International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:8, No:7, 2014

Proactive Approach to Innovation Management

Andrus Pedai, Igor Astrov

***Abstract*—**The focus of this paper is to compare common approaches for Systems of Innovation (SI) and identify proactive alternatives for driving the innovation. Proactive approaches will also consider short and medium term perspectives with developments in the field of Computer Technology and Artificial Intelligence. Concerning Computer Technology and Large Connected Information Systems, it is reasonable to predict that during current or the next century intelligence and innovation will be separated from the constraints of human driven management. After this happens, humans will be no longer driving the innovation and there is possibility that SI for new intelligent systems will set its own targets and exclude humans. Over long time scale these developments could result in scenario, which will lead to the development of larger, cross galactic (universal) proactive SI and Intelligence.

***Keywords*—**Artificial intelligence, DARPA, Moore's law, proactive innovation, singularity, systems of innovation.

I. Introduction

SYSTEMS of Innovation (SI) provide framework for understanding innovation and innovative process. As collective activity, innovation usually is related to larger system, defined as Innovation System or Systems of Innovation (SI). The specifics of SI depend on the flow of information and technology between the people, institutions and large companies. SI are commonly categorized in following ways: technological, geographical (national, regional) and sectoral (socio-economic). These interacting dynamics of SI are shown in Fig. 1. All of them include creation and knowledge based creativity [1].

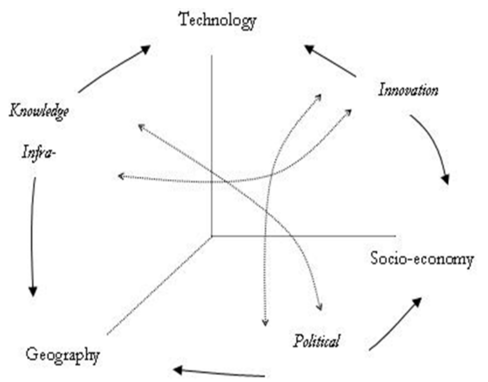

Fig. 1 The dynamics of SI

A. Pedai is with the Department of Computer Control, Tallinn University of Technology, Tallinn 19086, Estonia (e-mail: andrus.pedai@dcc.ttu.ee).
I. Astrov is with the Department of Computer Control, Tallinn University of Technology, Tallinn 19086, Estonia (phone: 372-620-2113, fax: 372-620-2101; e-mail: igor.astrov@dcc.ttu.ee).

According to [2] all SI's can be characterized by the same basic building blocks or components. These are actors, institutions, networks and technology. For example:

- Actors: Education, R&D, industrial activities, and consumers.
- Institutions: Legislation and technology standards.
- Networks: Linkages between organizations in research projects and advocacy coalitions.
- Technology is part of the SI as it enables and constrains the activities of actors in the SI.

II. National Innovation System

National innovation system (NIS) was originated by Freeman and Lundvall in the 1980s. While Lundvall originally distinguished between a narrow and a broad definition of national innovation system, today the broad definition is commonly used. Next to "organizations and institutions involved in searching and exploring — such as R&D departments, technological institutes and universities", the broader view on NIS includes the diffusion, absorption and use of innovation. Additionally e.g. R&D efforts by business firms and public actors, learning processes, incentive mechanisms or the availability of skilled labor as well as interactions between organizations and institutions are also included [3].

III. Technological Innovation System

The Technological Innovation System (TIS) is a concept developed within the scientific field of innovation studies which serves to explain the nature and rate of technological change. A TIS can be defined as "a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" [4].

IV. Regional Innovation System

A regional Innovation system is relatively new concept. Lundvall, one of the first authors to promote thinking about SI, suggested that transnational innovation interactions were likely to gain in importance over national ones. European Commission was developing and implementing opposite approach, Regional Technology Plans and Regional Innovation Strategies precisely because of the weaknesses of national innovation systems in the EU over producing rates of innovation competitive with those of the USA [5].

V. Artificial Intelligence and Singularity

Artificial intelligence and singularity was first mentioned in May 1958, by mathematicians, Stanislaw Ulam (designer of the hydrogen bomb) and John von Neumann (his last work was unfinished manuscript "The Computer and the Brain"). Ulam wrote, "There is accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the human race beyond which human affair, as we know them, could not continue" [6].

Singularity has roots in relativistic physics, it represents a point of infinite gravity. From singularity nothing can escape, not even light. In astronomy these places are known as black holes, they have an event horizon, boundary in space-time beyond which events cannot affect outside observer. The technological or computer singularity is theoretical emergence of super intelligence through technological means [7].

Singularity spokesperson, inventor and futurist Raymond Kurzweil describes the singularity as resulting combination from three technologies: genetics, nanotechnology, and robotics (including artificial intelligence) [8]. He predicts that by 2019, a $1000 personal computer will have as much raw computing power as human brain. 2029, a $1000 personal computer will be 1000 times more powerful than a human brain. By 2045, a $1000 computer will be billion times more intelligent than all humans combined. Even small computers will exceed the capabilities of entire human race. After 2045, computers became so advanced that they make copies of themselves that are ever increasing in intelligence, creating a runaway singularity. To satisfy their never-ending and continuously growing appetite for computing power, they will begin to devour the earth, asteroids, planets, stars, and even affect the cosmological history of the universe itself.

Justification for these predictions can be easily translated from Moore's law, a rule that has driven the developments in computer industry for over fifty years, setting the pace for today's civilization. Moore's law states that computer power doubles about every eighteen months. It was first stated in 1965 by Gordon Moore, who was one of the founders for the Intel Corporation.

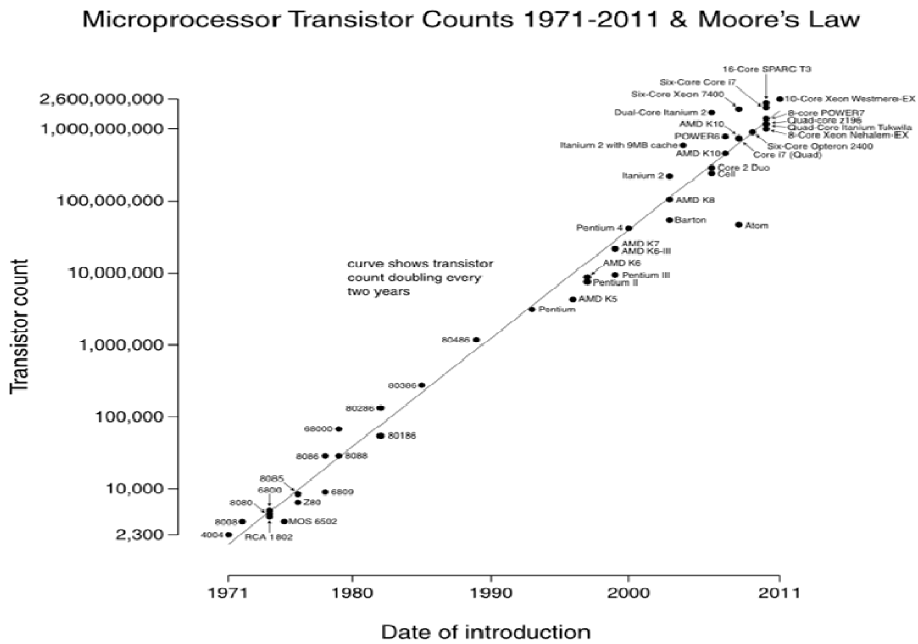

Fig. 2 Plot of CPU transistor counts against dates of introduction

Note that Fig. 2 shows that the line corresponds to exponential growth with transistor count doubling every two years [9]. The additional notes include:

- It is interesting to note that by extending the graph, so that it includes history, like mechanical adding machines, the line can be extended more than 100 years into the past.
- Illustration for the exponential growth in Moore's law can be done with following examples:

1. Today our average smart phone has more computing power than all of NASA had back in 1969, when it landed first astronauts on the Moon.
2. Latest Sony PlayStation gaming console has the capacity of the military supercomputer from mid 1990's. There is also the significant reduction in cost for these devices.

- People's view on the future and innovation has also changed remarkably. In 1949 Popular Mechanics predicted that computers would grow linearly into the future. It wrote "Where calculator like the ENIAC today is equipped with 18000 vacuum tubes and weights 30 tons, computers in the future may have only 1000 vacuum tubes and weight only 1.5 tons" [10].
- Moore's law allows us to predict the evolution of the computer into short term future. In coming decade chips

will be combined with supersensitive sensors, so that they can detect diseases, accidents, emergencies and alert us before situations get out of control. Devices around us will recognize human voice, faces and converse in formal language. They will be able to create entire virtual worlds that we can only dream of today. Around 2020, the price of a chip may drop below penny, which is the cost of scrap paper. We will have millions of connected chips distributed everywhere in our environment, silently monitoring and carrying out orders. Ultimately the word computer itself will disappear from English language [11].

There are many scenarios, for the long term future concerning developments with bionics and possibility for human's step by step merger with robots. In the ultimate scenario [12], the humans will discard their bodies entirely and eventually evolve into pure software programs that encode our personalities. Individual personalities are downloaded into computer and we become immortal, but spend our time trapped inside vast computer system, interacting with other people in gigantic cyberspace/virtual reality.

VI. Alternative and Proactive Approaches to Traditional SI

Although different SI's have similar components, their behavior remains individual. In [2], the approach for measuring how SI's are functioning is described. These assessment criteria for the central functions in SI are labeled in the literature as "functions of innovation systems".

- Entrepreneurial activities
- Knowledge development
- Knowledge exchange
- Guidance of the search
- Formation of markets
- Mobilization of resources
- Counteracting resistance to change

In spite of the tools for SI assessment, benchmarking SI's remains difficult. Differences in results will depend on geographical area, level of scientific & commercial competition and involved funding.

Traditional SI supports organic growth for the new technologies. Often that involves start-up businesses and new generation entrepreneurs. Innovation is involved, but the process remains time consuming and its contribution to national economies remains modest.

Global picture provides us several examples on alternatives for the traditional SI's.

A. DARPA and Proactive Innovation Management

The Defense Advanced Research Projects Agency (DARPA) was founded under United States Ministry of Defense by 1958.

DARPA was founded as response to single event – launching the Sputnik by Soviet Union. It was great shock for the USA as they found themselves behind Soviet Union in the race for space exploration. USA identified shortages in organization and innovation management that concerned advanced sciences, technology and national security. Radical change was required. Merging from these drivers was the new concept to organize advanced research – Advanced Research Projects Agency. The name changed in 1972 to Defense Advanced Research Projects Agency.

DARPA's mission is to investigate new emerging technological capabilities that have prospects to create disruptive capabilities. It is differentiated from other R&D organizations by a charter that explicitly emphasizes "high-risk – high-payoff" research.

B. DARPA Model

DARPA's role is to support advanced technologies that provide "revolutionary" advantage for the USA military. Consistent with this mission, DARPA is:

- Independent from the military services
- Pursues higher-risk research and development (R&D) projects
- Aiming to achieve higher-payoff results compared to traditional R&D

DARPA program managers are encouraged to:

- Challenge existing approaches
- Seek results rather than just exploring ideas
- Support technology and component development

DARPA's operational and organizational characteristics include:

- Relatively small size
- Lean, non-bureaucratic structure
- Focus on potentially change-state technologies
- Highly flexible and adaptive research programs

It is important to highlight that, DARPA was designed to be different from traditional approaches:

- It did not have laboratories
- It did not focus on existing military requirements
- It was separate from any other operational or organizational elements
- It was explicitly chartered to be different, so it could do fundamentally different things than had been done by the military service R&D organizations

During its fifty years of operation, DARPA has yielded or supported launching several services and technologies that have indeed been revolutionary and that have changed the way modern society is operating. These technologies include:

- Internet
- Global Positioning System (GPS)
- Voice recognition
- Computer mouse
- Artificial Intelligence
- F-117 Tactical Stealth Fighter
- ...and several others

Note that the nodes at UCLA and the Stanford Research Institute (SRI) are among those depicted [13].

At this moment DARPA has divided its operations between 7 offices [14]:

1. Adaptive Execution Office (AEO) prepares and coordinates field trials and demonstrations of advanced technology developed by DARPA.

2. Biology, Technology & Complexity (BTO). Its work goes beyond life sciences applications in medicine to include areas of research such as human-machine interfaces, microbes as production platforms, and deep exploration of the impact of evolving ecologies and environments.
3. Defense Sciences Office (DSO) provides bridge from fundamental science to applications by identifying and pursuing the most promising ideas within the science and engineering research communities and transforming these ideas into new capabilities. DSO is also exploring methods for drastically lowering the time and cost of manufacturing highly complex products in low volume.
4. Information Innovation Office (I2O) aims to ensure USA technological superiority in all areas where information can provide a decisive military advantage. The I2O portfolio covers a broad space, investigating enterprise networks, secure communications, industrial systems, and purpose-built military systems.
5. Microsystems Technology Office (MTO) supports DARPA's mission of creating and preventing strategic surprise by investing in areas such as micro-electro-mechanical systems (MEMS), electronics, computing, photonics and biotechnology. MTO seeks methods for countering threats (both incidental and intentional) that arise from sustained advancements in cheap and readily available technologies.
6. Strategic Technology Office (STO) is focused on technologies that enable fighting as a network to increase military effectiveness, cost leverage, and adaptability. STO's areas of interest include: Battle Management, Command and Control (BMC2); Communications and Networks; Intelligence, Surveillance, and Reconnaissance (ISR); Electronic Warfare (EW); Positioning, Navigation, and Timing (PNT); and Foundational Strategic Technologies and Systems.
7. Tactical Technology Office (TTO) 's objective is to provide or prevent strategic and tactical surprise with very high-payoff, high-risk development of revolutionary new platforms, weapons, critical technologies and systems, approaches addressing affordability, as well as rapid agile development.

In DARPA projects the work is finished, when operational prototype is ready. It is remarkable that DAPA has managed to achieve average 4 years lead time from the original idea / vision to ready-made prototype [15].

C. Peculiarity of DARPA Model

They only work with near impossible or "wicked problems". These problems are usually very complex and systematic. The task consists of large number of complex and integrated challenges. Solving these problems requires gross-science; target focused, synchronized, and networked approach. DARPA also requires that project outcome needs to have significant impact. Changes in modern society due to introduction of Internet are good example of this target setting. DARPA is currently working on limitless real-time language translation possibilities that could have similar global impact. If it successes, this project removes global language barriers, having similar effect to the Internet revolution.

In its work and project selection process DARPA is enjoying great autonomy. Agency is acting independently from regulations to public offices. It does not need to call for public bidding while selecting cooperation partners. Decisions are done by the assigned project manager and specific office manager. This autonomy with operations is one of the keys to the Agency's success. DARPA has removed all obstacles to avoid hard reaching consensus decisions affecting financing for the radical ideas.

Autonomy is extended also to project execution. Program based approach can be identified as another driver behind DARPA model's success. Dedicated program manager is responsible for specific project. Program manager is without exception hired externally, having deep practical experience on specific field. Work agreements for the program managers have fixed term (for example, 4 years). This approach ensures good flow of field experience and fresh ideas for the project work. It also avoids stuck in barriers due to limited understanding on field operations.

Program manager has full authority to hire research partners to the projects. He can also cancel specific cooperation partnership if needed. He can call for gross-office task management if this is supporting achieving program's targets, or he needs to extend the number of problem solving methods. Financially, program manager could be authorized to decide on the usage of hundreds of millions USD.

DARPA's projects have been by specifically very risky. Agency's investment strategy begins with a portfolio approach. Reaching for outsized impact means accepting the risk and high risk in pursuit of high payoff. That is a target in DARPA's programs. Agency pursues its objectives through hundreds of programs. By set-up, these programs are finite while creating lasting revolutionary change. They address a wide range of technology opportunities and national security challenges. This assures that while individual efforts might fail - a natural consequence of taking on risk - the total portfolio delivers [14]. According to Anthony Tetherin, DARPA's Director (2001 – 2009): about 85 to 90% DARPA's projects fail. It means that from DARPA's three billion USD annual budget, more than 2.5 billion USD of taxpayers' money is spent on unsuccessful projects, intentionally. In CNN article [16], the DARPA specialist Michael Belfiore comments the failure:

"DARPA only undertakes projects that have a good chance of failing - projects that few others dare to take on. Projects like hypersonic flight. The failure is not surprising; permission to fail is what has enabled the agency's spectacular success over its 53-year history.

Failure, as it turns out, has to be an option to enable the big successes".

The culture of failing was first highlighted by former DARPA's Director Charles Herzfeld, already in 1975, by stating "When we fail, we fail big".

VII. Conclusions

Conclusions for current research work can be divided into two parts, long term scenarios and short term proactive approaches for SI.

Concerning long term scenarios for SI's, mathematician and computer scientist Venor Vinge [17] provides us following conclusions "As ongoing explosion in computing power and developments in bionics continue, we will have the technological means to create superhuman intelligence. Shortly after that moment, the human era will be ended. Once this superhuman intelligence gets involved, the pace of technological developments would accelerate even further than the doubling we have gone for the last generations. There would be a constant feedback loop of artificial intelligence always getting better by improving itself, but now with humankind now outside the equation. This would be the point where old models must be discarded and new reality rules." Considering the above and extending the scope for [7], humanly nature in will keep us pushing for continuous improvements and developments with SI. Artificial, technology based intelligence will be the ultimate milestone for human driven innovation. After that moment the speed for innovation will improve dramatically. Whether humans will be part of these future developments depends on the building blocks that are jointly defined and laid down during coming decades.

Concerning short term proactive approaches for SI's, introduced DARPA model is worth further investigation also in Estonia. Looking at the success of DARPA model we should force down the "not invented here" (NIH) barriers and bravely attack the challenging list with "mission impossible's".

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