HPC MARKET DYNAMICS MODEL AND FUNDAMENTAL FORECAST ASSUMPTIONS

At the most basic or abstract level, the traditional HPC market can be defined as money spent on computational solutions to support scientific, engineering, and analytic problems. This definition leads to a number of questions. What are the sources of the problems? What level of solution, in terms of cost, is necessary to solve a problem? How do problems move between solution levels given underlying advances in technology, absolute performance, and price/performance?

Figure 1 presents Intersect360 Research's overall conceptual model of the HPC market. It consists of problem sources, a problem sink, and a "solutions pipeline" based on the cost of the computing system or environment necessary to solve a given class of problems. This pipeline is broken into four major product class stages. In general, problems enter the pipeline at higher costs and then flow to lower-cost solutions over time based on improvements in price/performance and applications software.

We see three major sources of problem sets driving the market:

1. Unsolvable/impractical problems – Unsolvable problems possess computation requirements that exceed the capabilities of the most powerful systems at any given time. More importantly, they are also problems that are not solvable within the economic or time constraints imposed by a given organization. In other words, the problem may be solvable, but the cost of the system necessary to address the problem is beyond the resources of a given organization.

2. Problem expansion – Problems have the ability to regenerate within a solution's pipeline at a particular cost level. Over time users increase the fidelity or complexity of a solution to take advantage of increases in system performance. This can also be viewed as problem "stickiness" within the pipeline.

3. Convertible and found problems – An HPC problem set also grows by accretion; once computational methods have been demonstrated to be effective, users move (or convert) some problems that have been solved using experimental approaches to computational approaches. In such cases computational methods may be used in support of experimentation or, less often, to replace experiments. In addition, once experience is gained with computational approaches, users find other problem sets that can also effectively be addressed computationally.

Figure 1 suggests that problems exit the market after moving from higher-cost solutions to lower-cost, entry-level platforms. Although we see this as the most general case, it is possible for problems at any level to become "uninteresting" or "solved." We see problem sets leaving the market for three main reasons:

1. Trivialization – Problem requirements do not keep up with advances in computational technology, in which case the problems become trivial and are moved to general-purpose workstation or PC platforms, or they become components of larger problem sets.

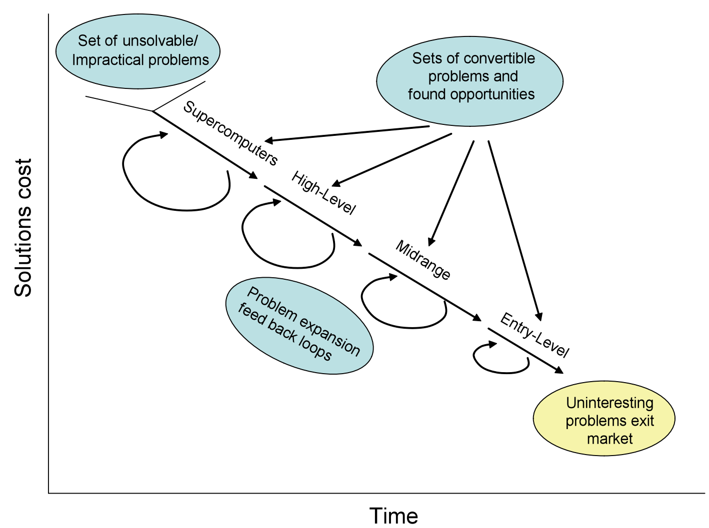
2. Solutions found – In some cases the solution space for a given problem set may be adequately explored. This may involve "good enough" product designs, scientific inquiries that hit dead-ends, or areas that simply lose the support of the market or of funding agencies.

Intersect360 Research
P.O. Box 60296 | Sunnyvale, CA 94088 | Tel. [408] 306-2926
www.Intersect360.com | info@Intersect360.com

3. Componentization – Some problems are amenable to componentization where special hardware or software is developed that allows the solution to become viewed as simply a part of the underlying computer system, or else the problem is moved to specialized solutions.

Problems may exit the market for a combination of these reasons, and it can be difficult to identify specific causes of such exits. Examples of problems that once contributed to the HPC market but now have negligible impact include: operator in the loop simulations (e.g. flight simulators), process control systems, digital signal processing, graphics generation, and so on.

Figure 1. Traditional HPC Market Dynamics



Source: Intersect360 Research 2010

Fundamental Market Assumptions

This conceptual model of the market sets the stage for a number of underlying forecast assumptions. However, it explains neither why there should be investment in HPC technology in the first place nor what the limits on that investment might be. Before going further we will list what we see as the fundamental drivers and dampers to the traditional HPC market.

Fundamental Drivers

Growth in the traditional HPC market is driven by a combination of increasing complexity of scientific, engineering, and associated problems, the competitive nature of society, and the economics of simulation and modeling versus other methods. Specific factors include:

- Nature of science, engineering, and related fields – *"Once you solve the problem it is no longer interesting." – Ancient Cybernetic Proverb.* Scientific inquiry and engineering development efforts work to solve specific problems, which in turn generate new, usually more complex problems to solve. The solutions to the new problems often require more powerful tools, including computers. By contrast, the

Intersect360 Research | P.O. Box 60296, Sunnyvale, CA 94088 | Tel. 408-306-2926
www.Intersect360.com | info@Intersect360.com

watchword for standard business computing is, *"Once you solve the problem, for heaven's sake don't touch anything."*

- Only option – In some cases, experimentation may not be possible due to physical limitations, political realities, time constraints, the abstract nature of the problem, and so on.

- Economics – Once the computational infrastructure is in place, it is generally both much less expensive and much faster to run a simulation of an experiment or test a design computationally than it is to run the physical counterpart.

- Competitive forces – Scientists compete to be the first to make a discovery, engineers compete to patent their ideas before others, industries compete based on time to market and quality of products, security agencies compete to identify and defend against threats before they can be realized, etc. Computational methods have proven to be powerful competitive tools in all these areas.

- Required tool – To the extent that computational methods have become integral to scientific research, product design, or other processes, they are to a large extent buffered from short-term economic effects. For example, an organization that competes by bringing new or enhanced products to market must first have tools in place (including computers and HPC models) to create those products.

Fundamental Market Dampers

No matter how valuable a technology or how high the potential return on investment, there are bounds on any market's growth. HPC growth is bound by the market's ability to absorb the technologies and by the worldwide budget for research and development. Specific factors include:

- Architectural complexity – Historically, increases in performance have come at the expense of more complex computer architectures, mainly in the form of greater parallelism at all levels. Although increased complexity slows system implementation at all levels (e.g., component design, system integration, system maintenance, and so on), its major impact is seen at the programmer level for system software and application software. Developing both system software to manage this complexity and application software that makes effective use of the resources is a difficult and time-consuming task. Without software the systems have no value. Thus software development and porting become a rate-limiting step. In addition, software development generally cannot begin in earnest until hardware is available. *"We can build computers with arbitrary levels of complexity, but the complexity of the average programmer remains a constant." – Ancient Cybernetic Proverb.*

- Availability of personnel – The problem of system complexity is exacerbated by limits on the numbers of competent system management and software development personnel. In this case the HPC market is competing for a limited supply of people with the innate ability, training, and inclination to do this type of work.

- Total budget – There is a limited amount that any organization will spend on research and development. Of this amount, there is a further limitation on the amount of money that will be spent on tools. Changes in these amounts are determined only in part by the expected return for R&D or the competitive risks from not engaging in R&D activities. These changes are also determined by economic and business factors, such as: how much money is available to invest; the expectations for future funds availability; whether it is better to invest it in R&D, expanded distribution channels, or salaries for high-value employees; and what other real or potential risks must be addressed at this time. Budget issues are important to consider in order to avoid two forecasting fallacies:

1. The "all the money in the world" fallacy – any forecast that predicts non-linear growth into the indefinite future will eventually predict irrationally high values for the market (usually sooner, rather than later).

2. The "Midas touch" fallacy – a forecast that assumes a constant return on investment from a particular product or strategy – and assumes that buyers will continue to raise their investments based on the ROI – will eventually have unreasonable spending within the buyer's sector.

- Cultural change limits – For organizations that decided to incorporate new R&D tools (in this case computational tools), there is a limit to the rate at which these tools can be incorporated into the organization. This limit is based on how quickly people within the organization can learn to use and (more importantly) develop trust in the new technologies, and how quickly the new technologies can be incorporated into existing processes and workflows. We see this as a cultural issue, because once it moves beyond single or small groups of researchers or engineers, the use of a significant new tool involves changes in decision-making approaches, budgets, and organizational processes that extend beyond the actual users of the tools.

Model-Based Assumptions

Our fundamental assumptions can be reframed in terms of the market dynamics model for a somewhat abstract set of assumptions:

Basic Market Drivers

Growth is driven by a combination of new problems entering the market and the expansion of existing problems. Our market driver assumptions include:

- We don't know everything – The pool of unsolved problems will not be exhausted any time in the foreseeable future.

- Significant amounts of wet-bench and physical-world applications exist – The set of convertible and found problems will not be exhausted within the foreseeable future.

- Sticky problems – There is a high degree of problem expansion feedback for basic science and national security problems, particularly within the Supercomputer and High-End segments.

Basic Market Dampers

The market is limited by a combination of the rate of technology advancement, the rate at which problems fall out of the system, and limits to funding:

- Rate of price/performance improvements – Price/performance improvements tend to move problems from higher-cost systems to lower-cost systems. Although this flow can move problems into high-volume markets, therefore leading to growth, it can also move problems out of the HPC market altogether, leading to a drop in spending.

Intersect360 Research | P.O. Box 60296, Sunnyvale, CA 94088 | Tel. 408-306-2926
www.Intersect360.com | info@Intersect360.com

- "How many flops does it take to design a toaster?" – In theory there may be no end to the degree of detail and fidelity at which a problem can be studied. At some point adequate or "good enough" answers are found. This "good enough" effect causes some problems to disappear from the market outright, and reduces the stickiness of other problems, causing them to move to lower-cost solutions.

- Minimal R&D strategy -- Many organizations do not view engineering or R&D leadership to be their competitive differentiation. In addition, even when R&D is recognized as a competitive option, organizations may believe their strengths are in other areas, such as brand management, product support, marketing and sales, distribution channels, low-cost production through process or financial mechanisms.

- Funding restrictions – No matter how high the potential return from using any technology, there are limits to the amount of money any organization can or will spend. The amount of money an organization will invest in a technology is dependent on competitive conditions, economic conditions within the organization's sector, overall economic conditions, organizational strategy and self-image, etc.

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