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Submitting Organization: Integrated MagnetoElectronics (IME)
Contributing Organizations: None
Contact: Richard Spitzer, PhD
IME
1214 Oxford Street
Berkeley CA 94709-1423
Voice: 510-841-3585
Fax: 510-841-2405
richard.spitzer@transpinnor.com

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Summary

The gross national product of the United States increasingly depends on electronic transactions across the entire spectrum of commerce. But this trend towards electronic ordering and delivering of goods and services – and towards effective consumer communications – is seriously threatened by several interrelated root problems of information technology (IT):

1) severe energy inefficiency attendant on increasing performance requirements; 2) escalating facility costs; 3) near-complete migration of semiconductor manufacturing to offshore foundries, with resulting loss of manufacturing jobs in the U.S. and of U.S. security.

This paper focuses on these problems of this important industry, and suggests why there is a critical national need to promote U.S. development of breakthrough technologies in key electronic hardware components of IT.

Crisis in Information Technology

For years, the varied technologies that collectively form the backbone of IT have successfully, and in general reliably, functioned in the applications for which they were originally intended. However, increasingly demanding IT configurations were not envisaged when these technologies were originally developed. Inherent inadequacies have come to light as these technologies are called on to work together in the convergence of the computing, communications and consumer industries. Various root problems have become intractable:

- hard-disk storage of data is highly energy inefficient; it now consumes as much as 3% of all electrical power used in the U.S., and the yearly cost of electricity in operating data centers now exceeds their capital cost
- flash memory is the fastest growing segment of the semiconductor industry, primarily because of its nonvolatility, which is critical for its use in mobile electronics, itself the fastest growing segment of consumer electronics; yet the performance limitations of flash make it woefully inadequate for this rapidly growing application
- capital costs of semiconductor manufacturing facilities are roughly doubling every two nodes, a major factor in the migration to offshore foundries of most semiconductor manufacturing; the attendant negative impact on the U.S. has been severe: 1) major loss of manufacturing jobs; 2) only a small fraction of the integrated circuits used by the U.S. military are now being manufactured in secure facilities run by American companies; this use of globally-sourced technology presents a serious security risk to the nation

Critical National Need

The "Report to Congress" by the Environmental Protection Agency, 2 August 2007, specifies five pressures on commerce, all having to do with IT:

- electronic transactions
- internet communications and entertainment
- electronic medical records
- global commerce
- satellite navigation and shipment tracking

The magnitude of the problem is illustrated with reference to two of the problems cited above: energy inefficiency in data centers and security risk.

Energy inefficiency A study from Lawrence Berkeley National Laboratory (J. G. Koomey, Estimating Total Power Consumption by Servers in the U.S. and the World, LBNL, February 15, 2007) shows that total power used by servers (including cooling and auxiliary infrastructure) represented about 1.2% of total U.S. electricity consumption in 2005. The total corresponding power demand is equivalent (in capacity terms) to about five 1000 MW power plants for the U.S. and 14 such plants for the world. The total electricity bill for operating those servers and associated infrastructure was about \$2.7 B and \$7.2 B for the U.S. and the world, respectively.

The total energy consumed in this sector in the U.S. has grown from 1.0 % to 1.5 % in the first five years of this decade, and is predicted to reach 2.0 % by 2010. The total cost (new servers together with power and cooling) of server rooms based on HDD in U.S. market has risen from \$20B in 2001 to \$60B in 2008, with \$80B projected in 2009. The corresponding fraction of total cost for power and cooling has risen from 10% in 2001 to 50% in 2008, with 70% projected for 2009 (R. F. Freitas and W. W. Wilcke, IBM J. of Research and Development, July 2008, vol. 52, issue 4, p. 439-447; www.research.ibm.com/journal/rd52-45.html).

The Department of Energy recently estimated, in background information for its role in the stimulus package, that server farms and data centers now consume as much as 3 % of all electricity in the U.S.

Security risk Only about 2% of the more than \$3.5B of integrated circuits bought annually for use in military hardware is presently being manufactured in secure facilities run by American companies. The threat of so-called Trojan horses hidden in equipment circuitry, which could disable missiles and other weapons, is among the most severe threats the nation faces in the event of any conflict in which communications and weaponry rely on computer technology.

Taken together, the root problems facing the IT industry translate into a serious threat to the U.S. economy and security.

Why Government Support is Needed

These broad problems have been recognized within the industry for some twenty years, and industry is not unaware that the hodgepodge of memories and storage is a roadblock to significant progress in information technology as a whole. In other words, development of a transformational technology is necessary. Yet two decades of effort by multi-billion dollar companies has failed to produce the desired result, or even significant progress, clearly indicating not only that the development of such a disruptive technology is a high-risk challenge, but that it requires a degree of novelty and freshness of approach absent in large companies.

For example, current methods and strategies for reducing power consumption in computers involve only incremental improvements. A typical large server, such as Fujitsu-Siemens', costs about \$1M; with redesign it has reduced energy consumption from 16Kw to 10Kw daily. Sun has done the same. Micron Technology offers a line of low-voltage servers that result in lower power demand. Further, at least two companies have bundled flash devices as solid-state disks to lower power consumption in data centers. The societal challenge to reduce power consumption is not being addressed by such incremental approaches to improvement in computer storage.

These product innovations do, however, attest to the urgency of the overall problem. They also indicate why a more disruptive approach has gone unfunded, and is unlikely to be funded in the future, by private capital. Venture capital firms avoid investing in companies interested in preserving their existing products, with market presence, and with the manufacturing and sales capability to maintain their market share. ‘The extreme difficulty of displacing individual companies pursuing incremental advances in their own products’ is a large barrier. [T. Coughlin in the opening talk at the IDEMA (International Disk Drive Equipment and Materials Association) Technical Symposium, "The Future of Nonvolatile Technologies", held 11 December 2008 in Milpitas, Calif.]

Current strategies prevent the successful development of a solution to the critical national need in the growing demand for IT efficiency. Only Government action has the potential to overcome this barrier, and Government support is desperately needed to infuse fresh thinking by innovative young companies into the process. Such development will have a high-reward impact on the U.S. economy: long-range solutions that can transform the U.S. economy in terms of job creation; broad benefits in energy conservation, telecommunications, and commerce; bringing electronics manufacturing back to the U.S.; and improved national security.

Consequence of Inaction

Failure to address the challenges faced by IT will severely inhibit the Nation’s economic growth and further erode its security. An approach to the problem by a disruptive change, rather than the current incremental approaches, is clearly called for to meet these challenges. If the U.S. does not take the lead against this crisis, other countries inevitably will, and American technological superiority will suffer, across the board, as a result.