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THE MILITARY AS A PUBLIC SPACE: THE ROLE OF THE IDF IN THE ISRAELI SOFTWARE INNOVATION SYSTEM

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The Military as a Public Space – The Role of the IDF in the Israeli Software Innovation System

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All mistakes are solely the author's.

Introduction

This paper focuses on the role played by the Israeli military -- the Israeli Defense Force (IDF) -- in creating and sustaining the highly innovative Israeli software industry.

The IDF is often credited with a large role in the creation and sustained success of the Israeli high-tech industry. However, besides a few remarks in various papers and colorful articles in popular business journals and newspapers, which attribute to the IDF the training of Israel's technological entrepreneurship elite as well as a multitude of spin-offs, no serious research has been done to date.[1] Especially interesting is the question of the IDF's role in the creation of the software industry, the latest IT industry to emerge in Israel. I will concentrate on the IDF's central computer unit (MAMRAM), and especially on the School for Computer Related Professions (hereafter: "the School"), the main programming, software engineering, and computer users training unit in the IDF. I argue that while the IDF helped the industry as a factor creating mechanism (i.e., through high skill labor training) and through fostering spin-offs, concentrating solely on those obscures the much more important role the MAMRAM played by supplying a semi-public good.

The MAMRAM is an especially interesting case study of the influence of the IDF, and hence the state, on the development of the IT industry for four reasons:

1. While the creation, development, and activities of the MAMRAM were and are highly important for the Israeli software industry as a whole, the MAMRAM was not created with that goal in mind. The MAMRAM was created in order to

solve some specific perceived needs of computerization in the Israeli Defense Forces. Thus, the MAMRAM is a valuable case in which to show the long term positive institutional effects of state intervention, without needing to attribute to the state the kind of almost godlike prophetic strategic vision sometimes ascribed to it by statist theorists.[2]

2. The leaders and policy makers who decided on the creation of MAMRAM and other early defense-related high-tech agencies are the same group of people who, in the second half of the 1960s and throughout the 1970s, formulated and implemented Israel's science and technology and industrial policies.[3] It is therefore important to follow their early activities and achievements in high-tech and R&D if we want to understand why they later conceptualized Israel's economic future solely in the area of "science intensive" activities, at a time when Israel had a very low scientist and engineer per capita ratio in its workforce.[4]
3. While there has been no formal declaration that one of the goals of the MAMRAM and the School is the sustained development and upgrading of the Israeli software innovation system, unofficial recognition exist at the highest levels of both. Accordingly, some of the School activities are devised around the unofficial goal of supplying a public good for the Israeli software industry. As will be shown later, this unofficial recognition is exactly what makes the dialogue between the School and the industry so robust.
4. Software programming training in the IDF is the only technological training done typically inside the boundaries of the military by the School, which is in turn the

only full-scale technological professional training unit that is operated and managed completely inside the IDF. In order to acquire engineering skills for all hardware and other engineering disciplines, the IDF is either recruiting or sending its conscripts to acquire academic education.

For these reasons a case study of the MAMRAM not only highlights an important part of the Israeli software innovation system and helps explain its development, but can also provide us with insights into the long-term institutional effects the state has had on the industry's development path. Further, the MAMRAM is a clear case in which the state did not set out to have these positive influences. Moreover, this case study can help us to understand the development of the science, technology, and industrial policies more generally from the 1960s onward.

The paper is organized as follows. First, I present an argument about the specific positive effects that the School has had on the Israeli software industry. A short description of the performance of the Israeli software industry and its uniqueness compared with two other successful cases of software industry development in India and Ireland illustrate my argument. A description of the history and operation of MAMRAM and the School follows, with a short case study of one routine activity of the School -- the restructuring of the software design course -- one of the major software engineering courses. I conclude by emphasizing the importance of deep institutional guided historical and process analysis in any research that aims to shed light on the development and sustainability of high-tech industries.

The data for the paper was gathered mainly through over 80 unstructured interviews (1-2 hours each) with Israeli IT industry leaders (founders and CEOs of companies, venture capitalists, former Chief Scientists of the Ministry of Trade and Industry, etc.). Over half of the interviews were conducted with former officers of the School, the founders of software programming and software engineering in the IDF and the state apparatus, and the managers and cofounders of the leading private professional schools. The interviews were conducted in December 1999 and the summer of 2000. Complementary data were gathered from archives, secondary sources, and state and industry associations' reports.

Argument, method, and findings

This part of the paper begins with a presentation of the main arguments. I then briefly describe the Israeli software industry and follow with a short history of computerization in Israel. I conclude with the main findings.

My main argument is that the military should be viewed not only as a mechanism for producing highly-trained professionals and as a source of new technologies via various spin-offs, but also as one of the main nodes in the national innovation system that diffuses information, spurs collective learning, and creates standards for the whole industry.[5] The military has played two important roles in the history of computing in Israel. First, from 1960 until the 1980s, the military played a crucial role in the diffusion of computerization and IT skills and use in Israel, thus helping the creation of an

independent industrial sector. [6] Second, viewed as an intrinsic part of the Israeli software industry, the MAMRAM continues to perform six important functions:

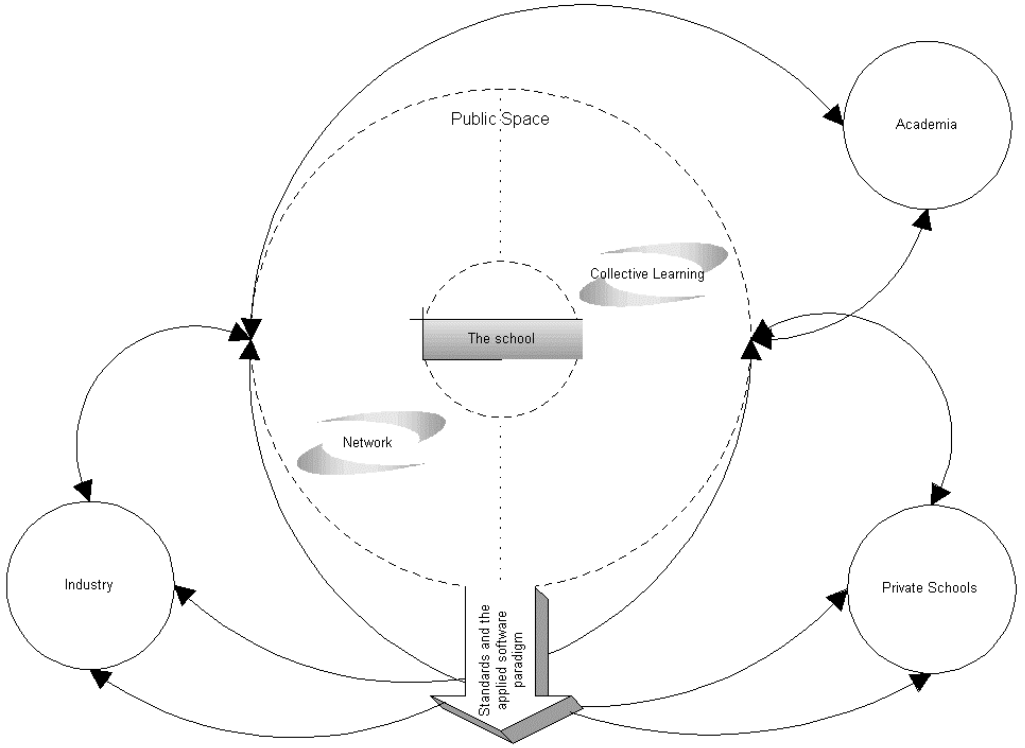
1. Software development and engineering standard-setting: as the largest organization, one of the main customers of software products, and one of the main trainers of programmers and system analysts and designers in Israel, the military through its decisions helps to solve the basic dilemma of collective action which is inherent in standard setting.[7]
2. Training and human capital: The IDF has relatively limited resources and cash. This constraint, together with the knowledge that its best people will stay only for a period of 5-6 years, and its inability to hire mid-career professionals to serve for long periods of time, results in very intensive investment in human capital and extremely large amounts of responsibility for R&D being given to very young personnel, compared with equivalent civilian organizations. These two factors, coupled with the IDF training system that is based on the Planning By Situation (PBS) approach to instructional material development (explained below), produce high quality and highly trained personnel, experienced in R&D product innovation and development.
3. Historical role: due to the particular timing of its creation, the MAMRAM had two unique roles: (1) The IDF, through the MAMRAM, became the main stimulus for the diffusion of computer technologies and their application to create new software and hardware products throughout the Israeli economy. (2) Since the MAMRAM was set up many years before computer science became an

established academic discipline, and because it developed its own concept of software programming as a profession aimed at creating operational systems, the School helped to create, and is the center of, a major paradigm of software development in Israel which I will term the *applied* or *professional* approach to software.[8] The School developed a distinctive approach to teaching software programming, and trained professional trainers in that approach. These trainers subsequently founded private computer-related professional schools, and in this way the paradigm experienced rapid diffusion and acceptance in the private sector.[9] Moreover, the School is the only institution in Israel devoted to the creation, gathering, teaching, and diffusion of knowledge of software as a professional activity as such, i.e., not only as a revenue-generating activity.

4. Network: MAMRAM graduates and reserve personnel create a dense network of knowledge, recruitment, and venture capital. This network not only lowers the transaction costs associated with doing business throughout the Israeli software industry, but it also enables its members and their companies to tackle and solve R&D problems that are beyond their present knowledge or skills. As one of my respondents said: "I am not afraid to take any consulting job in the field, because I know that in the worse case scenario I am at most four phone calls away from a world expert for any software related problem."[10] The existence of such dense and large networks gives the Israeli industry as a whole a distinct advantage.
5. Collective learning and diffusion of knowledge: The School provides three major settings for collective learning. First, through its activities in the creation and

dissemination of software teaching and learning material, the School sponsors multiple activities of collective learning. These activities are carried out by small project teams. The teams are composed of military and reserve duty soldiers who are civilian experts from a multitude of firms and academic institutions, working together and sharing their knowledge with each other in a way that would never have been possible outside the School. Second, Israel's best experts in various fields of software R&D teach and publish textbooks and instruction material only through reserve duty at the School. Third, the reserve personnel themselves are constantly exposed to the knowledge gathered and created in the School, knowledge they take back and utilize in their firms. Lastly, all these are strengthened by the IDF's policy of not seeking any property rights or patents on technologies developed under its sponsorship. Accordingly, the School's graduates freely transfer technology to the civilian market when they finish their service period.

6. Foreign Knowledge transfer: The School and the private schools founded by its graduates serve as an important point of contact for knowledge from foreign software-tools development companies like Oracle, Sun, or Microsoft to the Israeli system. Thus, before a new development tool is released the Schools have often already acquired the knowledge from abroad and organized courses to train professionals in the use of these tools, enabling faster diffusion of the latest software development techniques in Israel.



Source: Breznitz 2002

Diagram 1 - The School as Public Space

It is important to note that if indeed these six functions have been serving an important role in the creation and continuing success of the software industry then two additional effects of MAMRAM's exclusivity on the industry need to be considered:

1. Access exclusivity – two questions are to be asked about the restrictions on entry to the MAMRAM. The first is the inherent dilemma of Israel's defense industry over the recruitment and training of Israeli Arabs. While in the end it may prove to be insolvable (especially after so many years of exclusion) the influence that this exclusion has on the so called "digital divide" and socio-economic mobility of Israel's Arabs, not to mention the vast waste of human resource from a national point of view, should be acknowledged. (The other group that does not enter the MAMRAM is the Ultra-Orthodox. However, as the members of this group choose not to serve in the IDF and individuals that choose can theoretically serve in the MAMRAM this is a different socio-political question to be considered in a different article). The second question that should be asked is about the demographic recruitment to the MAMRAM from the IDF-serving Jewish community. As the MAMRAM bestows on its graduates improved economic skills and enhanced socio-economic mobility, and as the MAMRAM does not require any previous training, it might prove to be an optimal tool of social mobility for low-income conscripts. On the other hand, it might prove to be a mechanism of elite reproduction. Hopefully the IDF would allow in the future researchers to conduct a large N study on MAMRAM's graduates that should enable us to answer this question.

2. Output exclusivity - access to the School's material and knowledge is limited to a "club membership" of reserve personnel and hired consultants. Moreover, diffusion to the industry is done on ad-hoc basis and necessitates individual initiatives. It might prove to be a bigger problem to formalize these output flows, and one can see how formalization might endanger the trust that enables the networking and collective learning activities to be so successful in the first place. However, from a national point of view it might be that a bit more regular and extensive diffusion of the School's outputs to industry and private market is worthwhile.

As the role of the IDF is to grant the best security possible to Israel, some might argue that it should not take into account such considerations. However, as this paper aims to highlight the overall influences of MAMRAM on the Israeli industry they should be noted here.

The structure of Israel's software industry

The Israeli software industry is a phenomenal success story. Annual total sales rose from $380 million in 1989 to $3.7 billion in 2000, with an even more spectacular growth in exports, from $5 million in 1984 to $2.5 billion in 2000.[11] A very interesting feature of the Israeli industry is the large role that the local market has played in its development. The local market was already well developed in 1984 with $370 millions in sales, while exports as noted were only $5 million. Local demand continued to develop, inducing rapid growth in local software sales throughout the 1980s and into the 1990s. By

comparison, total sales by the indigenous Irish software industry did not reach $370 million until a decade later, in 1994. Another distinctive feature of the Israeli software industry was the prominent role played by small-to-medium size firms marketing their own innovative products. India's and Ireland's software industries, by contrast, relied to a greater degree on MNCs, either as regional HQ platforms, as in Ireland, or as "software factories" offering low-cost good- quality programming services, as in India.[12] The importance of the domestic market in Israel is reflected in the fact that less than 30% of total sales by the Israeli software industry from 1993 to 1995 were exported, compared with more than 60% of a much lower base in India and Ireland.[13]

Another distinctive feature of Israel's software industry business structure (and in fact the structure of the Israeli high-tech industry as a whole) is the large number of Israeli high-tech firms listed on NASDAQ. In November 1999, ninety-six Israeli firms were listed (with another hundred or so Israeli firms that registered themselves as US companies). Only the US and Canada had more listed firms. By contrast there were one Indian, and fourteen Irish listed (four of which had no connection to high-tech whatsoever).[14] A related feature is the high level of Venture Capital (VC) investments in Israel. By the late 1990s the amount of VC investment in Israel was exceeded only by that in Silicon Valley and Massachusetts. VC investment in Israeli companies reached $1.003 billion in 1999, and Israeli VCs raised over $3 billion in 2000.[15]

In sum, the Israeli software industry has not only grown very rapidly, but has also exhibited many of the characters of a "Silicon Valley" – like industrial structure, consisting of a multitude of small-to-medium size firms that develop original products.

Historically this industry focused on a relatively large and sophisticated local market. Thus, in order to understand the international success of the Israeli software industry, we need to understand the specific domestic institutional conditions that produced the market structure and technoeconomic paradigm of highly innovative small firms. We begin by sketching the history of computing in Israel, with a particular focus on specific institutions and milestones associated with software development.

The early history of computing in Israel

The official history of computing in Israel began in 1947 at the Weitzmann Institute of Science, before the creation of the state of Israel as an independent national identity.[16] However, the 1948 war of independence and the continuing security threats quickly propelled the development of computing in Israel onto a different track. While academia, mainly the Weitzmann Institute, continued to develop three generations of scientific computers called the "Golems," the defense apparatus and the state bureaucracy quickly became the torchbearers of software development in Israel.[17]

Probably the first unit in the Israeli defense complex to develop and use computers was RAFAEL (the Hebrew abbreviation of: Armament Development Authority). RAFAEL, the first, and for many years almost the only body in Israel to conduct high-tech R&D, had already started to use computers in the 1950s. In 1956 RAFAEL, then still a part of the IDF, developed an analog computer, one of the first analog computers ever made and developed in Israel. In 1959, RAFAEL developed a more sophisticated analog computer, "Itzik," to enable larger-scale simulation. After more

researchers were recruited RAFAEL developed a few early digital computers. In 1959 RAFAEL, military intelligence, air force and logistics, join forces to call for the acquisition of a large-scale mainframe computer.[18] In 1959 a joint committee of RAFAEL and the IDF inquired into the data processing needs of the Israeli security forces, and advised the government to buy a digital mainframe computer in the US. In 1960 MAMRAM ("Center for Computers and Mechanized Records") was created, the IDF bought a Philco computer in the US, and Mordechi Kikion was transferred from RAFAEL to become MAMRAM's first commander.[19]

A second major software programming effort was conducted in another important part of the state bureaucracy, the Ministry of Finance.[20] In 1960 the Deputy Income Tax Commissioner Emmanuel Sharon decided that it might be more useful and efficient to computerize the tax assessments before handing them to the taxpayers. After a presentation of his ideas in the Ministry, Sharon and the head of the Ministry's SHAM ("Mechanized Processes Service") conducted a 43-day tour of Europe where they were introduced to the uses of electronic computers in ministries, municipalities, and public companies in France, Germany, Switzerland, the Netherlands, and the UK.[21]

After their return, the Ministry decided buy an NCR computer.[22] Due to the non-existence of software programmers in Israel, SHAM arranged a special course, very similar in organization to the MAMRAM's core programming course, on a onetime basis. Graduates of these two courses later became the leaders of the Israeli software industry.

Thus, nine years before the internationally recognized "official" 1969 birth date of the software industry as a different industry from hardware (marked by the famous

anti-trust court case which led to IBM's unbundling software sales from its hardware) the Israeli state was busily creating software training and development centers throughout its apparatus.[23]

In sum, this short account of the history of computing in Israel teaches us that large-scale software training and development began inside the state apparatus in order to solve specific security, administrative, and R&D problems that required large-scale data processing and simulations. The view of software programming as an applied engineering profession aimed at developing complete software systems, i.e., finished products, began to emerge in Israel in the early 1960s.

The MAMRAM and its school

An integral part of the establishment of the MAMRAM in the IDF was the creation of an internal training unit, the first such unit to be created in Israel. This unit became an independent unit in the second half of the 1990s and is now called "The School for Computer Related Professions" (the School). The training unit evolved in size and sophistication over the years until it reached its present shape as the School; however, its basic procedures and operational methods have remained the same. I now describe the career paths of software programmers in the IDF as an introduction to the School's activities.

At the end of high school, usually at the age of 18, most young Israeli adults face compulsory military service of two years for females and three years for males. However, if individuals wish to serve in special positions, or to get special extensive training, they

must stay for longer periods of service (usually any period of time after the first compulsory period is called 'permanent' service and provides the soldier with full salary benefits). One of these positions is that of software programmer. In order to enter the School's core programming course, the applicant must agree to stay in the IDF for about three more years of service. A second way to secure a software development position in the IDF is to apply for the academic reserve, a service path where candidates first finish an academic degree and then serve about two more years of service above the compulsory two or three years.[24] As a result, programmers in the IDF serve for a minimum of five and a half to six years.

To be accepted into the School's programmers' course, the candidate must pass a day of exams given to specific candidates after an IDF prescreening process. These two screening processes ensure that those who start the course belong to the intellectually gifted elite. The School usually recruits only people who do not have perfect health profiles; those who do are usually sent to combat units.[25] However, each year the School can choose up to six perfect health profile candidates, who must pass a second special day of exams. Those who pass these exams are exceptionally gifted mathematically (or, in the language of the School's website, acknowledged geniuses).[26] There is no requirement for prior knowledge of software programming.

The course lasts six months and consists of around eight to nine hours per day of formal classes and another six to seven hours of lab practices and exercises. The instructors are either reserve duty personnel (more about the reserve personnel later), who usually are industry professionals, academics, and former School personnel, or the

School's active duty personnel, who are soldiers who have received especially high scores in the basic courses in the past and were given the opportunity to stay and become part of the School. In the past only about 50% of those accepted into the course finished it. Today, due to growing demand in the IDF, a higher percentage is finishing. The School trains around 300 programmers each year.

The School also trains system managers (for both small and large systems). To ensure the full absorption and optimal use of information systems throughout the military, the School trains around 500 application instructors each year who are assigned throughout the IDF to train users. Moreover, the School sees itself as responsible for making sophisticated users out of the IDF commanders and trains them to the level where they can relate, identify, and define requirements to the system analysts and programmers in their own units.[27] To achieve that end, the School conducts several system analysis courses for managers each year and also offers personal training courses to the IDF's high commanders. From time to time, the School also opens a special course in educational software and learnware to maintain these specialized skills.

The School also gives its programmers extensive advanced training throughout their service and constantly offers professional courses on specific platforms, systems, or languages (e.g., Oracle, Sun, Linux). A year after completing the core-programming course, the School's graduates return for a one-week basic software design course. After another eighteen months of service they return to the School for an advanced design course of five weeks. The design courses will be described fully in a short case-study of the courses last routine restructuring in the School.

After the advanced software-designing course, the programmers' careers follow specific professional paths. Those who specialize in infrastructure continue to take advanced courses in infrastructure subjects; those specializing in application programming usually go to a yearlong (one day a week) system analysis and design course and project management course. In order to take the last two courses the soldier must enroll for another short period of service. In the past, soldiers were also offered professional courses toward a diploma as a computer technician or engineer. Moreover, for those who wish to study for an undergraduate degree in computer science and technological management, a leave of one day a week may be secured throughout the academic year. According to the School's web page, a special program toward an undergraduate degree in an Israeli university will be offered in the near future.[28]

The typical advancement of MAMRAM's graduates is as follows. After the core course the programmer usually operates as the junior member of a project team - "the apprentice of the magician apprentice" as one of my interviewees put it. After the basic design course they usually become deputy team leaders, and after the advanced design course (i.e., 2.5 years of experience) they either become team leaders or go to officers course. Thus by the age of 21, MAMRAM programmers are already well-developed programmers with extensive experience. As a former school official with years of experience in private industry observed: "This 21 years old kid has already worked in multiple projects, sometimes even in different units; he is an efficient and experienced programmer by that stage." Or, in the words of another interviewee, "There was no way I would have gotten to the same position I had in the IDF at the age of 20 in any civilian

organization, no way, never!" Approximately one in four programmers also acquires a long (i.e., 1-2 years) experience as manager of a full scale programming team before leaving the army. Around one in ten becomes section head, responsible for a specialized sub-unit with a tight budget and long term project management and control responsibilities.

Moreover, because the IDF tended to define its programming needs for many years in terms of specific software products, and because the computer units were always defined as service provider units, a very high level of attention has been given to training these programmers to understand and define their customers' and units' needs. Thus a MAMRAM programmer, when leaving the army, has already had several years of experience in analyzing and defining the needs of the 'market' she operates in and in creating products to meet these needs.

In comparison with the equivalent computer units in the American army, the MAMRAM is financially limited and its commanders need to be very frugal, careful, and persistent in procurement activities. For example, one of my interviewees recollected what he needed to do in order to buy a new and long overdue computer for the School:

> It was unimaginable, I had negotiations with the one specific company from which we needed to buy the computer. The only good argument I had in my arsenal is that this computer would be used to train all the IDF personnel and they would then create demand for the company products. Being very persistent I lowered the price to 10% of the original price. The computer was essential for the unit, and still, the commander of the whole MAMRAM and I had to spend hours in special meetings. I think I spent tens of hours of work just to find the money.

Another of my interviewees recollects similar memories from his time as a commander in one of the Navy's computer units: "In order to get a year-and-a-half-old computer, you had to do various kind of manipulations and politics."

Those budgetary limits have, however, a few advantages in the training of MAMRAM's personnel. The constraints act as what Michael Porter termed *Selective Factor Disadvantage.*[29] They encourage the R&D personnel to devise innovative ways to compensate for lack of finances, and provide incentives to acquire a far deeper knowledge of the capabilities of any piece of equipment. The process was described by a former commander of the computer unit of semi-civilian manufacturing part of the IDF, now a CEO of a venture capital firm:

> The systems [hardware] in the army are relatively old, by the way this is a subject which is very interesting to think about its implications, as the level/class of improvisation [you do in order to supply workable solutions] needs to rise in breath taking rates, since there are not a lot of financial resources. There is no such thing like what we usually do in the civilian market: if it is no longer working throw it away and buy a new one. You must find a solution and you must find it on a very tight budget by optimizing the equipment you have at hand.[30]

In a follow up question the interviewee who described his experience of buying a mini computer for the School answered,

> How do you deal with it? [i.e., the severe budgetary limits] you deal with it by working around the clock, 14-15 hours of work a day. As a matter of

> fact, those who didn't work until the middle of the night soon found out that they developed a "bad reputation." The other way of dealing with it is the quality of the personnel. Not only does the MAMRAM recruit whoever it wants, but you also have that deal with the reserve personnel, a thing without a parallel in the civilian life… some of them you will never be able to hire in the private market. However, they need to serve their reserve duty, they prefer doing it in the School, and you have the whole industry to chose and pick from.

The other more mundane effects lie in the experience gained by the MAMRAM management personnel. Not only do they learn how to manage their units under constraints, with tight budgets and deadlines, they also have the unique experience of working with a very high quality workforce and of managing, while still in their early 20s, the most experienced personnel from the private industry.[31] This shared experience also helps to explain the highly egalitarian work place behavior of most Israeli IT firms.

The applied software paradigm – the effects of the Planning By Situation model

As mentioned above, the MAMRAM was the first institution to begin training software programmers on a regular basis. As the main goal of the School was to train high skill labor that could develop operational systems, the School developed a particular view of software training that was based on the idea of software development as an engineering

profession whose aim is the development of products, systems, and solutions that answer the growing needs of a modernizing market, military or civilian.

Since the first academic computer science departments were not opened until 1969 and at first offered only graduate degrees, this paradigm became de-facto the hegemonic paradigm in the Israeli industry. Further, since the School became the major training institution for software professionals and served as the main center for instructional materials and course creation for many years, it inevitably became the center of this paradigm. The paradigm was than diffused and reinforced throughout the Israeli software industry both by MAMRAM graduates who became industry leaders and by the many private schools for computer-related professions that evolved in Israel since the beginning of the 1980s, all founded by former officers of MAMRAM and the School.

In the 1980s the IDF developed a special approach to the creation and development of courses and instructional material, the Planning By Situations (PBS) model. The PBS model was quickly diffused to the private market. The PBS played a critical role in the rise to dominance of the applied or professional approach to software development throughout the industry. At the heart of this engineering-like approach is the assumption that any training by the IDF and similar organizations should achieve one goal: the creation of professionals capable of operating in a specific role in the organization. In other words, the PBS is a pragmatic holistic approach to the creation and teaching of discrete bodies of professional knowledge.

The building of a course according to the PBS model starts by analyzing the responsibilities of a specific profession: what are the duties of the professionals working

in that role? What do they need to operate? What do they need to produce? And what accompanying skills, e.g., ability to work in teams, should they acquire? In a way similar to any engineering system analysis project, the course developers analyze both (a) the activities of professionals in the field and define the 'current state description,' called 'analyzing the working process components' in the PBS model, and (b) the professional components (the skills required by the specific profession).

The planning of the course begins with devising the final exercise, called the "summarizing exercise." The exercise simulates a situation that is as similar as possible to the actual required operation of the graduate. The exercise should require the student to demonstrate a satisfactory level of all necessary skills of the profession. For example, for many years an appropriate summarizing exercise for MAMRAM's core programming course was a few-days team mission to design and write an interpreter.[32]

The key difference between the PBS and conventional software training models is illustrated by the following example. If an organization or an individual wants to specialize in web-programming ,the courses that would be typically offered are courses in specific programming languages and tools from which they would pick and choose, aiming to fill the gaps, e.g., Java, Dreamweaver, etc. In contrast, a training institute which developed a course modeled on PBS would try to understand what a "web programmer" profession is and would develop a tailored mix of specific technology courses along with some added accompanying skills classes, e.g., reading design requirement documents, or the principles of good distributed database design. This package would be offered as one course, leading to a professional diploma. The result is that while software programmers

in other countries wishing to specialize in web based programming might need to go to four or five courses both in specific programming languages and in specific disciplines (if they can even find them), knowing that a large percentage of what they learn might be irrelevant and either too narrow or too broad to help them in their daily work, their Israeli counterpart working in an environment where software is viewed as a profession can more easily find a complete course in a specific sub-specialization. This institutional environment is self-reinforcing, with IT professionals, institutions and schools all looking for, developing, and paying for professional 'packaged' courses.

This approach also has some weaknesses compared to academic education, especially in regard to depth in particular subjects, and knowledge of advanced mathematics, which might be the exact skills needed in a start-up environment. However, graduates of MAMRAM's programming course are professionals trained to work as developers, with specific methodologies of development, have a common professional language, acquire extensive knowledge in software engineering, and, most importantly, see software writing as a profession whose main goal is to produce solutions for practical problems, and are highly trained to accomplish that specific goal.[33] The market in Israel appear to value those skills, offering MAMRAM graduates salaries that compete with experienced programmers who possess computer science or electric engineering academic degree. Moreover, as this approach and the system of private schools that thrives on it exist side by side with the research universities and academic institutions that are world renowned as centers of research and education in mathematics, computer science, and electric engineering, it is evident that these two approaches are mutually compatible and

can enhance the level of software programming in a national setting. Nevertheless, if in the future researchers would be allowed to conduct large N research, a survey of the roles given to MAMRAM graduates in the private market and the percentage of them that decide subsequently to pursue a CS degree would enable us to decide whether MAMRAM graduates are equipped with the skills needed by new technology-based firms.

The effects of MAMRAM and the PBS model on the private market are pervasive. Israel has a broad range of competing private professional schools for computer related professions that were founded or managed by former officers of the School, all of whom brought the PBS model with them and claim that it gives them an advantage when trying to move their activities to a global scale. Israeli software professionals usually have more options for professionally oriented complete sub-discipline courses than their counterparts worldwide.[34] Furthermore, the students of these courses gain widely accepted professional diplomas. Some cases like that of system analysts are now recognized professions with their own association. This recognition has far-reaching effects; for example insurance companies tailor specific policies and benefits for system analyzers, and require private firms to employ them in order to get various kinds of professional liability insurance.

The founders of these schools readily attribute their success to the training and course development methods they were taught in the School. A founder and managing director of one of the leading schools recollected how he and his partners diffused the PBS model to the private market.

> We took a lot of the success of the training models and methods of the School, and as a matter of fact we copied them into the private market, both in the creativity in course creation, and teaching and working methods… we took a lot from the School and we are very proud of it, I can show you that in all of our presentations we present ourselves as MAMRAM graduates; it gives us an enormous competitive edge.

The particular role of the PBS method in contributing to the dominance of the applied approach to software development in the Israeli market and the impact that this paradigm has had on the whole concept of 'software programming' in Israel, is apparent when these schools try to widen their activities to a more global scale. According to the same interviewee:

> We almost never add any value to the official courses that the software and hardware vendors create. We are adding value when we create packages to offer specific "professions" courses or specific professional specialization courses. Those we create with the PBS model. We now start to work in Europe, where we work with local schools and the major American vendors like Microsoft or CA, we found out that the PBS and the packaging of courses approach is unique, usually the courses offered worldwide are at two extremes: either highly academic, or very, very narrow…. The concept of professional software training in most of the [continental] European states is somewhat backward compared to Israel; it is probably very disappointing to the European but very interesting as a market opportunity for us. Most of the PBS packaging things we do here are not known there and they are very keen to get them. For example, CA Europe wants us to export everything we have done and develop in Israel, to Europe.

In short, the School along with the private professional schools founded by its graduates, has been crucial to the creation and diffusion of a specific paradigm of software development, focused on the concept of software programming as a profession whose role is the creation of software solutions and products. This paradigm was strengthened by the diffusion of the IDF's PBS training model to private industry and is now at the base of a mutually reinforcing institutional system.

The transparent borders between military and industry – the role of reserve personnel

One of the most important ways in which the School operates as a major node of information creation, sharing, and dissemination throughout the Israeli software industry is via its extensive use of reserve personnel and its unique exploitation of their *civilian technological knowledge.* This section explores the role of the reserve personnel in the School and the way in which their participation in its activities transforms it from an isolated military space into a "public space" that provides essential public goods.

Reserve duty is one of the prominent facts of life for any Israeli, especially males. Each Israeli citizen who has served in the IDF is required to serve for up to 30-40 days a year on reserve duty. Men serve usually until the age of 50+. Women are usually exempt, except those that have specific skills and training, who are usually called to reserve duty until the age of 26.

For most people, reserve duty is done with an organic unit, which trains and serves in some front line or guard duty for a preordained couple of weeks period each year. Smaller numbers of people are retained in the more technical units and are recalled to serve as technicians or developers to continue the same role they had before. Even smaller numbers of people are recalled to training units to be trainers in the army courses. Of these training units, the School, being the only large scale technical and technological training unit in the IDF, is unique in the way it recruits and uses its reserve personnel.

The reserve personnel of the School are usually industry experts. While many of them have served in the School in the past, many more are recruited from academia and industry. They are given three main responsibilities:

1. Teaching – The reserve personnel are usually responsible for the more complex or industry specific material in the basic courses and are almost solely responsible for the advanced courses, e.g., system analysis, design, or project management, where at least 97% of the classes are taught by reserve personnel.
2. Developing and upgrading the School curriculum – Reserve personnel serve in the steering committees of the School courses, and make up most of the teams that develop and upgrade the programming and advanced courses.
3. Creation and writing of instructional and reference material – One of the School's main activities is the creation and writing of reference and instructional material. This is highly important as the School is the central organization, if not the only one, writing original advanced reference material in Hebrew. Most of this writing is done either by or with the help of the reserve personnel. Moreover, this

> activity creates a unique environment for the processing, sharing, and dissemination of invaluable professional and tacit knowledge. The people who write this reference material are industry professionals who would have never had the opportunity to write and share their knowledge in their daily lives. Hence, the School prevents information diffusion bottlenecks and knowledge "loss" throughout the industry. In addition, due to the fact that serving on reserve duty is seen as a citizen's responsibility and is conducted in a public space of a national service environment, and as there is usually a delay of at least one year before this material finds its way to the civilian market, the level of trust and information sharing is exceptionally high.

The relative prominence of the reserve personnel in the School is evident if one looks at the manpower available to the School. The School has it its disposal about one hundred regular full time personnel and around four hundred reserve personnel. Thus, the School has about 20,000 days of reserve duty per year, equivalent to one hundred work-years - the same amount of time it has from its regular serving personnel, but provided by a much more professional and experienced source. It is not surprising that the task of managing the reserve personnel is highly important. In the words of one of my interviewees, "very shortly after you are nominated to be a section head you understand that your first priority is managing your reserve personnel: they give you the same amount of time as your regular soldiers, but there is no comparison in their professional level and quality."

The reserve personnel serve as a two-way conduit, from the industry and academia to the School and hence the IDF, and from the School to the industry. Moreover, the School serves as a point of contact to other industry professionals and between the reserve personnel, the School's regular duty personnel, and their students, creating a strong multi-cohort network, which is rare among other teaching institutions. In addition, the School's reserve personnel are privy to all of the material written and created in the School, which they bring back with them to their civilian life. A testament to the strength of these information flows can be found in the answer of a cofounder and managing director of one of the private schools when asked about the source of knowledge and materials:

> When we left the IDF, we had a very strong influence of The School, but now you have to remember that my partner, that rewrote our professional conversion course, was in the exact same time very active in the steering committee of the upgrading project of The School's basic programming course, and was leading its creation. So from where exactly the knowledge arrives and to where does it flow? I have no way to tell you.

The same was true all through the 1980s, as another interviewee who led the rewriting of the system analysis course both in the IDF and the civilian market was happy to recount:

> I can tell you that there was a sort of a positive conspiracy between The School and ourselves – we write material for instructions for the IDF but in exchange we also use them for our interests -- sort of a gentlemen's agreement that we and

> The School take material from one another. There was a lot of interaction, oh yes there certainly was a lot of interaction.

A few examples might be appropriate to illustrate the uniqueness of the School: One of the School's officers told me how he specifically encouraged his reserve personnel to create reference books on the basis of the instructors' tacit knowledge:

> For example I had a reserve instructor that was expert on the outside disciplines of software engineering, I encouraged him to write a few classes on the subject. It is not exactly the main stream of the knowledge, but there are in these class notes, a huge amount of professional tricks and capabilities that you cannot learn from any other source, only a person who had done it many, many times had developed these capabilities. For example, when, how, and why to write a log, it is not really related to mainstream software engineering, but when you actually go and write a system, you find that this knowledge is invaluable. This guy never wrote reference material before, and would have never found any other place that would let him write this kind of instruction material.

Another contrast is between the behavior of these industry experts when they do agree to teach in civilian courses and when they teach in the School during their reserve duty. While almost none of them agree to write or develop instructional material on their specific knowledge for the civilian schools and while they hardly participate in the creation and maintenance of the private courses' material and instruction, they are actively participating and sharing their knowledge in the School's environment.[35]

> When I go to the School to teach software engineering courses, about 99% of the people are reserve personnel, they talk with one another, make sure that they teach the material in a coherent way, develop new instructional material, lecture to one another about their specific fields, and I do the same. But when I go to a civilian school and they organize a team meeting, I keep my mouth shut, because I know that this material is worth its weight in gold, I do not develop any written material… There is no way they can pay me enough to write these things, and I tell you, anyone who is worth his salt behaves in the same way.

These symbiotic relationships go in both directions -- reserve personnel who developed and taught a course in the IDF get all the relevant course's material for their own use. Students who participated in courses and lost their material can usually get another copy even after leaving the IDF. Moreover, due to the fact that School officials are aware that these reserve personnel are going over and above the call of duty to help the School, they are very willing to help them in their requests. An example is given by one of the School's dormer section heads:

> One of my reserve people that also work in a civilian professional school called me and told me that they cannot write a specific set of classes, so I immediately gave him a booklet of 120 pages with questions, examples and instructions written by our best instructors. This is a guy that when we couldn't develop something and he heard about it he forced three of the industry leaders to volunteer for a whole day to come to help us to understand a specific very complex process. So of course I helped him when he needed my help.

Another interesting effect of the involvement of industry leaders in the School's activities is the positive influence that they have on the motivation and behavior of the School's regular personnel. In almost every interview I heard a variation of the following recollection of a former officer of the School:

> Soldiers have a huge motivation to be good in the IDF. Because if you are good in the IDF, you get a vast exposure throughout the industry, and you will get very good offers even before you leave the army, and you should remember life only begin at 24. It happen to me: one example was an offer to work in the most interesting team of a leading software company accompanied by the most competitive terms offered in the market, I was not even 24 and this was just one offer of many.

In short, the extensive use of reserve personnel in the School blurs the borders between military and public space. Moreover, the School not only creates an environment of information sharing, gathering, creating, and disseminating, but also acts as a node where information flows not only in and out but *between* industrial firms and academic organizations. In this way it provides the Israeli software innovation system with a vital and unique public service.

The School's contribution to Israel's software industry – a case study of the design course

This analysis concludes with a discussion of a detailed case study of the routine upgrading of one of the School's advanced courses -- Software Design -- the software engineering course given to the IDF programmers about two and half years after they finish the basic course and start working as programmers in the IDF.[36]

The use of the software design course for this case study is appropriate for several reasons. First, it is an advanced course, but not one of the most advanced. Thus, not only is every programmer who has been through the basic MAMRAM programming course given this course, but its upgrading was done not as a result of an overall industry decision, but as an internal affair of The School. Secondly, the new format of the course is unique throughout the industry, and the course was probably one of the only such courses given in the world at that time, especially in the scope given in the IDF. The specific software engineering and designing methods taught in the course have become the standard throughout the IDF and have now spread to the private industry. Thus, the upgrading project was a de-facto standard-setting activity for the whole industry.

Software design and engineering, like any other product design process, is an unsolved discipline.[37] In its broadest definition software engineering is the domain between the unquantified, undefined, and amorphous reality, and the translation of this reality into defined logical structures that can be transformed to programmable source code.

There are two phases to an ideal software engineering process. The first is the system analysis phase. In this stage the system analyst interacts with the customers and in the end writes the product definition and the accompanying requirements document.

Ultimately this document describes what the customers really want and the two sides, the software programming side represented by the system analyst, and the market, represented by the customers, know exactly what the product should do.

The second phase is software design. In this stage the designer takes the requirements and definition document and translates them to specific software units. These are defined up to the level of classes, objects, etc. The designer also defines how all these units relate and exchange information with one another, in order to get the functionality defined by the system analyst. For example, the system analyst decides what is the needed reliability of that system e.g., 99.99%; the software designer then determines how via the use of different software units and specific algorithms, the system would actually achieve the needed 99.99% reliability requirement.

One should be aware, however, that due to organizational and time constraints most software houses rarely create full high-level and low-level design for all of their projects. Moreover, while the design method and standard termed UML (Unified Modeling Language) offered by Rational (an American company), is slowly gaining a wide audience, many different designing techniques and methods are still in use.

The upgrading project of the School's design course started during the second half of 1996. At that time a new officer became responsible for software engineering in the "advanced training" department of the School, and decided to start a project parallel to the PBS-based upgrading project of the core-programming course that was already well advanced. He started to organize a group of reserve personnel, and through various resources like the School's library, his own research projects and outside information

agencies like the Gartner Group started to assemble knowledge about software designing. At the time, the group now known as Rational that advances UML, had not yet coalesced and consisted of three unrelated advocates of software designing. After a few months of research the responsible officer decided to model the new course around their proposed standard.

It is important to note that from all accounts both the responsible officer and the team of reserve personnel that he formed around the project knew from that early phase that their decisions would affect the whole industry:

> We decided that we will teach the state of Israel how to design software. It was obvious that only in the IDF could one do such a thing. If you want to know how to properly design software and to solve complex problems, it's a long process that takes a long time to organize and costs a lot of money. Moreover, not everybody would understand that immediately, you must also change the organizational culture, and send a critical mass of programmers to this course. Thus, only in the IDF could it be done… we thought it would succeed because the IDF is a place where 90% of the people leave after six years, and than they become the leaders of the industry. Moreover, every year you infuse the industry with another cohort of your graduates.

The awareness throughout MAMRAM that the decisions made by the School affect the whole system and that these decisions can serve to some degree as an instrument of national industrial policy is evident in an interview with a former overall commander of MAMRAM,

> I saw my role as the commander of MAMRAM in the national aspect. In addition to the primary and pure military goals and aims of MAMRAM, another goal that MAMRAM has, is to take part in the building of the human infrastructure of Israel. This is a role which is highly important due to the fact that the universities do not train people in the practical side of software programming in the same way that MAMRAM does and do not train them on the technological edge in the way the IDF does as a derivative of our security needs. I didn't always have the support for that from other parts of the IDF. The planning bureau was all against it, and rightly so from its strict financial point of view, but we did it all the same. What we mainly do is (1) to push the use of new technologies, (2) standard setting and method using decisions that diffuse throughout the industry, and; (3) the building of infrastructure technologies and the passing of them on to the whole industry. We stuffed the School consciously with the best manpower available and used a lot of reserve personnel, which was good for both sides, the industry and us, and created a lot of information flows... The School is the main way to fulfill our national duty, the building of human infrastructure, a person that learns all these things in the IDF goes to the private industry with all this knowledge and skills in his head.

The involvement and intimate relationship between the School and the industry was apparent as early as the planning and requirements definition phase of the project. In accordance with the PBS model, the first stage was to define the designers' role. Due to the fact that the IDF had no designers working at the time, the first step in the PBS model -- analyzing the working process components -- was done solely in industry and academia. The team conducted four months of research and observation of the state of

affairs in the private market and academia, including about 60 interviews with the leading experts on software design.

After finishing the research phase, a bigger team that again consisted almost solely of reserve personnel started actual development. The project team was divided into five teams of reserve personnel, each focused on a specific sub-discipline, e.g., User Interface, Databases. Each team prepared the specific classes, steps, and exercises of that sub-discipline in accordance with the level and background knowledge the student will need to acquire using the PBS model. The teams met at scheduled meetings to show each other their progress, debate needed changes, and run quality assurance tests. Feedback from the industry was also sought on a regular basis. The initiating officer, who had some secretarial help from one compulsory duty soldier, managed the project, and the reserve personnel did everything else. It is important to note, however, that the initiating officer was involved not only in all the work of the teams, the definition of the course rationale, and the overall strategy, but also in securing the agreement of MAMRAM and the various computer units of the IDF to the various changes in the course and to the need to send all of their programmers back to the School for five weeks, after two and a half years.

About his own role and the IDF's reaction to his activities in the project, the initiating officer, now a manager of a private firm, recalled,

> Think about it, where would you find such a big organization and bureaucratic system that would let a 23 years old kid manage a real method project, which is

> above his evident capabilities? I was in such a system that was only too happy that I do it for it. In that the IDF is unique.

After the course was developed it was presented to the MAMRAM commanding officers, and in 1997 the first pilot course was conducted. After a few minor additional changes, the course was standardized and is now being run on a regular basis. As is the case with other advance courses more than 95% of the classes in the design course are instructed by reserve personnel. Moreover, all of the results of the project were given to all of those involved and were quickly diffused throughout the industry.

One of the project members described the participation of private industry in the course-building project as an overall effort, and the diffusion of the information from collective learning back to industry as follows:

> All the reserve personnel put their practical knowledge into this collective effort and got all the information created and gathered in the project. Almost all of the big companies in Israel sent "their representatives" to the course… I worked with one private consulting firm, which we brought to consult us and I was surprised to find out that they learned more that what we learned from them. In later versions of their product I saw parts of our project… I know that team members took this information and assimilated the new design process in the private industry. I saw some specific classes in two private schools, I know that the industry is using our methods already, and I know that one specific private university based a whole course around our material… our graduates also came to us to tell us how they now understand what a mess the private firms they work with operate in, and they try to establish some order, and if they do not our next graduate would, I tell you, we fulfilled our patriotic duty.

In short, the School, through its various activities and through its involvement of industry leaders as its reserve personnel, became an important node of information creating, gathering, and diffusion for the whole software industry in Israel. Moreover, the School became a unique quasi public-space where important collective learning activities are conducted on a regular basis and important networking and standard-setting activities occur. In sum, the IDF as a whole and the School in particular should not be viewed only as a factor-creating institution and as a source for spin-off technologies, but as an integral part of the Israeli innovation system, and as a provider of an essential public good.

Conclusion

While the scope of our case study of the IDF's MAMRAM and the School for Computer Related Professions is too narrow to fully develop our understanding of the development of the Israeli software industry, it does suggest that the historical institutional approach can serve the dual purposes of focusing our empirical analysis and helping us to understand the development and role of specific institutions and organizations in the industry.

As our small empirical study shows, the effects of state institutions and organizations on the development and sustained success of the Israeli software industry and innovation system have been far reaching. Although the state of Israel did not create MAMRAM and its School in order to shape and sustain the Israeli software innovation system, one should not underestimate the impact that these decisions had on the creation

and development of the industry in Israel, and on its continuing success. In order to strengthen the initial results it is my hope that a large N study on MAMRAM's graduates will be done in the near future.

In relation to infrastructure, the School, since its inception, has been prominent in three areas: First, the early creation of skilled human infrastructure and the early incorporation of IT in Israel. Second, the creation of a specific paradigm of software development, and the subsequent creation of a supportive network of private schools, all of which teach and develop software programming as a profession and offer software developers in Israel a rich environment of continuous training. Third, the teaching and training of a large number of developers and users, who are subsequently exposed to cutting-edge technologies and released to the private market at a very young age.

In regard to knowledge and information flows and collective learning, the School plays a central role, enhancing the information flows and networks throughout the industry. Moreover, without the School's activities and use of reserve personnel, information bottlenecks would be more prominent and less collective learning would occur in the Israeli software system of innovation. While the influence of MAMRAM and the School on market structure in Israel is not obvious, the School clearly creates a public space for networks between various companies, and between them and universities. Moreover, the fact that the IDF does not try to obtain intellectual property rights on knowledge developed in its units creates a constant spillover of technologies to the private sector.

The internal organization of the School and the software programming in MAMRAM and the IDF is unique in requiring young personnel to take on managerial and critical development responsibilities in complex multi-million-dollar projects.[38] MAMRAM's projects are run under tight budget constraints that force its personnel to achieve higher levels of utilization of their equipment and their development abilities. In addition, due to the fact that most of MAMRAM's personnel leave the IDF after six years and the IDF has no way of recruiting experienced mid-career personnel to replace them, MAMRAM heavily invests in the training and selection of its manpower.

Much more research needs to be conducted on the Israeli IT industry and the Israeli state's science, technology, and industrial policies. Toward that end, it is my hope that this short paper shows how the use of institutionally oriented historical research can help us understand the important and complex role played by the IDF's computer units in the creation, development, and sustainability of the Israeli software industry and innovation system.

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[1] For examples see, Araiv, G. Goodman, Seymour, E. 1994. "Israel: Of Swords and Software plowshares." *Communications of the ACM.* 37(6): 17-21. Red Herring. September 2000. Special Report: Israel. Issue Number 82, pp: 237-334; Stacy Perman. "Israel: Startup Nation."*eCompany Now* November 2000. Vol. 1(6):134-153; *IEEE Spectrum* "Special Report – Israel: A High-Tech Haven" May 1998. pp. 22-32.

[2] For "Statist" explanations of economic development see, Johnson, C., A (1982). MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975. Stanford California, Stanford University Press, Amsden, A. (1989). Asia's Next Giant: South Korea and Late Industrialization. Oxford, Oxford University Press, Wade, R. (1990). Governing the Market: Economic Theory and the Role of the Government in the East Asian Industrialization. Princeton, Princeton University Press, Evens, P. (1995). Embedded Autonomy: States and Industrial Transformation. Princeton, Princeton University Press.

[3] For example, the Katzir (Kachalsky) brothers who formulated the first S&T and industrial policy that reformulated the role the chief scientist, were the early leaders of "The Science Corps" in the early days of the IDF, professors in the Weitzmann institute, and prominent figures in REFAEL in its first years, the first Chief Scientist of the Ministry of Trade and Industry, Itzhak Yaakov (Yatza), last role before joining the civil service was the IDF's chief scientist and the head of the IDF's R&D unit at the time of Mamram's inception. (Yatza had a famous battle with the special Government Committee on Air-Conditioning, which couldn't understand why Yatza insist that a machine (i.e. the computer) needs air-conditioning, see Yediot Aheronot 5/4/2001).

[4] As late as 1968 the number of scientists and engineers in the Israeli industry was 3,400 or 1.3% of total employment. (Source: Ministry of Trade and Industry as reported in Teubal, M. (1993). The Innovation System of Israel: Description, Performance, and Outstanding Issues. National Innovation Systems. R. R. Nelson. Oxford, Oxford University Press.). For more about the conceptualization of Israel economic development policy around the creation of "science based" industries, see Breznitz, D. (2002). Conceiving New Industrial Systems: The Different Emergence Paths of High-Technology Companies in Israel and Ireland. Paper Presented in the Annual Business History Conference, Wilmington, Delaware, 2002.

[5] "Spin-on" refers to the process in which technologies developed for the civilian market are transferred to the military market, in contrast to the "spin-off" process, in which technologies are transferred in the opposite direction. For more information about spin-on, spin-off, and dual-use technologies, see Samuels, R., J (1994). Rich Nation Strong Army. Ithaca, Cornell University Press.

[6] As early as 1973 Pinchas Zussman, the then economic advisor to the Ministry of Defense, argued that the Mamram and computerization is the best example of the IDF critical role in the adaption and application of new technologies to create new products in the Israeli economy, Zussman, P. and D. Tolkowski (1973). The Defense Establishment and its Contribution to Technological Progress. Jerusalem, Van-Lir Institute (in Hebrew).

[7] On the problem of collective action, see Olson, M. (1965). The Logic of Collective Action. Cambridge, MA, Harvard university Press.

[8] On the importance and effects of research paradigm, see Richard, J. Samuels Ibid, and Dosi, G. (1982). "Technological Paradigms and Technological Trajectories: A suggested Interpretation of the Determinants and Direction of Technical Change." Research Policy **11**: 147-163.

[9] All the founders of the major professional computing schools in Israel (a major industry in of itself) are former instructors of the school, serve in the school on their reserve duty, recruit large quantity of their instructors from the school graduates, and base their all instructing approach of technology training around the school's approach.

[10] Interview with former official of The School.

[11] Source: *The Israeli Association of Software Houses*, followed with a telephone interview with Amnon Leibowitz of the IASH on the 12/22/99.

[12] See, O'Riain, S. (2000). "The Flexible Development State: Globalization, Information Technology, and the "Celtic Tiger"." Politics and Society **28**(2): 157-193, O'Sullivan, M. (2000b). "The Sustainability of Industrial Development in Ireland." Regional Studies **34**(3): 277-290. For a more comparative study see Jacob, J. S. (1998). Barriers to the Growth of the Hong Kong Software Industry. Cambridge, MA, MIT: unpublished master thesis.

[13] Sources: Breznitz, D. Ibid. O'Riain, S. (1997). "An Offshore Silicon Valley?" Competition and Change **2**: 175-212. Pp. 183, *The Israeli Association of Software Houses. National Informatics Directorate, Dublin, Ireland.*

[14] Source: NASDAQ news 11/22/1999, www.nasdaq.com.

[15] Source: *Israel's economic Overview.* 1998. Ministry of Trade and Industry, and the Giza Group: Israel Venture Capital survey, 01/15/2000. Even more astonishing is the fact that for Europe as a whole the total technology-oriented VC capital in 1999 was only 8.4 euros billion (Source:PriceWaterhouseCoopers (2000). Money for Growth: The European Technology Investment Report 2000, PriceWaterhouseCoopers.). It important to note that over 50% of Israeli start-up finance doesn't come from Israeli VC funds. Thus the 3$ billion raised by Israeli VCs in 2000 represent only a fraction of the future investment earmarked for Israeli companies.

[16] See, Ariav, G. and. Goodman S.E. (1994).

[17] It should be noted, however, that the Golems were highly advanced worldwide. The building of first electronic computer in the US was finished in 1952, the first Golem, which was built on a similar scale to the first US computer was finished in 1954.

[18] It is important to remember that the head of RAFAEL even after it was separated from the IDF was a member of the chief of staff forum ("Forum MATCAL") the leading discussion and decision body in the Israeli security apparatus, a telling indication to the importance given to indigenous R&D throughout the history of the Israeli state.

[19] Some of the data regarding these decisions is still classified; however, large parts of it are now published. For more details see the memoirs of Munya Mardor RAFAEL's first CEO, Mardor, M. M. (1981). RAFAEL. Tel Aviv, Ministry of Defense of Israel Press (in Hebrew). And *In the Beginning: 40 Years of Computing in Israel.* 1999.

[20] An interesting and in retrospect highly amusing, were the conclusions of the 1960 ministry of finance committee for the assessment of computer uses in the Israeli national economy. Headed by Professor Dostrovsky from the Weitzmann institute, the committee concluded that two Philco computers should be enough for the needs of the whole national economy in the years to come. These conclusions were sponsored by the ministry of defense that hoped that someone would buy a second Philco to be used as a backup to the one in Mamram. Fortunately enough no one paid any attention to these conclusions, not the least the committee's own secretary Emmanuel Sharon, which in the same time was busy organizing the computerization of the finance ministry.

[21] See, Sharon, E. and Y. Naamen (October, 1961). Electronic Computers in Taxes and Administrative Services: A Report of a European Survey. Jerusalem, The State of Israel: the chamber of the state's revenues.

[22] The decision to buy an NCR was made after they correctly analyze the potential of a new information storage media, the hard disk. IBM in these years vehemently fought against this new innovation and declared it to be "inconsistent with the good working of a computer" (interview with E. Sharon 12/19/1999).

[23] The first designated computer-science program in the universities opened in the Hebrew University as part of the mathematics institute only in 1969. Indeed by 1960 all the universities already had mainframe computers, and the Weitzmann institute was the first Israeli institution with an electronic computer as early as the 1950s. Nevertheless, none of the academic institutions in Israel neither taught programming and computer science as an academic discipline or thought about using these computer for anything else beside scientific calculations for some years after the IDF, the state bureaucracy, and some of the large public companies and banks were already training personal and using computers on a day to day basis. Another important effect of these early efforts was the accumulation and development of Assembler and machine language skills that requires a more intimate understanding of the working and capabilities of computers than the more modern programming languages. On IBM's decision of unbundling the sales of software from hardware, see Mowery, D., C., Ed. (1996). The international computer software industry: a comparative study of industry evolution and structure. New York, Oxford University Press.

[24] Due to the recent surge in the use of computers throughout the IDF, and the limited amount of programmers supplied by the school, several units in the IDF, mainly the intelligence and the air force, started to circumvent the official programmers recruiting paths and started to offer what they term "PC kids", i.e. high-schoolers with extensive knowledge of programming special shortcuts service of only three years, with almost no formal training.

[25] There is almost no correlation between being healthy and having a perfect health profile. Most of the population doesn't posses a perfect health profile, for example if one needs glasses, suffer from any minor allergies, or was unfortunate enough to break too many bones in his body as a child; one's profile is no longer perfect.

[26] It is important to note that in the last two decades the requirements of the computer science department in the universities also ensure that only these who score exceptionally high on both the Israeli SAT and the national matriculation exams in the end of high-school are admitted, i.e. in both recruitment paths the IDF accept as programmers only these who belong to the national intellectual elite.

[27] On the important of a common language to product development and design process, see Piore, M., R. Lester, et al. (1994). "The organization of Product Development." Industrial and Corporate Change **3**(2): 405-434. Where the authors offer a new interpretive approach to product design.

[28] The School's website (Hebrew) is: http://www.idf.il/hebrew/organization/comp_school/info.stm

[29] See, Porter, M. (1990). The Competitive Advantage of Nations. New York, Free Press. Pp. 81.

[30] It is a very interesting fact that 'improvisation' is a distinct and special word in Hebrew (Le-Alter) with ancient origin in Aramaic, with distinct modern meanings, and, unlike improvisation, without any negative meanings whatsoever. Moreover, Ailtor (the capability to improvise) is considered as one of the most highly rated characteristics of the Israeli R&D personal, not only as a commonsense knowledge of all Israelis, but as an important factor mentioned by all of my interviewees, and by the popular press. One should note, however that for many years that did not translate to high level of technological entrepreneurship, see Breznitz, D. (2002). Conceiving New Industrial Systems: The Different Emergence Paths of High-Technology Companies in Israel and Ireland. Paper Presented in the Annual Business History Conference, Wilmington, Delaware, 2002..

[31] This experience is far from being ideal, however, a 23 years old that successfully managed with all its problems a mixed team of very young soldiers, and some industry veterans and few world-renowned professors in computer science and mathematics with the average age of 45 and social network ties with her

superiors, had probably gained invaluable managerial experience for the rest of her career, an experience that no private firm is able to offer.

[32] An interpreter is a programming language, which take the instructions that the programmer write and translating them into machine code that enable the computer to execute them.

[33] As attest by the high market value these graduates have in the private market both in Israel and the US.

[34] For example in December 1999 John Bryce Training, one of the leading schools ran twenty six parallel year long professional diploma granting courses in system analyzing and designing, each of these usually has twenty to twenty five students.

[35] All of the private schools write original material. However, only their in-house instructors usually write it, and they are highly limited by profit consideration.

[36] As mentioned earlier the upgrading project was conducted on the two design courses, however as the first one is only a one-week introduction to the field of design, we will concentrate mainly on the second one.

[37] For an example of how Microsoft couldn't fix its software design issues and instead uses on the fly designing techniques, see Cusumano, M. (1995). Microsoft secrets : how the world's most powerful software company creates technology, shapes markets, and manages people. New York, Free Press. For more information on product design, see Piore at el. Ibid.

[38] While I haven't dwell on these here this approach of letting and even forcing technical personal to take major responsibilities in complex projects is prominent throughout the IDF R&D units and other defense R&D organizations like REFAEL, as attest to by the logic of the IDF's elite Talpiot project aiming to create highly skilled 21 to 26 years old R&D officers through special training of gifted 18 years old.