CONFIDENTIAL

Conceptual Plan for an Ovonic Cognitive Processor Company
Provided to the Singapore Economic Development Board
January 31, 2006

This conceptual description of our proposal to commercialize our technology should be evaluated as a work in progress. We believe that the descriptions will lead to a good understanding of the significance of our technology and one means for its commercialization. Our financial projections are based on assumptions we are still refining, and we hope this document will effectively serve as a significant step toward construction of a formal business plan including perspectives of the Singapore Economic Development Board (EDB).

We do not want to understate the potential of our technology, as we believe it could revolutionize information processing, ranging from use in personal computers to a host of specialized applications. Making assumptions toward a financial projection necessarily limits statement of the potential, but with the benefit of enabling a financial evaluation in a specific case.

The financial numbers in this document are preliminary. We will continue to refine the assumptions within the context of our discussions EDB which will lead to a formal business proposal.

Executive Summary

The Opportunity

Many complex tasks readily and intuitively performed by humans remain difficult or impossible for current computers, and conceptual, physical, and economic barriers prevent their reaching such a goal. A paradigm change is needed, embracing new concepts and materials, to achieve the required massive intrinsic parallelism. Personal computers are a commodity product offered by a large number of companies. New products clearly differentiated from the existing low-margin products of this industry would complement and dramatically extend performance by adding intelligence. Cognitive processors would be completely new products that would provide new capabilities already in high demand. They are expected to evolve rapidly, both in sales and in technology as this new industry segment emerges and then develops toward maturity.

Our technology offers a value proposition to the customers based on speed and functionality. The difference in speed is in some cases large enough to enable applications not currently feasible because conventional processors take so much time the computational tasks are not attempted. New functionalities are enabled because the technology extends processing capability making pattern recognition, including images and speech, practical from perspectives of accuracy and pattern sizes. Many other applications are candidates because the processing power dramatically lowers overall cost, as in automotive applications where the processing capability overcomes the need for more expensive components like sensors.

Our Solution

Small, thin-film, scalable, fast, nanotechnology, chalcogenide-based Ovonic devices with plasticity, nonvolatility, multistate capability, and biomimetic neurosynaptic behaviors have been successfully demonstrated by Energy Conversion Devices, Inc. (ECD). Next generation computers could be made possible by these devices, and also much more powerful neural and related networks, but more importantly these devices could enable cognitive processing. Our goal is the creation of a family of unprecedented powerful cognitive devices and processors. Applications include data mining; image and sound recognition and compression; pattern recognition in general; medical diagnosis; factoring; and intelligent information organization, searching, and analysis. Our massively parallel configurations could potentially, for example, search at a rate 400 times faster than a Pentium IV processor. The Ovonic phase-change materials from which are these devices are fabricated have already been proven in CD-RW, and DVD-RW, and in semiconductor memories being commercialized by Intel, ST and Samsung. After further development to advance our devices, circuit designs and software, we plan first to introduce cognitive processors in a generalized format which can be used in plug-in boards compatible with personal computers, transforming them to new, intelligent machines.

ECD has a strong track record of commercializing technologies, and we plan to create a company that would be incorporated in and have its headquarters and manufacturing facilities in Singapore. Its Chairman would be Pasquale Pistorio; Stanford Ovshinsky would be its Vice Chairman and Chief Science and Technology Officer; its President and CEO would be GianGuido Rizzotto. We have a team of scientists, engineers and business professionals who would provide essential expertise and talent to fully develop and commercialize the technology. ECD has a proven track record for moving our technologies to commercialization. United Solar Ovonic is manufacturing and selling unique photovoltaic products, COBASYS for our nickel metal hydride batteries, and perhaps most importantly, Ovonyx, Inc. ("Ovonyx"), a company we formed with Tyler Lowrey, the former Vice Chairman of Micron, to commercialize the closely related Ovonic Unified Memory. Ovonyx is working with Intel, ST, Elpida, Samsung and others to commercialize those products.

The Reward

Products based on this new technology could start in the short term, and more importantly, grow rapidly as new applications are addressed and through continued development of the materials, devices, circuits and software. The advent of the transistor revolutionized electronic devices, and the continued development of silicon-based devices in integrated circuits opened commercial opportunities that have led to a one trillion dollar market. However, the continued progression following Moore's Law is threatened, and the end is in sight as the silicon devices face fundamental physical limits which will lead to the end of the scaling that has enabled their continued progression. This technology has the attributes to extend that progression well into the future. We project that with a cash investment of approximately $142 million we can build a business that would start product sales in the fifth year, and grow to generate $1.2B in sales in the tenth year, employing over 500 people in Singapore. This is just the start: Bill Gates, founder of Microsoft, predicts that "if you invent a breakthrough in artificial intelligence, so machines can learn, that is worth 10 Microsofts."

It is Singapore's intent to become a knowledge-based society in order to maintain and improve its position within the global economy. Creation of the proposed company would help Singapore succeed in its move towards the forefront of knowledge-based societies.

Business Opportunity

Market Need

The advent of the transistor revolutionized electronic devices, and the continued development of silicon-based devices in integrated circuits opened commercial opportunities that have led to a one trillion dollar market. However, the continued progression following Moore's Law is threatened, and the end is in sight as the silicon devices face fundamental physical limits which will lead to the end of the scaling that has enabled their continued progression. A new technology is required to extend the scaling of electronic devices. Moreover many complex tasks readily and intuitively performed by humans remain difficult or impossible for current computers, and, even should the physical barriers be overcome, conceptual and economic barriers would prevent their reaching such a goal. A paradigm change is needed, embracing new concepts and materials, to achieve the required massive intrinsic parallelism. Finally, modern society increasingly relies on information to improve efficiency in communications and decision making processes. Concurrently, as personal computers are used by ever growing numbers of people and with the growth of the internet, the information that exists in electronic form has become overwhelming. The desire and need to interpret that information on short time scales is increasing. Currently, the magnitude of the task of managing information is leading to its migration away from the individual personal computer into the internet as search engines like Google provide quick access to large amounts of information through content-based searches. A processor that could efficiently search by content would be a powerful adjunct to personal computers for a wide range of applications.

The need for a new computer technology to overcome the physical, conceptual, and economic barriers currently faced is widely recognized within the computer industry. It is anticipated that the solution will be provided by nanotechnology. The International Technology Roadmap for Semiconductors envisions a transition to such new nanotechnology devices as single-molecule or single-electron transistors around 2015. There is thus a 10 year window of opportunity to create a dominant commercial position.

Market Opportunity

Our technology when fully developed can be used in many types of processors, designed in some cases for generic application and in some cases for specialized application. Our plan is to begin with more generalized processors that can be productized as plug and play boards for conventional professional-level personal computers. In this way we can address a relatively large number of potential users to start sales.

Our analysis shows that there is a market of over $5B in computers used by sophisticated users; for example, in advanced computational applications, image and video processing and pattern recognition. Our first product would be a printed circuit board containing the Ovonic Cognitive chip. The board would be designed to plug into standard personal computers to dramatically enhance their computational and functional capabilities. We project first product sales starting in the fifth year of the venture, with unit volumes in the fifth, sixth, eight and tenth years of 200,000, 700,000, 2.6 million and 4 million, respectively. This is based on an assumption of 50% market penetration of advanced users in the tenth year.

The market for personal computers is shared by a large number of companies, all competing to sell very similar product offerings. The products proposed here would be clearly differentiated from the existing low-margin products of this industry based on this new, disruptive technology. They would complement and dramatically extend performance in new ways. Cognitive processors would be completely new products that would provide new capabilities already in high demand. They are expected to evolve rapidly, both in sales and in technology as this new industry segment emerges and then develops toward maturity.

As the business progresses, we would address other applications requiring other product forms. Automotive engine control is a prime example. Increasing demands for low-emission vehicles require increasing processing to provide signals that can be used to control air/fuel mixtures in a dynamic mode. Neural network implementations in conventional microprocessors are already being used for this type of control. Our processors would allow substantially increased control and give improvements in both emissions and performance. Applications in gaming, robotics and medical are also anticipated, among others.

Our Technology

Small, thin-film, scalable, fast, chalcogenide-based Ovonic devices with plasticity, nonvolatility, multistate capability, and biomimetic neurosynaptic behaviors have been successfully demonstrated by ECD. The Ovonic cognitive devices are based on the amorphous chalcogenide technology pioneered at ECD by S. R. Ovshinsky, inventor of phase-change devices, including phase-change optical memory, the Ovonic Universal Memory (OUM), the Ovonic Threshold Switch and three terminal devices.

We fabricate these devices in our wafer processing lab at ECD. We have all equipment needed for the fabrication and evaluation of chalcogenide devices such as these, and we can demonstrate the neuronal analog and synaptic weighting operation of the devices. In addition, we also fabricate devices for circuit control, including Ovonic Threshold Switch devices in two and three terminal configurations. The next step in device development is optimization of the accuracy of the device operation and feeding the results into circuit simulation programs to propose and then fabricate circuits entailing interconnection of large numbers of the devices.

Building on these accomplishments, next generation computers would be enabled by these devices, which combine memory and logic within a single device and thereby unify hardware and software. In addition to the cognitive devices, other devices can be formed by deposition of thin films, including programmable resistors, threshold switches now undergoing commercialization, and multi-terminal devices for logic and control. A key element of the technology is that the devices can be fabricated in three dimensional arrays to give reconfigurable interconnectivity and massive parallelism. The devices scale, operate at high speed, and have the plasticity that enables them to act like neurosynaptic cells with adaptive leaning capability. This combination of features enables fabrication of much more powerful neural and related networks, but more importantly enables cognitive processing.

We propose herein to develop and commercialize chips integrated into board-level solutions that provide cognitive capability for a wide range of applications. Our ultimate goal is the creation of a family of unprecedentedly powerful cognitive computers. The initial product would consist of a multiple chip set, based on a powerful intermediate-scale Ovonic cognitive processor with 16,000 neurosynapses, on an embeddable card readily installed in a personal computer together with the relevant software transparently implementing our powerful new proprietary algorithms. It would be addressed to diverse markets, some of which are listed in the chart in the Applications section below. It would set the stage for subsequent chip sets of even more powerful processors, with a hundred million neurosynapses, achievable with current technology. Complex problems normally reserved for supercomputers would then become accessible to personal computers. We have demonstrated similar cognitive functionality when using optical energy to address the devices, enabling future hybrid electro-optical circuits.

Intellectual Property

The technology relating to the Ovonic Cognitive Computer (“OCC”) has two components. The first component is technology conceived, developed or reduced to practice and owned by ECD. The second component is technology conceived, developed or reduced to practice and owned by Ovonyx. Ovonyx is exclusively licensed under our patents and technology in the field of Ovonic Universal Memory (“OUM”) and we receive a grant back exclusive license from Ovonyx in the field of OCC. OUM is generally accepted to be the eventual replacement for flash, EEPROMs, microcontroller memory and perhaps even DRAMs. Ovonyx has been working in the field of OUM with joint development partners for over 5 years and has a large number of patents. By combining ECD’s background OUM patents and know how with those patents developed by Ovonyx and then adding ECD’s more recent work specifically directed to OCC, ECD is now protected by many broad basic patents as well as more limited, but yet important, improvement patents. We have over 90 patents in our field of OCC covering many aspects of the OCC technology. More specifically the patents cover the cognitive operation and functionality of the phase change materials; memory, processing and logic devices made from such materials; methods of fabricating the devices; circuits relating to device and circuit operation and control; and algorithms relating to the use of the devices and circuits. ECD has an additional 10 pending patent applications directed to further aspects of its OCC technology. We feel that the patent portfolio that we have already developed will prevent companies from moving into the field of cognitive computing using Ovonic devices without a license from ECD.

Applications

Applications for our technology fall into the broad categories of neural networks, fuzzy logic, and cognitive systems. Although the nearer term applications are in fuzzy logic and neural networks, we believe that the larger markets will be in cognitive systems. However, the distinction between true cognitive systems and neural networks and fuzzy logic is not distinct in the cases where the size and power of the latter two is beyond what can be accomplished today. Our technology enables that, and therefore we believe that we can expect high demand based upon levels of performance not yet available.

The basic advantages we offer are made possible by the high level of functionality of our individual devices. Coupled with much simpler design implementations and ease of fabrication, we can build much more powerful processors. This translates into higher levels of computation which enable higher level function in searching, pattern recognition, intelligent information organization and analysis.

The graphic below shows at a summary level the customer value proposition we offer. One can easily see that the range of applications is broad, and to establish a scenario for making financial projections we have selected one product category. We chose the introduction of generic cognitive processors as our base case.

Applications
For
Ovonic Cognitive Processors

Application Area	Key Attributes
Personal Computers General purpose processors Specialized Processors	Data mining and analysis Pattern recognition Voice recognition Complex computational processors
Gaming Advanced generation control	Image processing Voice recognition
Automotive Engine control systems	Emission controls Fuel economy Safety systems
Robotics Vision systems Motion control systems	Image processing Pattern recognition Neural networks Voice recognition and control
Medical Image interpretation Diagnostics	Image processing Data analysis

NewCo

The new company (NewCo) would be structured as a Limited Liability Company (or equivalent) formed in and having its headquarters in Singapore. Its Chairman would be Pasquale Pistorio; S.R. Ovshinsky would be its Vice Chairman and Chief Science and Technology Officer; its President and CEO would be GianGuido Rizzotto. NewCo would have four centers of activity, one in Italy under the direction of Mr. Pistorio and Mr. Rizzotto, two in Singapore also under the direction of Mr. Pistorio and Mr. Rizzotto, and one in Michigan under the direction of Mr. Ovshinsky.

The Michigan center would lead cognitive device and computer development. It would employ approximately 20 individuals focused on cognitive device and computer technology. In addition to the continuing development of Ovonic cognitive devices, networks, chips, and chip sets, it would provide technology training for employees in Italy and Singapore facilities.

In the Italian center, approximately 20 employees would focus on the creation of algorithms and architecture for Ovonic cognitive processors, on the development of system platforms, and on system integration.

In Singapore, a group of approximately 20 persons would collaborate with the Singapore research center, ASTAR, to carry out prototype manufacturing of devices and chips using ASTAR's existing wafer-production facility.

The headquarters and manufacturing facilities would also be located in Singapore. There are two manufacturing options. In the first, chip fabrication would be outsourced to a vendor meeting our capability requirements for the fabrication of Ovonic cognitive chips. Although this capability is not yet available, we are anticipating that several companies will be producing OUM chips in the very near future. Since the processing technology for OUM and the new cognitive chips is very similar, these companies would likely be potential vendors for our chip sets. Chip sets would then be assembled on boards in the NewCo facility. It is fabrication of these boards that will be the primary activity of NewCo. Alternatively, chip fabrication and board assembly would both be carried out in the NewCo facility. This alternative would be based on using a conventional silicon foundry to fabricate silicon wafer based control circuitry, and then in the NewCo facility we would complete the fabrication by adding the Ovonic layers. The product development plan and the business plan financials in this document are based on the first option, board assembly using purchased parts.

The operational management structure would evolve from the primarily R&D organization in the first years to a production oriented management in the following years. This operational management structure would be located in Singapore, and be comprised primarily of Singaporeans. As the company progresses from R&D to manufacturing, the fraction of Singaporeans in the company would progress from about one third of staff to well over 90% of staff.

Commercialization Strategy

Our overall plan is long ranging, but in this proposal we focus on the first products. Products based on this new technology could start in the short term, but perhaps more importantly, the company could grow rapidly as new applications are more specifically addressed and through continued development of the materials, devices, circuits and software.

The Ovonic phase-change materials from which are these devices are fabricated have already been proven in rewritable optical disks including CD, DVD and are now incorporated in both proposed formats for HDTV content storage. The Ovonic Universal Memory (OUM) invented by Ovshinsky and now being commercialized through Ovonyx, is very near to product introduction. Ovonyx' licensees include Samsung Electronics, BAE Systems, Intel, STMicroelectronics, Nanochip, and Elpida Memory. Of the several candidates for electronic devices that go beyond the scaling limits of silicon transistors, the OUM has been chosen by these and other companies because of a combination of characteristics including scaling, but importantly also because of ease and economy of manufacture. To fabricate the circuits we describe herein, we shall build upon the technology base that has moved OUM to production. The circuits we propose are based on very much the same fabrication technology used for the OUM. Consequently, the opportunity exists of outsourcing chip production to a company engaged in OUM production. Alternatively, chip production could be carried out in-house as well. Our business plan assumes that chips would be produced by an industrial partner brought by the Singapore Economic Development Board.

We plan first to introduce cognitive processors in a generalized format which can be used in plug-in boards compatible with professional-level personal computers. Our customers would be both manufacturers of the computers, and users who would upgrade their own computers. We would assemble the boards in-house under either scenario. The functionality of the boards would compliment the capabilities of the existing digital processors. These products would introduce the technology to industry, and demonstrate the capability of the processors for a wider range of products. We envision our chips and chip sets being used in most electronic devices, ranging from personal computers through automotive control systems to voice recognition systems in cell phones, personal digital assistants and a wide range of appliances in between. The initial products, based on the powerful intermediate-scale Ovonic cognitive processor with 16,000 neurosynapses, would address low end needs of these diverse markets.

Pattern recognition would be a broadly utilizable high-end application of our Ovonic cognitive technology.

Management Team

The Board-level management of the venture is led by Pasquale Pistorio and Stanford Ovshinsky. Mr. Pistorio most recently led STMicroelectronics (ST) to its position at the top ranks of international semiconductor companies. Mr. Ovshinsky founded ECD and is the prime inventor of the materials and devices which enable this opportunity. Mr. GianGuido Rizzotto would be the CEO of the new company. Mr. Rizzotto brings international leadership and a history of demonstrated success in developing and commercializing new technologies

The support teams in both Italy and the US consists of scientists, engineers and technicians all of whom are experienced in the field.

Product Development Plan

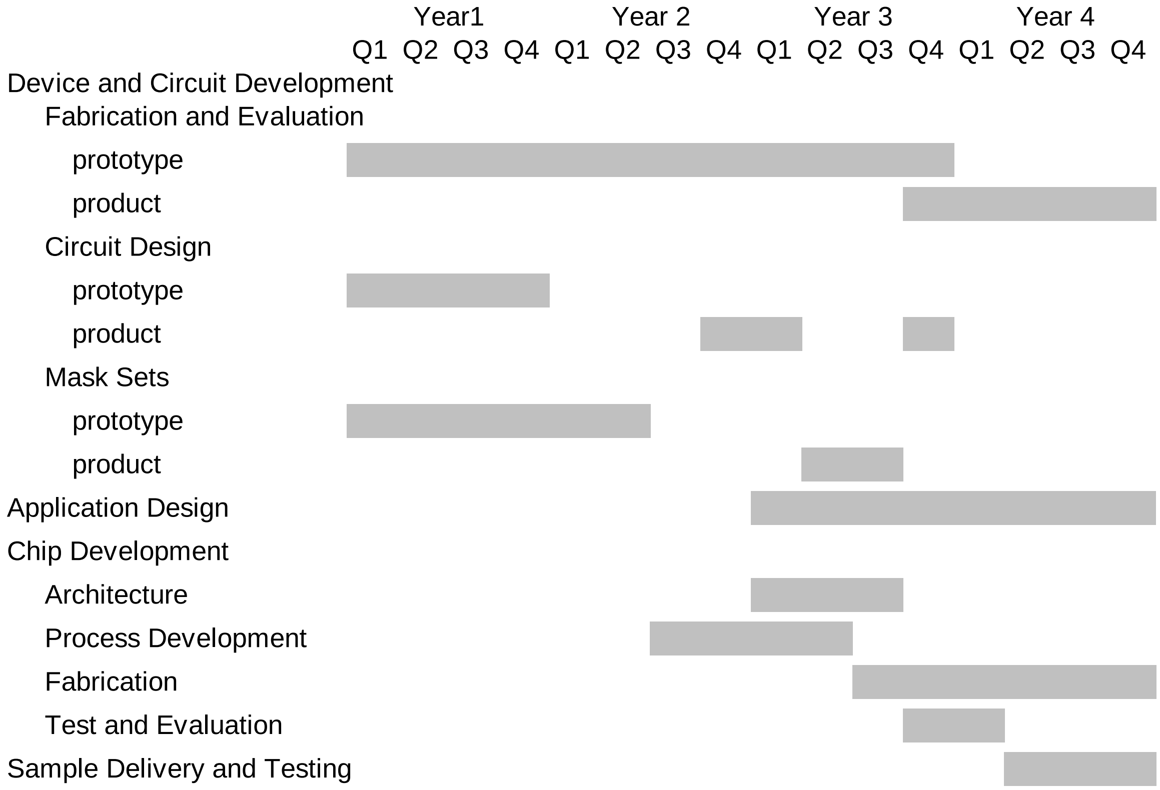
The first product would be a circuit board incorporating a cognitive chip set based on an array of cognitive devices that gives capability not possible in silicon implementations. The board would be a plug-in suitable for use in any personal computer, although our target market is high-end users. The cognitive chip set would enable new types of computational processes, and facilitate application in areas that can't be practically addressed by today's technology. The Gantt chart below summarizes the development plan.

We can already demonstrate the performance of our several types of devices. Our next development efforts would be to optimize the basic circuit building blocks we have and combine them into complete circuit solutions. This will be done in conjunction with further development of processing algorithms, and through materials and device optimization in response to circuits and algorithms that would be defined as work in those areas progresses.

A key strategy element we are incorporating is a flexible design that allows both efficient optimization and reconfiguration in the development phase and that can also be used as the basis for the first cognitive chips. The design used during the first two years of development would have flexibility to enable implementation of variations of a basic circuit. This would allow test and evaluation of differing algorithms and architectures during optimization.

This chip development would be a cooperative effort between the group in Michigan and ASTAR in Singapore. Materials and device function optimization would be led by the group in Michigan. ECD has a fully equipped wafer fabrication laboratory which allows us to make state-of-the-art devices. (Our joint venture partner, Ovonyx, also uses this fabrication facility, leading to many technical successes in their joint development programs with their licensees.) Test wafers would be fabricated and evaluated both in Michigan and at ASTAR. Continued development of materials and devices would continue in the third and fourth years, supporting commercialization of the first chips and migration to the second generation, much more powerful chips.

Development Plan Gantt Chart



The group in Italy would lead development of algorithms, architecture and software, with support from the group in Singapore. This work would elevate to commercial product development starting in the second year. The development of carbon nanotubes for interconnections would be accomplished by the groups in Italy and Singapore, with integration assistance from the group in Michigan.

The group in Singapore would develop the boards that would be the commercial products. The working relationship with the groups in Michigan and Italy would serve as the technology transfer vehicles so that the Singapore group can easily transit to commercialization.

We anticipate that multiple companies will be manufacturing OUM devices before this venture requires chips, and we could expect to purchase chips from such a company. We hope fabrication of the chips could be accomplished in Singapore by an industrial partner brought by the Singapore Economic Development Board. Their technology development would be facilitated through chip development included in our plan within the ASTAR group and ECD.

Customers and Sales Channels

We can address two groups of customers, original equipment manufacturers and individual users. Our anticipated products would have the capability for installation into computers already in the field, however, we anticipate that products offered to customers through purchase of a new computer presents a better business opportunity. NewCo also benefits from this in the following ways. First, the number of customers is much smaller and therefore easier to manage. Second, sales through computer providers also add benefit to those companies as well, so we engage our most important customers as opposed to circumventing them. Third, this approach automatically adds sales and distribution channels.

Pricing

Our sales price assumptions are based on comparisons to other board-level components used in personal computers. However, the solution we provide to the customer goes beyond those comparables. For instance, the software Microsoft provides converts basically useless hardware into sophisticated and powerful information processors. Our products would provide analogous capability in the sense that new, much higher levels of performance would be enabled by our combination of hardware and software.

Further, we are providing a revolutionary new product. Our intellectual property position allows us to control competition. We believe that we would be able to command attractive sales prices as has repeatedly been the case with other new, high technology products.

We are anticipating two products within the scope of our financial projections. The earlier product is at a performance scale that stresses early product introduction at an attractive performance level. We assume an initial price of the first board-level product of $320. Our plan assumes that a second, much higher performance product will be introduced two years later at an initial price of $600. In both cases, we assume selling price declines of 12% per year.

Financial Summary

We have constructed our financial plan using assumptions based on our collective experience in the field. We have based our market projections on data from independent, professional personal computer market forecasts and estimated chip manufacturing costs, board assembly costs and comparative selling prices of high-performance plug-in circuit boards for those computers drawing upon the knowledge of our experienced team.

We are making assumptions at three levels: a base case, an optimistic case, and a more conservative case. These assumptions are given in the following table.

	Base Case	Optimistic Case	Conservative Case
Year of first product sales	5	4	5
Addressable Application Market	High performance computers	Additional computers, drawn from lower performance market segment	High performance computers
Profit margin in 10th year	52%	60%	30%
Market penetration in 10th year	50%	200% (based on market expansion)	*25%*
R&D Investment required before 1st sales	$82M	$82M	

We have preliminary financial calculations for the base and optimistic cases, and we are working on the conservative case. In the base case we project that with a cash investment of approximately $140 million we can build a business that would generate approximately $1.2 billion in sales in the tenth year, and employ over 400 people in Singapore. Financial highlights are shown in the table below.

Tenth Year	Base Case	Optimistic Case	Conservative Case
Annual Units (000's)	4,000	13,000	
Annual Sales ($000's)	$1.2B	$4.1B	
Annual Income ($000's)	$621M	$2.5B	
Maximum Cumulative Cash Out ($000's)	$142M (in year 5)	$142M (in year 5)	
Internal Rate of Return (excluding terminal value)	42.8%	83%	
Total Employment	504	1,300	

Sources of Investment

ECD has formed a subsidiary company named the Ovonic Cognitive Computer, Inc. (OCC) for the purposes of commercializing the technology. OCC is owned 95% by ECD, and 5% by Ovonyx. All technology related to cognitive processing developed by either ECD or Ovonyx including future developments is exclusively licensed to OCC on a royalty bearing basis. The new proposed company in Singapore would be owned 51% by OCC, 21% by Pasquale Pistorio and 28% by investors in Singapore. The shares of NewCo owned by OCC are in consideration of the license to technology and contribution of and/or access to extensive equipment and the clean room wafer processing facility at ECD. Mr. Pistorio's shares are in consideration of the technology and reputation contributed, and the shares owned by investors in Singapore are in consideration of cash contributions.

Financing would come in part from the Singapore Economic Development Board and in part from industrial partners in Singapore. The Singapore Economic Development Board would provide the industrial partners in Singapore.

Prospects for Success

ECD and its founder S.R. Ovshinsky have a strong history of successful invention, innovation, and commercialization of products of great importance in major areas of technology. We have created strong intellectual property positions including know-how in the information, and energy fields. Our successes in commercialization are exemplified via our joint venture strategy and are detailed below.

In the area of *energy generation*, their triple-junction amorphous semiconductor solar cells are the low-cost leader in the very rapidly growing industry of solar energy. ECD's wholly-owned subsidiary, United Solar Ovonic, operates a state-of-the-art manufacturing facility whose major asset is a fully automated production system utilizing machines designed and built by ECD's Machine Building Division. The factory has an annual capacity of 25 Megawatts of photovoltaic modules, and the company is currently expanding to double its manufacturing capacity. All of the output of the current machine is being sold, and the demand we are receiving will easily require the capacity after the expansion. Further near-term expansions are anticipated.

In *energy storage*, ECD's nickel metal-hydride batteries are transforming the automotive industry as the penetration of hybrid vehicles increases. ECD has formed a 50/50 joint venture with Chevron, COBASYS, for production of battery systems for automotive and stationary applications. COBASYS has a manufacturing plant with an annual capacity to build two million battery modules for hybrid vehicles. Production is starting, and GM has committed to use COBASYS battery packs in its new Saturn VUE Green Line Hybrid SUV.

In *information systems*, optical memory technology has become standardized on Ovonic phase-change materials including CDs, DVDs, and currently BluRay and HD-DVD as well. ECD has licensed manufacturing rights to the leading companies in the optical storage community. Those phase-change materials provide the basis for the emerging OUM electrical memory industry as well, aimed at replacing flash memory, DRAM, and SRAM.

Commercialization of the OUM technology is proceeding at several major companies through licensing and technical support of Ovonyx. Ovonyx has partnered with Intel, and licensed the technology to STMicroelectronics, Samsung, Elpida, BAE systems and others. The Ovonic threshold switch is now in the earliest stages of commercialization. In particular, this long history of the success of ECD Ovonics and Mr. Ovshinsky in information systems establishes a global experience on which success of the proposed company will rest. (For more information visit www.ovonic.com.)

In addition, strong scientific and management expertise is brought to NewCo through the involvement of Paquale Pistorio, formerly President and CEO of STMicroelectronics. Starting as President and CEO of the SGS Group, the only Italian microelectronics company, he presided over the integration of SGS with Thomson Semiconductors and the evolution of the merged companies into a world-leading microelectronics company, STMicroelectronics (ST).

Thus, both elements of leadership necessary for the success of the proposed company are present – the technology and commercial development leadership from ECD Ovonics and Mr. Ovshinsky and managerial leadership through Mr. Pistorio.

The prospects for return on investment are strong. Analysis of the first commercialization based on plug-in boards for professional-level personal computers shows returns of 42% before terminal value, and 82% after terminal value based on a ten year plan.

It is Singapore's intent to become a knowledge-based society in order to maintain and improve its position within the global economy. Creation of the proposed company would help Singapore succeed in its move towards the forefront of knowledge-based societies in two complementary ways. First, Singapore would become the pioneering center for the manufacture of a new, transformative industry, the cognitive computer industry. Second, the collaboration between the company and ASTAR would build up within Singapore a knowledge base for that industry that would inevitably lead to a broad range of spin offs.

Appendices

Applications

Market Opportunity – Research & Assumptions

Key Management Vitae

Business Plan Financials

Applications

Applications of our proposed chip set, which incorporate cognitive neural networks, mathematical networks, and search engines, are numerous and wide ranging. A few specific examples are data mining; image and sound recognition and compression; pattern recognition in general; medical diagnosis; factoring; and intelligent information organization, searching, and analysis. They fall into two broad categories, information processing and the simulation and optimization of dynamic systems, although aspects of each are present in the other. We interpret dynamic in the broadest possible sense, incorporating repeated operations such as iteration, repeated events in real time, and processes continuous in time. Within each category there are many possibilities. A few prominent examples are as follows.

In the dynamic systems category, two quite different applications illustrate the range of possibilities. The first is speech recognition. Current digital programs work with high accuracy for unknown speakers with a limited preset vocabulary in a stimulus-response mode. Digital programs which are trained to recognize the speech of a single individual work with less accuracy but with a much larger vocabulary. Within the context of speech with pauses between each word, they can recognize up to 20,000 words. Most such programs simulate neural networks in conventional computers. Our cognitive neural and other networks would greatly increase hearing capability through their superior scalability to higher densities as well as superior speed via hardware architecture adapted to the task as opposed to the hardware of a general purpose computer, via our novel software adapted to the hardware as well as to the task, and via intrinsically faster devices. We expect to be able to understand a 50,000 word vocabulary of an unknown speaker. It is a holy grail, and we believe it reachable via our proposed technology when scale up is achieved.

The second product family addresses the solution of complicated boundary value problems. Finite element programs are in routine use in all fields of engineering for design and for analysis, and similarly in architecture. Our current software for use with conventional computers is 10 to 100 times faster for the complicated thermal problems we have studied, and the speed-up is generic and not related to the specific problem. Moreover, opportunities for further increase in the speed of our programs exist by intensive substitution of single-step network operations for operations which scale as N or N^2 in conventional computers, where N is a number measuring the size of the data operated on. Substituting the hardware and software of our cognitive networks for the simulated neural networks and conventional codes we have used thus far would yield a total dramatic increase in speed estimated to be on the scale of 10^6. Thus, a substantial market would exist for a cognitive chip set for a wide range of applications. For example, a major automobile maker now bases its engine designs on a finite-element model so computationally complex that it cannot be used for design optimization even when run on a supercomputer. Instead, some performance information is generated, and a computationally simple surrogate model is fitted to that enormous data set. With our goal of a factor of 10^6 increase in speed via our cognitive networks, the time scale would be reduced from months to seconds, permitting full use of the design model and avoiding the use of much less accurate surrogates.

With the addition of fuzzy logic, to which Ovonic cognitive devices are well adapted, our software developed for the solution of complex boundary value problems can morph readily into powerful, generic pattern recognition software applicable to the speech recognition challenge noted above and to all other real-time dynamic pattern-recognition problems. The necessary speed is achievable through implementation on the Ovonic cognitive computer chip set which we are proposing to develop.

The information processing category is vast. Examples are static language processing, e.g. translation as opposed to speech recognition in real time; intelligent information organization, searching, and processing; pattern recognition; etc. A fast processor specialized for searching and recognition could greatly accelerate such information processing. Our efficient new search algorithm could be implemented on a network of these new Ovonic cognitive devices specifically adapted for it. With a $10^4 \times 10^4$ network of our new devices and 16 states per synapse, our simulations lead us to project that our search rate would be equivalent to about 2×10^{12} 32-bit words per second. This rate is 400 times faster than the rate we estimate to be about 5×10^9 32-bit words per second for a Pentium IV processor, a very significant acceleration. However, this four-hundred-fold acceleration of a simple word-by-word comparison, though important, is not the most significant improvement achievable with the proposed technology. With a hierarchical integration of modules consisting of our neural networks, mathematical networks, and search engines, we can develop a hierarchically organized taxonomic or cladistic data base much like the Linnean classification system and its successors. Highest level features would be extracted initially from input data, and a clustering analysis performed to establish the highest level category and so on down the hierarchy using multivalued logic at each transition. Such a system could be used as a powerful associative memory, for pattern recognition, for classification, for such bioinformatics as genomics and proteomics and for many other applications; it would advance us towards active cognition.

One example of a low-end application would be a chip set consisting of a neural network with supporting networks embedded within an automotive control system. The neural networks currently in use for automotive control are simulated on a conventional microprocessor, typically have 10 input neurons and 10 output neurons, and operate on a 10 millisecond time scale. They contain too few neurons for optimal performance and are about a factor of 5 too slow. One of our 128 x 128 networks would contain the equivalent of 16 x 16 neurons and would operate on a microsecond time scale, a significant improvement over current products.

Market Opportunity – Research & Assumptions

Overall IT Market[1, 2]

- Global information technology industry = ~US$1 trillion (2005)
- 18% growth during 1999 to 2003 (4.1% CAGR); continued growth expected at ~5%
- Hardware accounts for ~35% (US$350B) of the IT industry
- 600M PC users globally (2004); expected to reach 1B by 2010
- Worldwide PC installed base = 713.91M (2002); 11.19% CAGR (2001-2004) yields a 2005 installed base of 980M (many PC users have multiple systems)
- PC unit shipments growing at 10.5% in 2005 (mobile at 26%)

High Performance Computing Market ("Sophisticated Users")[3, 4]

- Total high performance technical computing market = US$5.617B (1999)
- Breakdown (1999) = vector supercomputers (US$500M), large parallel processing computers (US$443M), and remaining "technical capacity" market (US$4.683B; 9.3% CAGR).
- Assuming continued growth per 1999 growth estimates and actual PC growth benchmark, the "early adopter" technical capacity market is now ~US$7B (2005)

Total Addressable Market.[5, 6, 7]

- The ~US$7B technical capacity market represents 2% of the total US$350B global hardware market. NewCo is initially targeting specialty applications in this technical and business computing niche where high processor speeds and throughput on many small jobs are essential.
- Additional potential markets *not* included in this analysis could more than double the above figure: (1) "computer gaming" (at least US$10B with ~20% CAGR), (2) high-tech military applications (billions), (3) "new" commercial applications not currently feasible (e.g. the advanced speech translation market is ~US$1B and growing at >60%/yr), and (4) high-end PC applications as personal computing and technical computing applications converge.

[1] Frost & Sullivan Country Industry Forecast – The U.S. Information Technology Industry (9/12/05)
[2] Frost & Sullivan Decision Support Database - Consumer Electronics: Personal Computers (8/20/02)
[3] Defense Science Board Task Force on DoD Supercomputing Needs. 2000.
[4] Foster, R. et. al. "Evolution of the High End Computing Market in the USA." International Journal of Technology Management. Vol. 24, Nos. 2/3, 2002.
[5] IDC Analyst Report, 5/24/2004. www.zdnetasia.com/news/internet/0,39044246,39180532,00.htm
[6] Electronic Arts CEO John Riccitiello quoted in Fool.com interview 12/02.
[7] Frost & Sullivan Technical Insights: "Voice Recognition: Innovation Brings Speech to the Market" (3/8/00)

Key Management Vitae

Stanford R. Ovshinsky, President and Chief Scientist and Technologist, ECD, founded ECD in 1960 with his wife, Dr. Iris M. Ovshinsky, to apply his pioneering work in amorphous and disordered materials to build new products that would benefit mankind and strive to solve important societal problems. His fundamental and basic contributions established the field, resulting in unexpected new physical, chemical and electronic mechanisms. He is a prolific inventor who has enabled technology in four major areas: *energy generation*, including photovoltaics and fuel cells; *energy storage*, including Ovonic nickel metal hydride consumer, electric and hybrid vehicle and stationary batteries and solid hydrogen storage; *information systems*, including amorphous semiconductors, switching and phase-change memories, both optical and electrical; and, *atomically designed synthetic materials* for a wide variety of uses.

Stan Ovshinsky is a fellow of both the American Physical Society "for his contributions to the understanding, applications and development of amorphous electronic materials and devices" and of the American Association for the Advancement of Science. He is recipient of the American Solar Energy Society *Hoyt Clarke Hottel Award*, the *Karl W. Böer Solar Energy Medal of Merit*, the International Association for Hydrogen Energy *Sir William Grove Award*, and was named Hero of Chemistry 2000 by the American Chemical Society. Recipient of the 2005 Innovation Award for Energy and the Environment by *The Economist*. In 1968, he received the *Diesel Gold Medal* presented by the German Inventors Association (Deutscher Erfinderverband), in recognition of his discovery of the semiconductor switching effect in disordered and amorphous materials. He is among 35 American inventors over the past century profiled in *Inventing Modern America*.

Pasquale Pistorio graduated in 1963 in Electrical Engineering from the Polytechnic of Turin with a Degree in Electronics. He began his career with Motorola and in 1977 become Director of International Marketing and Vice President of Motorola Corporation. In 1978 he was promoted to General Manager of Motorola's International Semiconductor Division, responsible for design, manufacturing and marketing activities for all regions outside of the United States.

In 1980 Mr. Pistorio became President and Chief Executive Officer of the SGS Group, the only Italian microelectronics company. His unwavering commitment to build the company into a profitable broad line semiconductor manufacturer led to one of Mr. Pistorio's most significant achievements to date: the successful integration of SGS with the French semiconductor champion, Thomson Semiconducteurs, in 1987. This was a powerful merger, which put the newly formed company, SGS-THOMSON Microelectronics (renamed STMicroelectronics in 1998), in a strong position to compete on the international market.

As President and CEO of that new company, Mr. Pistorio has been responsible for developing ST's diverse product portfolio based on high-growth applications, as well as its worldwide network of strategic alliances. This business model has proved so successful that ST is now positioned at the highest level in the worldwide ranking of semiconductor companies.

In the last two decades, Mr. Pistorio has championed the cause of Europe's microelectronics industry and his role has not been one of pure theory but has produced concrete and important industrial results.

As a firm believer in corporate social responsibility, Mr. Pistorio takes a special interest in the cause of fighting the Digital Divide -- the huge imbalance between those who have access to information technology and benefit from it and those who do not. As a member of the United Nations Information and Communications Task Force dedicated to bridging the Digital Divide, he helps develop proposals to attract corporate attention and commitment to this new worldwide challenge.

Upon his retirement as President and CEO of STMicroelectronics in 2005, Mr. Pistorio was appointed by the Company's Managing Board as Honorary Chairman, where he acts as an ambassador of the Company while continuing to make available to ST, as appropriate, his wealth of experience and insight into the semiconductor, electronics, and industrial worlds.

A third key member of the management team is GianGuido Rizzotto. Mr. Rizzotto brings both valuable technical and management expertise to the venture and would become the CEO. Mr. Rizzotto graduated from the University of Milan in 1971 with a degree in Physics. He began his career in the telecom industry as a software analyst, working in both Italy and the USA. He moved into the semiconductor industry initially with Texas Instruments as Telecom Strategic Marketing Manager and then with National Semiconductor as Telecom Industry Marketing Director. In 1982, he joined SGS-THOMSON Microelectronics (now STMicroelectronics) as Strategic Marketing Director for the Telecom and Computer segments and shortly afterwards he was appointed Corporate Director, Advanced System Architectures, responsible for developing business opportunities for applied technologies and innovative methodologies.

Mr. Rizzotto was appointed in 1998 as Vice President and General Manager Corporate R&D for Soft Computing, Silicon Optics, and Post-Silicon Technologies, driving a 250-person multi-disciplinary and multi-national team into advanced R&D efforts involving automotive engine management and control, complex systems, multi-objective optimization, silicon nano-technologies, bio-electronics, and organic molecular electronics. In December 2004, his focus shifted to 'Post Silicon R&D' with an emphasis on carbon nanotubes (in Singapore and Italy), molecular electronics, nano-hybrid silicon structures (for memories and cognitive computing) and polymeric electronics for organic and flexible displays.

Mr. Rizzotto has played an important role in international research programs with several universities and research and development centers. His research and development activities have resulted in more than 50 patents. Mr. Rizzotto co-authored three publications on SoftComputing and has published over 100 articles and numerous conference reports.

With an extensive network in the research community, GianGuido Rizzotto heads the European PolyApply Consortium and sits on the Boards of the European NanoTechnology Association. He is a member of the Nanotechnology advisory board at CNR (National Research Council) Italy–Naples, the Board of the 'International Center for Security,' the board of the Master on Complexity, and the board of IMAST (Institute for Manufacturing and Sustainment Technologies). He is also the President of the International Information Academy and a foreign member of the Russian Academy of Science.

Business Plan Financials

Key Assumptions– Base Case

The following assumptions are for the base case (see page 14).

The plan is based on producing two products; each is a plug-in board for personal computers. The second generation product would have a much higher processing capability than the first. Plan is based on producing 2.2 million first generation boards in Year 10 and 1.8 million second generation boards in Year 10.

Plan is in 2006 constant U.S. dollars and is a 10 year plan. This plan is for a manufacturing facility to be built in Singapore with R&D offices in the USA, Italy and Singapore.

Plan is constructed using business/manufacturing/cost assumptions based on Energy Conversion Devices, Inc.'s experience.

First year of Sales is Year 5.

Plan assumes all facilities are leased.

A requirement for royalty expenses is included in the plan at a rate of 3.0 % of chip cost and additionally a royalty for Ovonyx technology at a rate of 3.0 % of chip cost based on sales revenue.

Receivables and inventory are assumed at 60 days.

Singapore corporate income taxes are assumed at 5.8%, with a loss carry-forward.

ECD will have 51% ownership in the JV, and Mr. Pistorio will have 21% ownership.

Warranty is 1% of Sales, Bad Debt is 1% of sales.

Scrap rate is assumed going from 15% in Year 5 to 0.25% in Year 10.

Production equipment is depreciated over 6 years.

Terminal Value for the Internal Rate of Return evaluation is calculated at 12 times pretax earnings.

Financial Highlights – Base Case

Investment is anticipated in the range of $142M. Current numbers assume approximately $25M in each of the first two years, $33 in the third year, $47M in the fourth year and $10M in the fifth year.

There are 504 employees in Year 10, including 87 R&D Employees, 371 Operators, and 46 Staff employees.

Tenth Year	Base Case
Annual Units (000's)	4,000
Annual Sales ($000's)	$1.2B
Annual Income ($000's)	$621M
Maximum Cumulative Cash Out ($000's)	$142M (in year 5)
Internal Rate of Return (excluding terminal value)	42.8%
Total Employment	504