, HP remains the only major U.S. vendor to fully bet its future on Itanium.

New Adventures in 64-Bit Computing

Though Intel might claim that its Itanium efforts are an exemplar of disruptive 64-bit technologies, we believe IT and market trends are considerably more multifaceted. Disruptive technologies earn their reputations, after all, because of their sheer unpredictability. Itanium's EPIC (Explicitly Parallel Instruction Computing) design diverged considerably from previous approaches, but realistically, Intel's efforts do little more than extend or parallel the trail broken originally by 64-bit's pioneers. At the end of the day, Itanium is and remains an exclusive 64-bit architecture whose migration path is equally complex as competing platforms. Moreover, IBM, Sun, SGI, and Fujitsu continue to press forward with their own well-established 64-bit processor architectures. As a result, rather than becoming the industry standard platform Intel and HP originally envisioned, Itanium is simply the newest member of a throng of competing options for enterprise 64-bit applications.

> *Overall, we believe that truly disruptive 64-bit trends are occurring not in high-end computing, but rather in the low and middle ground, sparked by processors that can natively support mixed 32- and 64-bit environments.*

The first of these (introduced in December 2002) was IBM's POWER 970 processor, which underlies Apple's 64-bit G5 systems and serves as the basis of IBM's JS20 POWER Blade servers. However, the introduction in April 2003 of AMD's new Opteron processor, which leveraged venerable x86 chip technologies with additional 64-bit extensions, has been the most influential of these solutions to date. In essence, Opteron natively executes both 32- and 64-bit-enabled operating systems and applications, which provides x86 users and developers a fluid multiple timeline migration path to 64-bit applications. A host of vendors has delivered Opteron-based systems, and the new processor found notable support among users of clustered high-performance computing (HPC) systems. Initially, Intel derided AMD's hybrid approach, but by early 2004 the company announced plans to deliver Opteron-style Extended Memory 64 Technologies (EM64T) to its x86 Xeon processors, a move supported by Intel OEMs including HP and IBM.

Shapes of Things to Come

In a sense, 64-bit extensions have provided a disruption to the hardware market similar to what Linux fostered in software. Opteron is considered an ideal solution for 32-bit customers with migratory or limited 64-bit needs. However, the chip's notable performance and scalability, due in large part to proprietary AMD Hypertransport and memory technologies, also makes Opteron a powerful, cost-effective choice for high-performance clustered applications. These capabilities are key to understanding the influence of disruptive technologies, whose success is not determined by their degree of disruption but by the opportunities they offer vendors and end users. Opteron has not only provided AMD unique new markets to explore, but has also helped to drive a new, multidimensional model of 64-bit computing emphasizing system flexibility and application addressability that does not require the robust muscularity or cost of traditional 64-bit solutions. This, in turn, is helping to promote affordable 64-bit computing among low- and mid-market users that would not have been conceivable two years ago.

AMD's efforts have also resulted in growing opportunities for vendors, developers, and end users. The price/performance of Opteron-based systems makes them ideal platforms for 64-bit experimentation, as well as for possible larger migration efforts, which should benefit vendors and ISVs as much as it

does end users. By offering a seamless 64-bit transition platform for 32-bit customers, Opteron could also become a significant general-purpose platform for SMBs and the mid-market.

> *Despite the efforts of some vendors to pigeonhole 64-bit extensions technologies as appropriate for only limited applications, the success of these platforms will depend more on the needs and imaginations of end users than on IT vendor strategizing.*

Historically, IT customers have tended to adopt solutions that offered significant price/performance advantages (such as 32-bit x86 servers) and to deploy them in areas vendors considered risky or inappropriate, but the continuing evolution of technology has tended to mitigate these risks over time.

Handicapping the Players

If a new market for flexible, affordable 64-bit computing does exist, how well are major vendors poised to profit from it? In addition, how will major vendors' traditional, high-end 64-bit efforts affect their ability to take advantage of these future opportunities?

Processors

AMD

> *As the Robespierre of the current x86 64-bit extensions revolution, AMD would appear to occupy a catbird seat of its own design.*

Opteron not only dominated the IT media for months after its launch, but AMD reported that the new chip generated initial sales of about 150,000 units in its first year. Nevertheless, notable success carries notable challenges. Rather than sitting on its well-earned laurels, AMD needs to drive continuing enhancements to Opteron. Signs suggest that the company is doing just that, recently announcing price cuts to all existing Opteron processors by between 19% and 43%, and pushing along the Opteron roadmap with the development of 90nm Silicon On Insulator (SOI) and low power technologies, critical issues for the clustered server environments where Opteron has found so much success.

Most worrisome for AMD is how the market will respond to Intel's competing 64-bit extensions solutions when they become available. Intel's decision to pursue 64-bit extensions marks the first time the company has taken (perhaps ripped is a more accurate term) a page from AMD's strategy book, and we expect Intel to move aggressively against Opteron. With this in mind, it is important to remember how much of Opteron's current and potential future success depends on the efforts and enthusiasm of AMD's OEM partners. While Opteron's performance and scalability make it a natural player in the clustered HPC market where many vendors focused their initial efforts, its flexibility also makes it an appropriate choice for a wider range of low-end general-purpose server applications. Overall, we believe AMD is only likely to reach its full potential if the company's OEM partners promote Opteron as a solution for these more mundane and broadly reaching capabilities.

Intel

Intel's 64-bit extensions efforts reveal a company's whose product strategy is in a state of transition. While it is doubtful that anyone within the company or among its Itanium partners expected the 64-bit road to be easy, IA-64 continues to struggle in a market that seems to have as many enterprise computing platforms as it really needs. Intel has achieved much, but the company has also racked up some notable failures, suggesting that while oligopoly may complement monopoly, throwing money at an opportunity is no sure way to success.

> *By focusing on another exclusive 64-bit architecture, Intel ignored the elemental lesson it taught the rest of the market; that rather than raining down from on high, elemental IT change more often bubbles up from below, causing geological shifts that fundamentally alter long-familiar landscapes.*

Intel's pitching of 64-bit extensions as a low-end migration technology raises questions about how the performance of EM64T-enabled Xeon (which, of course, does not incorporate AMD's Hypertransport or memory technologies) will stack up against Opteron. In addition, Intel's promotion of Itanium as an ideal HPC platform is a very long walk from the industry standard business-computing platform IA-64 was supposed to become. While Intel's plans to drive price parity for Xeon and Itanium by 2007 should pressure other 64-bit vendors, the use of common components such as motherboards across both platforms also opens speculation regarding an eventually more intimate blending of the two architectures. Overall, Intel's Itanium-centric strategy gave the initiative to AMD, left IBM's POWER architecture in peace, and provided Sun some badly needed breathing room. Today, Intel is validating AMD by pursuing EM64T and positioning its new offering to minimize further damage to Itanium.

Platforms/Software

Linux

Contrary to the desktop expectations of its proponents, Linux found its initial enterprise toehold in the server space, where it has continued to generate its greatest successes. While Linux's appeal was originally directed at low end-x86 servers, Open Source 64-bit development efforts raised its enterprise profile as an alternative OS for one- to eight-way UNIX servers. Indeed, one surprise of the growth of Linux has been its incursion in traditional UNIX markets, rather than in the Microsoft space where proponents supposed it would flourish. The result is that Linux has tended to be more disruptive to traditional UNIX systems players, especially those who laughed off Open Source as a second rate plaything instead of an enterprise-worthy computing alternative (an argument which many of the same vendors, ironically enough, used to castigate Wintel-based servers when they appeared on the scene).

> *Linux's natural affinity for 32-bit x86 applications and its emerging 64-bit capabilities have made it an obvious beneficiary of Opteron's success story.*

Indeed, Microsoft's ongoing absence has left the 64-bit extensions space open to Linux, a circumstance that has contributed to the success of Opteron among Linux-savvy HPC users and Open Source developers. We expect Linux to continue maturing in Opteron and other 64-bit environments. In addition, we expect that the new Linux 2.6 kernel, which increases support of 64-bit applications in eight- to sixteen-way servers, is likely to extend the development of enterprise Linux solutions. Though this development is likely to have a greater impact in traditional UNIX server platforms, 64-bit extensions-based solutions are also likely to benefit.

Microsoft

To date, Microsoft's efforts in the 64-bit space offer considerably less than meets the eye, mainly due to fact that the company's 64-bit Windows Server and SQL Server products are supported only on Itanium. While these solutions constitute a minor piece of the company's overall business, 64-bit aspirations lie at the heart of Microsoft's datacenter strategy and hopes as an enterprise IT vendor. As a result, 64-bit success remains a critical issue for a Microsoft, and

Itanium's failure to ignite market enthusiasm has squelched the company's ambitions. For that reason, 64-bit extensions produced by AMD or Intel represent a potential godsend for Microsoft that offers the company 64-bit outlets beyond Itanium and the slim cadre of serious IA-64 vendors. In addition, Opteron and EM64T provide the means for Microsoft to further leverage the considerable breadth and depth of its existing 32-bit solutions.

How much the company will really gain from AMD's and Intel's efforts remains a question. Windows-based Opteron solutions originally scheduled for release this summer have been pushed back to later in the fall, and the company has further delayed the 64-bit "Yukon" version of Windows SQL Server. Microsoft has also put off delivery until versions that support both Opteron and EM64T become available. There is some logic to this decision, but the fact remains that the delay helps Intel at the expense of AMD.

> *The real question is how Microsoft's product strategizing will affect the long-term benefits it receives from 64-bit extensions solutions. If Opteron and EM64T find their primary home in HPC and similar applications, they are likely to be a minor blip on Microsoft's radar. If they emerge as fixtures in lower-end, general purpose computing, Redmond could become one of the largest beneficiaries of 64-bit extensions technologies.*

64-bit Software

Beyond propriety and Open Source operating environments, a number of applications are likely to be beneficiaries of 64-bit extensions technologies. However, developments in these areas will follow a natural evolutionary cycle, with developers' efforts reflecting gradually expanding market demand. Over the short term, Opteron's established reputation for price/performance will continue to drive the growth of scientific, technical, and HPC-related Linux solutions (along with related database tools) at the higher end, and CAD/CAM workstation applications at the lower. The arrival of Intel's EM64T Xeon-based solutions, along with certified Windows operating systems and applications for both AMD and Intel solutions, will help expand the acceptance of 64-bit extensions-enabled servers for general-purpose computing processes, including DNS services, database front-ends, directory services, and messaging/groupware applications.

In addition, we expect some vendors to press Opteron as a platform capable of sustaining more complex full business workloads. Sun recently announced eye-opening performance numbers for a two-way Opteron-based Sun Fire server running the two-tier SAP(R) Sales and Distribution (SD) Standard Application Benchmark, significantly outperforming several comparable Xeon-based systems.

> *If Opteron-based systems continue to deliver breakthrough performance over time, they are likely, with the help of eager ISVs and willing enterprise customers, to break 64-bit extensions out of the box in which some vendors would prefer they stay.*

Systems Vendors

HP

HP's efforts in the 64-bit space are somewhat confused, especially of late. While the company co-developed Itanium, and remains its primary backer and beneficiary, the slow market uptake of IA-64 has complicated HP's post-Compaq strategy. In essence, that boils down to HP pursuing a Dell-like business model across all its enterprise hardware lines: embracing commodity-priced components, driving prices and margins down, and leaving costly

platform innovation largely to Intel. In addition, despite HP's stated allegiance to HP-UX and Linux, the company's deep ties to Microsoft have complicated HP's enterprise product messaging. The interdependence of HP, Intel, and Microsoft is not particularly surprising, considering Itanium's critical role in the future success of all three companies, but it does spark some reasonable questions about the logistics of HP's support for the PA-RISC and Alpha customers it intends to migrate to IA-64.

However, we also believe HP is not above a bit of genial arm-twisting when the chips, so to speak, are down. We suspect that HP's plans to support Opteron may have influenced Intel's eventual decision to pursue EM64T solutions. HP's decision to deliver Opteron-based systems is perfectly in keeping with a vendor that realizes, perhaps a bit belatedly, that its long-term success depends more on creating affordable solutions the market wants than trying to lead customers down a path they are reluctant to pursue. This is, after all, the essence of commodity-driven commerce.

> *Overall, we expect HP to promote EM64T with equal or greater enthusiasm that it does Opteron, and to leverage Microsoft solutions (along with a modicum of Linux) across both platforms for a variety of general and high-performance applications. How these efforts will spark the flickering flame of HP's Enterprise Products Group remains uncertain.*

IBM

IBM's position in the traditional 64-bit market is best described as an embarrassment of riches. The company's POWER-based server products are bolstered by three operating environments (AIX, Linux, and i5/OS), and its eServer i5 (previously iSeries) platform is the only 64-bit solution capable of supporting all three environments, plus Windows, simultaneously. IBM recently delivered the first eServer i5 products based on the newest generation POWER5 processors, with eServer pSeries servers scheduled to follow this summer. IBM has a long relationship with Intel, both in developing IA-32 and IA-64 solutions, and in voicing early support for the company's EM64T plans. More importantly, IBM was the first major vendor to back AMD's Opteron platform, and was instrumental in its early success in the HPC space. In addition, IBM's PowerPC 970 processor also offers the company some intriguing opportunities starting with the JS20 blade server.

While IBM's support has been crucial to AMD, the company has largely focused on delivering Opteron in HPC-specific solutions. With competitors including HP and Sun aggressively pressing forward with general-purpose Opteron severs, we believe this represents an opportunity IBM would do well to consider. The arrival of Windows solutions for Opteron and EM64T later this year should also enhance general-purpose servers based on these platforms. In addition, Opteron offers IBM some intriguing opportunities as regards the company's well-received BladeCenter product.

> *At the end of the day, IBM's limitation of its Opteron solutions might simply reflect brand sensitivity issues. This is not to suggest post hoc, ergo propter hoc reasoning, but by focusing specifically on Opteron-based HPC solutions, IBM mitigates any risks of confusion or overlap with both the JS20 blade products and Intel-based eServer xSeries, a situation which is likely to become even more complex with the arrival of Intel's EM64T technologies.*

Sun

Sun's embrace of Opteron offers the company both tantalizing opportunities and considerable challenges. Opteron provides Sun a viable, differentiated x86 product strategy that is unattached to Intel. In addition, the company's recently announced détente with Microsoft makes possible a future when Windows solutions could be integrated into Sun datacenters. Most intriguing is that Sun, alone among 64-bit vendors, has a tested, highly differentiated operating environment besides Linux or Windows for Opteron: Solaris x86, which affords the company a number of unique options for workstation and server solutions. The challenge for Sun is in actually delivering on this and other promises, no small feat for a company that, while struggling to staunch the bleeding in its enterprise organization, has had difficulty in developing meaningful or believable products outside of its UltraSPARC and Solaris comfort zones, be they the failed Cobalt appliance server experiment or commercialized Linux solutions.

> *In a sense, Sun offers a stark lesson in the dangers of successful evangelism. The company rode the notion of UltraSPARC/Solaris superiority to the summit of the dotcom boom, but missed or ignored the market's slow, inevitable shift towards less costly (if less robust) solutions.*

Eventually, while other vendors realized that decreasing hardware margins necessitated a strategic shift toward service-based revenue streams and made the necessary adjustments, Sun continued following the same old script like an aging vaudevillian who remains convinced that a tiring shtick remains good entertainment. That said, the recent appointment of Jonathan Schwartz as Sun's president and a spate of new announcements including an UltraSPARC processor co-development deal with Fujitsu Siemens suggests Sun may be getting back on track. Overall, Opteron offers the company a unique opportunity to revitalize its product strategy and take advantage of new markets. Sun's myriad supporters and customers can only hope that this opportunity is not squandered like so many others.

Other Systems Vendors

A number of OEMs create 64-bit server solutions that could be affected by issues we have raised here, but two vendors, Fujitsu Siemens and Dell, are worth some further consideration. Fujitsu develops mainframes, UltraSPARC-based PrimePower servers, Itanium-based Primergy servers, and the recently introduced dual Opteron Celsius V workstation; but the company is not a major player in the U.S. market. However, the company is a force to be reckoned with in EMEA. Fujitsu has not announced plans to deliver Opteron-based solutions beyond the Celsius V, but if successful, that effort could lead to other opportunities worth exploring. In addition, the company's recently announced UltraSPARC co-development agreement with Sun provides some interesting food for thought. While the deal aims initially to benefit both companies' mid-market products, Fujitsu's mainframe technologies deliver some capabilities that could also improve Sun's high-end solutions. Overall, Opteron offers both Fujitsu and Sun a way to significantly cut costs by leveraging AMD technologies for lower end servers, HPC solutions, and workstations.

Best known as a leading volume vendor of PC and server solutions, Dell has increasingly been setting its sights on higher-end enterprise offerings. However, while Dell and Intel have both leveraged their close relationship to good effect, Intel's strategic needs have sometimes been at odds with Dell's

tactical market approach. Dell is superb at squeezing every dollar out of volume sales opportunities, but the company has never been a purveyor or pursuer of innovative technologies. Likewise its expertise in selling and supporting lower-rung solutions to the small and mid market has not translated all that well into the highly specialized and attentive service that large-enterprise customers have come to expect. Dell was slow to join Intel's Itanium parade and currently offers only a single IA-64-based server, though the company recently announced plans to develop a four-way solution.. However, Dell supports Intel's EM64T and describes Xeon with EM64T as an "excellent platform for mixed purpose or infrastructure servers." Not surprisingly, this toes Intel's line regarding EM64T as simply an upgrade to Xeon, not a threat to IA-64. Dell is likely to benefit from 64-bit extensions as the technology gains traction in general purpose solutions, but it will do so on Intel's terms.

What Does It All Mean?

As with most other species, technological evolutions are sparked more by necessity than by want, but can be triggered by disruptive events that often emerge from unexpected quarters. Two years ago, some in the industry might have argued that IA-64 was causing elemental change in the industry, but such a conclusion would have required the assumption that Intel's new EPIC-based solutions represented a significant departure from and improvement over competing dedicated 64-bit platforms including IBM's POWER and Sun's UltraSPARC.

> *Recent events suggest that the 64-bit extensions technologies are more truly disruptive, and also highlight the fundamental error of Intel's Itanium strategy.*

Nevertheless, the acceptance of 64-bit extensions is more a story of one vendor's success than another's failure. The fact is that AMD took a huge chance with Opteron. By ignoring Intel's plans for the 64-bit marketplace, keeping its own counsel, and pursuing its own initiative, AMD created a host of new opportunities for enterprise customers and the vendors on which they depend. By leveraging its x86 expertise and following a less traveled path, AMD successfully created a disruptive technology that has spawned a host of market innovations. How much AMD will benefit from the events it set into motion, however, is far from clear. History abounds with the stories of innovators who enjoyed little in the way of personal reward.

> *In today's IT world, market success is a team sport that depends on the skills, spirit, and dedication of individual players, and Opteron's long-term fate will depend as much on the efforts of AMD's partners as it does on AMD itself.*

While some of those partners have been more enthusiastic and aggressive in their promotion of Opteron than others, how well those efforts will stand up when Intel takes the field remains to be seen.

Some trends, however, seem reasonable to consider. In truth, 64-bit extensions are likely to succeed most among those vendors who regard and promote them as complimentary to exclusive 64-bit solutions. In the applications where overlaps occur, vendors will find greater success by using 64-bit extensions to deliver unique new products to customers than by pigeonholing emerging technologies into non-threatening (and non-innovative) solutions. Thus, the value proposition of existing 64-bit technologies, especially those deployed in HPC environments, is not truly endangered by the availability of 64-bit

extensions, as the characteristics of compute and I/O intensive applications have not changed. However, dedicated 64-bit installations that were deployed simply because they offered the only effective way to address large amounts of data may prove to be a fertile breeding ground for 64-bit extensions technologies. In these accounts, the emergence of Opteron and EM64T-enabled Xeon alternatives may be met with accolades from customers, but are likely to garner more chagrined responses from vendors.

In the short term, we expect Opteron's short-term success to continue in the HPC and clustered environments where the platform found its initial support. That should play well for IBM, which has led the Opteron charge in this space, and could offer some interesting opportunities for Linux developers focused on this area. Over time, however, we expect Opteron's increasing market traction, together with the availability of Intel's EM64T-enabled Xeon processors, will begin to drive 64-bit extensions technologies into wider use. Given its relationships with both AMD and Intel, HP stands to gain the most from this trend initially, though it could also play well in Sun's x86 product development efforts, and should also benefit IBM's eServer xSeries business, if not its Opteron server business.

Microsoft stands as a wild card here. Since the company enjoys both a huge footprint in the 32-bit x86 space and close relationships with virtually every vendor involved with Opteron and EM64T, Microsoft could become a catalyzing agent for driving 64-bit extension-based solutions into the greater market. Such an effort would also greatly aid the migration to 64-bit Windows products, an issue Redmond is not likely to ignore.

While the long-term success or failure of individual vendors is interesting to consider, the greater effect of 64-bit extensions technologies lies in the opportunities they offer IT customers. No matter which vendors win or lose, 64-bit extensions technologies provide users IT capabilities once available only with dedicated, enterprise-class 64-bit solutions.

> *AMD's decision to deliver unique IT innovations to entirely new classes of customers may qualify as the largest disruption of all.*