A NANOTECHNOLOGY ROADMAP FOR THE TURKISH DEFENSE INDUSTRY

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ABSTRACT

A NANOTECHNOLOGY ROADMAP FOR THE TURKISH DEFENSE INDUSTRY

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Nanotechnology is one of the key pillars of the next industrial revolution. It is anticipated that many of the services and goods related to industry and daily life would be transformed through the advancements in nanotechnologies. Due to the fact that this fast developing technology can be applied almost all science and technology fields, it is considered to be one of the general purpose technologies, like information technologies. Therefore, investments in nanotechnologies are increasing day by day. In order to take advantage of this rapidly developing technology, it is important to identify the application domains and R&D priorities, which require long term foresight studies, particularly at the national level due to the strategic importance of the technology.

Defense sector is one of the most benefiting sectors of nanotechnologies. Warfare conditions change rapidly due to transformation of society, economy and politics. Technologies are constantly developed to address the new demands and to provide further opportunities. Due to a number of potential applications areas of nanotechnologies within this sector, the present study takes defense as a case and proposes a strategic roadmap for the use of nanotechnologies in the Turkish Defense Industry. Performing such a study is considered to be crucial for the armies of developed and developing countries in order not to stay away from the race in the military field related to this revolutionary technology. Study presented in this paper uses a bibliometric analysis of most cited publications at last decade with the aim of identifying featured words of nanotechnology.

Interviews were carried out with experts based on the featured words of bibliometric analysis in order to reveal the commercialization time of nanotechnological products and applications. After that a survey was applied to engineers for determining the possible emergence time of nanotechnology applications and/or products to be used in military up to year 2035.

Finally, a road-map was created based on the obtained data from bibliometric analysis, interviews and survey results. Some policy recommendations are given as Main Strategies & Sub-Strategies for TAF and Defense Industry. This road-map will contribute to the preparation of the defense industry for the future and keeping up with the technological developments.

Keywords: Military, Defense Industry, Nanotechnology, Bibliometric Analysis.

ÖZ

TÜRK SAVUNMA SANAYİ İÇİN NANOTEKNOLOJİ YOL HARİTASI

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Nanoteknoloji yeni sanayi devriminin temel taşlarından biridir. Sanayi ve günlük hayata dair birçok ürünün/hizmetin bu teknoloji yoluyla değiştirileceği öngörülmektedir. Hızlı gelişen bu teknolojinin neredeyse tüm bilim ve teknoloji alanlarına uygulanabilmesi nedeniyle nanoteknoloji, bilgi teknolojileri gibi genel amaçlı teknolojilerden biri olarak kabul edilmektedir. Bu yüzden son yıllarda nanoteknolojiye yatırımlarda artış görülmektedir. Hızla gelişen teknolojinin sağladığı faydaların çoğundan yararlanmak için uygulama alanlarının ve Ar-Ge önceliklerinin belirlenmesi önemlidir. Özelikle de teknolojinin ulusal düzeyde stratejik öneminden ve finansman ihtiyacından dolayı uzun vadeli Öngörü çalışmalarının yapılması gerekmektedir.

Savunma sektörü, nanoteknolojiden en çok yararlanan sektörlerden biridir. Muharebe koşulları toplumun, ekonominin ve politikanın dönüşmesi nedeniyle süratle değişmektedir. Teknolojiler, yeni taleplere cevap vermek ve daha fazla fırsat sağlamak için sürekli geliştirilmektedir. Bu sektörde nanoteknolojinin bir dizi potansiyel uygulama alanı olması nedeniyle, bu çalışma savunmayı bir vaka olarak ele almakta ve Türk Savunma Sanayiinde nanoteknolojinin kullanımı için stratejik bir yol haritası önermektedir. Bu devrimci teknolojiye bağlı olarak özellikle askeri alanda yaşanan gelişmelerden uzak kalmamak için böyle bir çalışmanın gerçekleştirilmesi, gelişmiş ve gelişmekte olan ülkelerin orduları için çok önemlidir. Bu tezde nanoteknolojinin gelişimindeki eğilimleri tanımlamak amacıyla, son on yılda en çok atıf alan yayınların bibliyometrik analizi yapılmıştır.

Nanoteknolojik ürün ve uygulamaların ticarileşme zamanını ortaya çıkarmak maksadıyla bibliyometrik analizde öne çıkan kelimeler (nanopartikül, nanoyapı, kendiliğinden toplanma, ilaç salınımı, grafen vb.) baz alınarak Uzmanlarla görüşmeler yapılmıştır. Bu görüşmeler sonrasında, 2035 yılına kadar orduda kullanılacak olan nanoteknoloji uygulamalarının ve/veya ürünlerin muhtemel ortaya çıkma zamanını belirlemek için mühendislere anket uygulanmıştır.

Sonuç olarak bibliyometrik analiz, görüşme ve anket sonuçlarından elde edilen verilere dayanarak bir yol haritası oluşturulmuştur. TSK ve Savunma Sanayi için politika önerileri kapsamında ana stratejiler ve alt stratejiler belirlenmiştir. Bu yol haritasının savunma sanayiinin geleceğe hazırlanmasına ve teknolojik gelişmelere ayak uydurmasına katkıda bulunacağı değerlendirilmektedir.

Anahtar kelimeler: Savunma sanayi, ordu, nanoteknoloji, bibliyometrik analiz,

To my precious family

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LIST OF ABBREVIATIONS

AFM	Atomic Force Microscope
BMBF	Federal Ministry of Education and Research
BTYK	The Supreme Council for Science and Technology
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CC	Competence Center
COSTIND	Commission of Science, Tech. & Industry for National Defence
DARPA	The Defense Advanced Research Projects Agency
DoD	Department of Defense
EC	European Commission
ERA	European Research Area
EU	European Union
FET	Future and Emerging Technology
FPs	Framework Programmes
GaN	Gallium Nitride
GCI	Global Competitiveness Index
GRMs	Graphene and Related Materials
GUNAM	Solar Energy Research Center
HIP	Operational Requirement Plan
ICT	Information Communication Technologies
ISI	International Scientific Indexing
ISN	Institute for Soldier Nanotechnology
METU	Middle East Technical University
MGSB	National Security Policy Document
MIT	Massachusetts Institute of Technology
MKEK	Mechanical and Chemical Industry Company
MOE	Ministry of Education
MoI&T	Ministry of Industry And Technology
MoND	Ministry of National Defense
MOST	Ministry of Science and Technology
MSIP	Ministry of Science, ICT and Future Planning

MoT&F	Ministry of Treasury and Finance
MÜKNET	Excellence Networks
NBIC	Nano-bio-information science-cognitive science
NCNST	National Center for Nanoscience and Technology
Nm	Nanometer
NNI	National Nanotechnology Initiative
NS	Nanoscience
NSC	National Security Council
NSET	Nanoscale Science, Engineering and Technology
NSF	National Science Foundation
NSFC	National Natural Science Foundation of China
NT	Nanotechnology
OYTEP	Ten-year Procurement Plan
PhD	Doctor of Philosopy
PTD	Project Identification Document
R&D	Research and Development
RF	Radio Frequency
RFI	The Request for Information
RFP	The Request for Proposal
R&T	Research and Technology
SaSaD	Defence And Aerospace Industry Manufacturers Association
SBIR	Small Business İnnovative Research
SCI	Science Citation Index
SHP	Strategical Objectives Plan
SME	Small and Medium Enterprises
SPM	Scanning Probe Microscope
SPO	State Planning Organization
SSB	Presidency of Defence Industries
SSDF	Defense Industry Support Fund
SSI	Defense and Aerospace Industry Exporters' Association
SSİK	Defense Industry Executive Committee
SSM	Undersecretariat for Defense Industries
STM	Scanning Tunnelling Microscope
SUNUM	Sabancı University NT Research and Application Center

TAF	Turkish Armed Forces
TLF	Turkish Land Forces
TMA	Turkish Military Academy
TUBITAK	The Scientific and Technological Research Council of Turkey
TÜİK	Turkish Statistical Institute
TÜMAS	Turkey's National Military Strategy
UAV	Unmanned Aerial Vehicle
ULAKBIM	Turkish Academic Network and Information Center
UNAM	National Nanotechnology Research Center
US	United States
USA	United States of America
USPTO	United States Patent and Trademark Office
WMD	Weapons of Mass Destruction
WoS	Web of Science
SCI	Science Citation Index
WTO	World Trade Organization
YÖK	Counsil of Higher Education

CHAPTER 1

AN OVERVIEW OF NANOTECHNOLOGY

1.1 Introduction

The Institute for Soldier Nanotechnology was established in the US in 2002. The institute consists of a three-member team including Massachusetts Institute of Technology (MIT), Army and Nano-materials Industry. They work collaboratively to enhance soldiers' survival and protection capabilities. This is done through the manipulation of the brain of soldiers in order to enhance their abilities of war using cerebral fluids consisting of nano-particles and nano-chips insertion in the brain. The aim is to enhance certain parts of their brains to ensure sustainability in the warfare (Jazib Ali, 2016).

This is just one of the thousands of news clips, which gives some ideas on how nanotechnologies could be exploited for the purpose of military. One would then wonder what would be the next? With the advancements in detection capabilities and manipulation techniques it can be foreseen that many further applications can be imagined and expected. One of the indicators of what is like to emerge is the increasing funding on nanotechnology research and development (R&D) programs, on-going national nanotechnology programs and trends in scientific publications. For example, since the beginning of the National Nanotechnology Initiative in 2000, the US has allocated ⅓ to ¼ of its annual billion dollar plus research budget to the Department of Defense. Estimates show that the US spends 80-90% of global expenditure on military nanotechnology, which is about four to ten times as much as the rest of the world combined (Altmann, 2008).

The investments made in nanotechnology increase every year. The worldwide investment in nanotechnology R&D reported by national government organizations and the EU has increased approximately nine-fold – from 432 million dollars in 1997 to about 4,100 million dollars in 2005. The proportion of national government investments for academic R&D and education are between 20% (Korea, Taiwan) and 65% (US), industrial R&D – between 5% (US) and 60% (Korea, Taiwan), and core facilities and government laboratories - about 20-25% in all major contributing economies (Roco, 2005).

Moreover, the US has invested 1.8 billion dollars in nanotechnology research only in 2013, Japan with a total of 2.8 billion dollars between 2006 and 2010, France a total of 3 billion dollars between 2009 and 2014 and China 2.25 billion dollars in 2011. Such a high amount investment demonstrates the nanotechnology race between countries (Bayındır, 2015).

It is clear that there are many efforts regarding nanotechnology R&D. However, commercialization of nano-enabled applications has remained limited so far. Although there is no consensus between scholars on when nanotechnology applications would become widespread, there is an agreement that the breaktrough will eventually happen (Saritas & Burmaoglu, 2016). Therefore, the current study aims to create a nanotechnology roadmap, particularly for the defense industry, where a number of advancements are expected to emerge.

Investigating nanotechnology studies thoroughly may provide new perspectives for both nanotechnology and the defense industry, and new opportunities for R&D, collaboration and further foresight studies. The case is applied within the context of a developing country, with the aim of pointing out that there are a number of opportunities exist in defense nanotechnology domain, not only for developed countries but also for the developing ones.

It is observed that some experts working on nanotechnology dates back the history of this technology to the 2000’s B.C. Although mentioned as the first nano products such as the nanoparticles in the ink used by the Egyptians in their writings on papyrus or the formation of layers of steel swords manufactured in Damascus during the Crusades, it is possible to argue that R&D studies have been carried out on this technology since the 60's intensely. “Nano” term expresses small and for a technological product including nano in its name, evokes advanced technology.

In addition to miniaturization, another feature attributed to nano products is that these kind of products are "smart". In this sense, from self-cleaning dyes to uncontaminated fabrics; from flexible but more durable concrete to coatings as hard as diamond; from killing cancer cells without harming the body to cream that does not lose its effect for days; from sensors that can detect even single anthrax germ to socks that do not smell because they kill bacteria or microbe-free refrigerators; nanotechnology that is starting to enter our life is perceived as a new technology revolution (Denizci, 2008).

By this technology revolution, products can be built up with every atom in the right place in order to ensure materials to be lighter, stronger, smarter, cheaper, cleaner and more precise. The implementation of nanotechnology is likely to bring a drastic reduction in the energy consumption and dramatically advance medicines abilities to cure and prevent diseases, and also to add significant increases in the precision and effectiveness of military devices and weapons (Kharat et al., 2006).

Nanotechnology has the potential to enable change in every aspect of life. It is also possible that new applications and new production techniques will be encountered apart from conventional production methods. In fact, nanotechnology has various solutions for the issues which have the potential to cause big problems for human being now and in the future if the world is faced with and no solution is found like water, environment, health and energy.

Nanotechnology, which is standing at the intersection of engineering, physics, chemistry and biology, has important implications in all areas of science and technology (Gsponer, 2002). According to Sean Howard (Disarmament Diplomacy No: 65) the emergence of nanotechnology is like that; "Historically, nanotechnology is a child of the nuclear weapons labs, a creation of the weapons of mass destruction (WMD) - industrial complex."

When viewed in the military context, in order to gain the advantage in terms of military power it is necessary that the technological capabilities, weapon systems and equipment must be better than the enemy has. Scientists/engineers are trying to develop weapon systems, uniforms and equipment used by soldiers in the light of war experiences in different parts of the world such as Afghanistan, Iraq, Kosovo and Syria. Equipment used by soldiers should be able to detect chemical and biological agents on warfare, to monitor the necessary signals of injuries (wounded) and warn the headquarter, do basic first aid and contact commanders etc. according to needs. The need to produce stronger, more durable and lighter materials for military applications lead us to head for the concept of nanotechnology.

Norio Taniguchi first used the word "nanotechnology" in 1974, which has such an important position for the development of science and technology (Tiwari, 2012). Since than, it has been observed that nanotechnology studies have increased very rapidly. Especially after the millenium, it can be said that a very tough race has started in this field among the countries. Developed countries allocate more budget for studying nanotechnology than other countries. At the same time, it is seen that new organizations/institutions are formed in order to make these studies better.

In fact, after the World War II, a competition was started between countries in the field of science and technology. From ENIAC, which was recognized as the predecessor of today's computers in 1946, weighing 100 tons to 1.7 centimeters thick “MacBook Air” introduced by Apple CEO Steve Jobs in January 2008 or the path that goes to smart phone competition between Apple and Samsung shows the direction of change and the point where the race reached today (Denizci, 2008).

Regarding the issue, Thomas (2006) stated that people were exposed to a different technology wave every decade or so and that today's technology wave is nanotechnology. Nanotechnology that describes atomic or molecular level processing can be called today's "technology tsunami". Countries are rapidly stepping up their investments in nanotechnology R&D for this reason. The National Nanotechnology Initiative (NNI), launched in the US in 2000, has become the largest publicly-funded scientific project of the United States after the Apollo project.

In recent years, significant increases in investment have been striking in the field of nanotechnology. In parallel with investments in nanotechnology, overall R&D investments are also increasing. In 2012, OECD governments on average invested the equivalent of 0.8% of GDP in direct funding of R&D at home or abroad; Korea and Finland invested over 1% of GDP. In addition, 27 of the 34 OECD countries and a number of non-OECD economies now indirectly support business R&D via tax incentives. In 2011, the Russian Federation, Korea, France and Slovenia provided the most combined support for business R & D as a percentage of GDP (OECD, n.d.).

According to the OECD Scoreboard; The United States has the largest number of nanotechnology-active firms (4.928), followed by Germany (960) and France (524). Data on business enterprise expenditures on research and development (BERD) for nanotechnology provide a better measure of the research effort. On average, nanotechnology accounted for almost 2% of total BERD in 2011. The United States has the strongest focus on nanotechnology R&D (4.8% of total BERD), followed by Mexico (4.6%) and the Russian Federation (3.5%) respectively. The United States spends the most on nanotechnology BERD (USD 13.500 million PPP). Nanotechnology R&D situation in the Business Sector is shown at Figure 1.1.

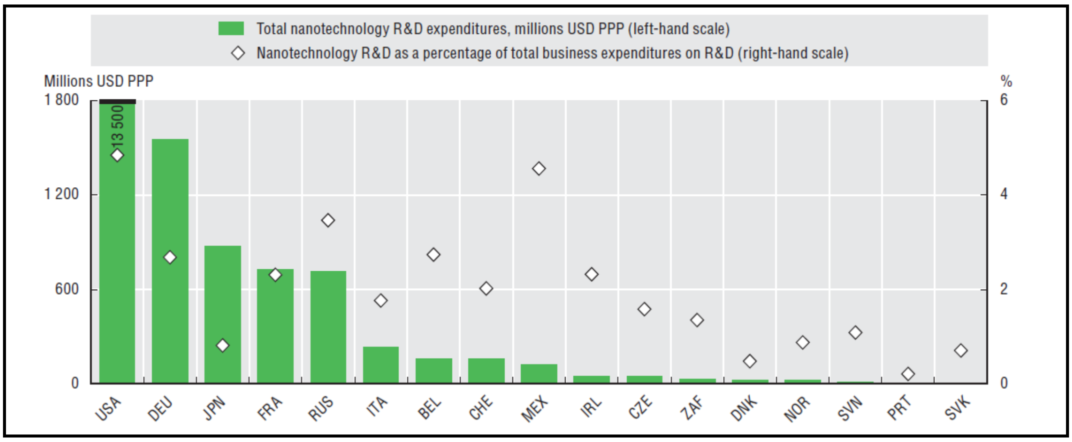


Figure 1.1 Nanotechnology R&D in the Business Sector, 2011.
Source: (OECD, 2015) and (OECD, 2017a)

The share of nanotechnology in the government and higher education sector's total expenditures on R&D provides an indicator of the importance governments accord to nanotechnology R&D. The share is the highest in the Russian Federation, at 5.6%, followed by Korea (4.7%) and Portugal (3.5%) (OECD, n.d.). Nanotechnology R&D in the government and higher education sectors is shown at Figure 1.2

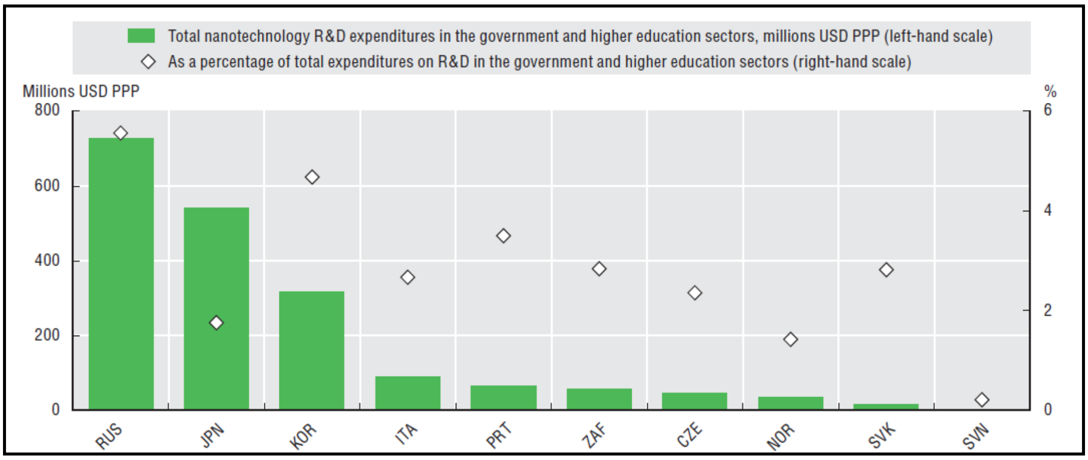


Figure 1.2 Nanotechnology R&D in the Government And Higher Education Sectors. Source: (OECD, 2015) and (OECD, 2017a)

Mihail Roco, nanotechnology advisor to the White House, predicts, “Because of nanotechnology, we’ll see more changes in the next 30 years than we saw in all of the last century.” Nanotechnology is likely to be the manufacturing wave of the future. In recognition of its importance, the National Nanotechnology Initiative (NNI) allocated almost half a billion dollars into nano research in the year 2000 alone. In the early 2000’s, industry leaders believed that by the year 2015, the global market for nanotechnological products would have exceed $1 trillion annually (Petersen & Egan, 2002).

There were 180 patents related to nanotechnology in 2001. The number of patents rose to forty five in 1999 when it was zero in 1989. Uldrich & Newberry, (2003) stated the importance of NT like that;

> According to Richard Smalley, the 1996 Nobel Winner in Chemistry: The impact of nanotechnology on the health, wealth and lives of people will be at least the equivelant of the combined influences of microelectronics, medical imaging, computer-aided engineering and man-made polymers in the twentieth century.

Nanotechnology is one of the key pillars of the next industrial revolution. It is anticipated that many of the services and goods related to industry and daily life will be transformed through the advancements in nanotechnologies. Due to the fact that this fast developing technology can be applied almost all science and technology fields, it is considered to be one of the general purpose technologies, like information technologies. Therefore, investment in nanotechnologies are increasing day by day. In order to make use of this rapidly developing technology, it is important to identify the application domains and R&D priorities, which require long term foresight studies, particularly at the national level due to the strategic importance of this technology.

Meissner (2012) points out in the article, examining the results and effects of national foresight studies, that in the short and medium term, these kind of studies provide significant contributions to the countries in the sample. Therefore, it can be said that the positive contribution of the foresight studies to be carried out in different areas will be important for Turkey, which sets targets for itself in and after 2023.

Even it seemed adequate to perform foresight studies for centuries in the past, the evolutionary nature of technology as Basalla (1988) stated, needs performing adaptive policy making and strategy studies more frequently now. In order to keep up with rapidly changing technological storm, it is important to evaluate future considerations continuously in the view of systemic perspective and dynamic environmental circumstances and to perform foresight studies with adaptive policy and strategy research for using national resources effective, efficient and productive.

In this context, it is foreseen by researchers that a special area such as nanotechnology will have a greater impact than the effect of Fordist practices in the industrial revolution. The importance of nanotechnology subject has been realized by The Scientific and Technological Research Council of Turkey (TUBITAK) and High Board of Science and Technology (BTYK) with publishing a Strategy Document. Nanotechnology is considered as a strategic technology field in National Science and Technology Policy 2003-2023 Strategy Document and emphasized that this subject should be studied under the headings as: (i) Nanophotonics, Nanoelectronics, Nanomagnetisma (ii) Nanomaterial, (iii) Nanocharacterization, (iv) Nanofabrication, (v) Nano Scale Quantum Data Processing, (vi) Nanobiotechnology in the view of welfare of the nation, economy and national security.

1.2 Organization of the Thesis

The thesis includes six chapters. Chapter 1 focuses on nanotechnology in general terms. This chapter briefly reviews the definitions, developments, application areas, approaches, tools and products of nanotechnology. In addition to these, the history of nanotechnology, economic value of nanotechnology, roadmaps and studies on nanotechnology have been mentioned in this chapter.

Chapter 2 focuses on military technology trends, changing characteristics of war, military applications of nanotechnology and defense planning system of Turkey. Chapter 2 includes four main sections. Section 2.1 presents military technology trends and changing characteristics of war. Section 2.2 reviews the changes in nanotechnology in the future and the effects of these changes on war. Section 2.3 explains the situation of the defense industry in Turkey and Section 2.4 gives some brief information about defense planning strategy of Turkey.

Chapter 3 focuses on the nanotechnology studies in Turkey and in the world. In this chapter, especially situation of nanotechnology in developed countries are examined firstly. After that the nanotechnology studies in Turkey have been mentioned in detail. This section also includes the studies on nanotechnology carried out by Turkish Armed Forces (TAF) and Ministry of National Defense (MoND).

Chapter 4 reviews the quantitative and qualitative methodologies used to collect data for this thesis. Three sets of data are collected; the first one is from bibliometric analysis of most cited nano related articles of last decade; second, from experts working at UNAM, GUNAM and SUNUM through in-depth interviews aimed at determining the commercialization time of nano products; third, from engineers working at MoND through a survey for evaluation of the use of nanotechnological products in the military field. This chapter also includes aim, significance, scope and limitations of the research.

Chapter 5 concludes the thesis. In this chapter, we present a summary of overall research findings of the thesis. Results of the study are given in detail related to nanotechnology. It is mentioned about how the warfare will be in the future, what kind of weapon systems will be used by soldiers and the outcomes of the military applications of nanotechnology.

Finally, policy recommendations are given at Chapter 6. At this Chapter, 17 Main Strategies and 76 sub-strategies are proposed for defense industry.

1.3 Definition and Development of Nanotechnology

Nanotechnology is defined by its scale "nanometer (nm)" or one billionth of a meter (10^{-9}). Basicly, nanotechnology refers to the ability to control the composition of molecules and atoms, with the range of 100 nm down to 1.0 nm, potentially enabling scientists to create specific molecular structures and devices. The sizes here are barely comprehensible. For example, given that the width of a human hair is approximately 80.000 nm, some 1.600 nanotechnological devices, each 50 nm wide would fit across a human hair (Bowman & Hodge, 2006).

Definitions of nanotechnology are not always clear or indeed agreed upon. The domain of nanotechnology is defined in terms of a length-scale – from 1 nanometer up to 100 nanometers – and by the appearance at these length-scales of different physical properties. These derive from the importance at small length-scales of physical phenomena that are less obvious for larger objects. Fundamentally, nanotechnology is referred to as the controllability of molecules and atomic compositions, and it is expressed to cover product developments in the range of 100 nm to 1 nm (Wood et al., 2003).

NT is an emerging manufacturing technology which will provide a very high level of control over the manipulation of matter. Machines, called assemblers, will be able to build things to atomic specification under programmable control. Their design and operation can be like robots and miniature factories, with levers, gears, bearings, electric motors, pulleys, cables, conveyer belts, and computers to coordinate their operation—all with parts of molecular dimensions (Forrest, 1989).

Table 1.1 shows different definitions of nanotechnology. In fact accordingly various institutions and organizations have defined nanotechnology in a similar way.

Table 1.1 Some Definitions of Nanotechnology

The Royal Society & The Royal Academy of Engineering	Published a report in 2004 named "Nanoscience and nanotechnologies: opportunities and uncertainties". **Nanoscience** was defined as "the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale;" and **nanotechnologies** as "the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale" at this report.
National Science Foundation (NSF) USA	A definition was made in 2003. According to this definition **nanotechnology** refers to the ability to manipulate individual atoms and molecules, making it possible to build machines on the scale of human cells or create materials and structures from the bottom up with novel properties ("NSF-National Science Foundation," n.d.).
International Organization for Standardization (ISO) Technical Committee 229	Understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nm in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications, Utilizing the properties of nanoscale materials that differ from the properties of individual atoms, molecules, and bulk matter, to create improved materials, devices, and systems that exploit these new properties ("ISO/TC 229 - Nanotechnologies," n.d.)
U.S. Food and Drug Administration (FDA)	A Report of the Nanotechnology Task Force in 2007; NT allows scientists to work on the scale of molecules to create, explore, and manipulate the biological and material worlds measured in nanometers, one-billionth of a meter. By way of comparison, a sheet of paper is about 100,000 nanometers thick; a human hair is about 80,000 nanometers wide (FDA, 2007).
Oxford Advanced Learner's Dictionary	The branch of technology that deals with structures that are less than 100 nanometres long. Scientists often build these structures using individual molecules of substances ("Oxford Advanced Learner's Dictionary," n.d.).

In these definitions, the structural feature, the physical property and the formation of a new substance come to the fore. Words like manipulate, explore, create, controlling are commonly used to describe nanotechnology.

Briefly summarizing the historical background of nanotechnology; attentions were turned to nanotechnology with a speech of physicsist Richard Feynman (Nobel Prize winner in Physics, 1965) in his speech in meeting at Caltech on December 29, 1959, where he stated that "there is plenty of room at the bottom" (Feynman, 2002). Feynman's ideas focused on the systems that will provide the opportunity to make a single atomic-level action.

Drexler (2004) argues that this phase of development, coined 'molecular manufacturing', would be underpinned by the creation of computer-directed nano-scale robots capable of precise manipulation of atoms to form complex atomic devices and machines. Drexler's vision is that such robots, known as 'assemblers' or invisible 'nanobots', will have the ability to self-replicate, or clone themselves, and have the subsequent ability to work in accordance with building macro-scale devices at large scale (Bowman & Hodge, 2006). This vision naturally includes some unpredictable threats and opportunities.

Twenty years after Feynman's speech, a group of researchers working at IBM in Zurich, have developed a device for seeing and processing single-atom by way of producing Scanning Tunneling Microscope (STM) (Binnig & Röhrer, 1982). Over the next following years, the Atomic Force Microscope (AFM) was produced (Binnig et al., 1986). These devices may be regarded as an attempt to fill a very important gap in the nanotechnology field. When working at the atomic level, seeing and manipulating can be considered as an important issue. Therefore, producing a microscope can be considered as a breakthrough development in nanotechnology. Another milestone is the discovery of Fullerenes as a molecule of carbon with great potentials for application in electronics and materials engineering (Smalley, 1996).

The developments in nanotechnology are continuing rapidly. The chronological evolution of nanotechnology is given at the Table 1.2. Especially from 2000's to the present day, there have been many developments and innovations in this field. Not all of these innovations and developments are given at the table, only the most striking ones are mentioned. In terms of chronological evolutions; tools, machines and equipments needed for the application of NT were invented until year 2000; after millenium, it can be said that firms, institutes and organizations have emerged for the spread of NT. Education programs have been started at the universities and more attention has been paid to commercialization of NT.

Table 1.2 Chronological Evolution of Nanotechnology

Year	Activity
1959	Richard P. Feynman‟s speech “There‟s plenty of room at the bottom”
1974	Taniguchi used term "nano-technology" in paper for the first time
1981	STM invented by G.K.Binnig ve H.Rohrer for seeing and processing single-atom. First technical paper on molecular engineering to build with atomic precision
1985	R.Curl Jr., H.Kroto and R.Smalley discovered C_{60}.
1986	G.K.Binnig, C.F.Quate, C.Gerber invented AFM. First nanotechnology book “Engines of Creation: The Coming Era of Nanotechnology” published by K.E.Drexler.
1987	Quantum property of the conductivity was observed for the first time. T.A.Fulton and G.J.Dolan made a single electron transistor.
1988	W.De Grado and his team made artificial protein for the first time.
1989	The word “IBM” was written by using 35 X_e atom in Zurich.
1990	First nanotechnology journal named “Nanotechnology” published.
1991	Iijima discovered multi-wall carbon nanotubes.
1992	First nanotechnology textbook “Nanosystems: Molecular Machinery, Manufacturing, and Computation” was written by K.Eric Drexler.
1993	Iijima and Bethune discovered single-wall carbon nanotubes. The first "nanotechnology" laboratory was established in Rice University First Feynman Prize was organized. Researcher was awarded for modeling a hydrogen abstraction tool useful in nanotechnology.
1995	First industry analysis of military applications was made. This analysis concluded that emerging technologies - as so often in the past - would reshape the way nations use force to achieve national goals.
1996	NASA began work in computational nanotechnology.
1997	N. Seeman made a nanomechanical device for the first time using a DNA molecule. First company founded named Zyvex.

Table 1.2 (cont'd)

1999	M.Reed and J.M.Tour made electronic key with single organic molecule for the first time.
2000	President Clinton announced National Nanotechnology Initiative (NNI). For the first time in the US, $ 422 million has been allocated for nanotechnology researches. First state research initiative: $100 million in California
2001	Transistors and logic circuits were built from nanotubes for the first time. First report on nanotechnology industry. U.S. announced first center for military applications.
2002	Superlattice nanowires were made. First nanotechnology industry conference. Nanotechnology Research Network Centre was established in Japan.
2004	First policy conference was held on advanced nanotechnology.
2005	The first four-wheeled nano car model was moved. Roco announced nanomachine/nanosystem project count has reached 300 at Nanoethics meeting.
2008	Technology Roadmap for Productive Nanosystems released. Protein catalysts designed for non-natural chemical reactions. Korean “Nanotechnology Roadmap” was published.
2009	An improved walking DNA nanorobot.
2010	DNA-based 'robotic' assembly began.
2011	First programmable nanowire circuits for nanoprocessors. IBM researchers produced a transistor containing graphene for the first time.

Source : Prepared by using (Erkoç, 2014a) and (Foresight Institute, n.d.).

When we look at the studies on the nanotechnology foresight, it is seen that (Lv et al., 2011) carried out a bibliometric study on graphene. The researchers scanned the key words "graphene” or “single layer graphit” in the topic title of publications analysis. Researchers were able to carried out 8727 research studies in total between 1991 and 2010. As a result, it has been revealed which subjects are focused on researches in the field of graphene and which researchers and research centers are working on these issues. Of course this research is only a special area of nanotechnology because it is a study focused on graphene. Due to the fact that this study is graphene-based, it includes just only a special area of the nanotechnology field.

There is another roadmap related to graphene “Science and technology roadmap for graphene, related two-dimensional crystals, and hybrid systems” developed within the framework of the European Graphene Flagship made in 2014. Road map is targeting an evolution in technology, which might lead to impacts and benefits reaching into most areas of society. The study provide an overview of the key aspects of graphene and related materials (GRMs), ranging from fundamental research challenges to a variety of applications in a large number of sectors, highlighting the steps necessary to take GRMs from a state of raw potential to a point where they might revolutionize multiple industries. Road map also defines an extensive list of acronyms in an effort to standardize the nomenclature in this emerging field. Road map is divided into eleven thematic chapters (fundemantal research, health and environment, production, electronic devices, spintronics, photonicss and optoelectronics, sensors, flexiable electronics, energy storage and generation, composits and biomedical application). Each of them comprises a dedicated timeline as 2016, 2018, 2020 and 2024 & later (Ferrari et al., 2015).

Another foresight study is about Taiwan's nanotechnology industry in 2020 (Su et al., 2010). In this study, Delphi-based foresight study was carried out. Information is gathered from 25 experts related to three main fields of nanotechnology such as nanomaterials, nanoelectronics and nanobiomedicine. Results of the study were given to nanotechnology industry as a target.

A study about management of nanotechnology was also conducted in Holland by (Van Est et al., 2012). They examined the issue from a more social perspective. The issue of drawing the framework of state-science-society relations has been put on the agenda in this study. As a result of this study, it has been emphasized that nanotechnology is not only a matter of engineering but also it should be considered together with social and management dimensions.

Another roadmap belongs to Thailand in this field. Nanotechnology Roadmap of Thailand was prepared for the years 2012-2021. One of the Agencies under Ministry of Science and Technology of Thailand; National Science, Technology and Innovation Policy Office (STI) was coordinator for the plan. The plan provided national direction for the next ten years. The plan included five strategic agenda and twelve target economic sectors which would help to improve quality of society and sustainable economy (Thailand, n.d.).

Philippinnes Nanotechnology Roadmap is another study on this subject. It was prepared for the years 2011-2016 by Department of Science and Technology. General approach was used in the roadmap study. Current and potential applications of nanotechnology (globally) were revealed firstly. After that, possible applications of nanotechnology were determined for Philippines. Finally, Nanotechnology Roadmap was prepared for Philippines. The Philippines' five-year-Nanotechnology Roadmap included four major programs: Nano-based technologies and materials, Nanosensors and nanodiagnostics, Nanometrology for Information and Communication Technologies (ICT) and Semiconductor and Nanostructured Solar Energy Devices and Storage. This roadmap covers a period of five years. Other road maps usually cover longer periods (Basilia, 2010).

Similarly, NANOfutures, European Technology Integrating and Innovation Platform on Nanotechnology, prepared a road map in 2012 named "Integrated Research and Industrial Roadmap for European Nanotechnology". NANOfutures Vision towards 2025 can be summarised as follows:

> By 2015; Nanotechnology World Market Size would hit 3 trillion Euros in a broad range of sectors (chemical manufacturing, pharmaceuticals, aerospace, electronics, materials etc.) By 2025; nanotechnology is expected to be a mature yet still growing industry, with countless mainstream products in all different industrial sectors.

In this context, Europe aims to play a market leader position, increasing its competitiveness in all different sectors where nanotechnology may have a strong added value. The growth and commercialization of nanotechnology must be guided and fostered by taking care of social and sustainability aspects. Road map covered 2013-2025 years. NANOfutures Integrated Industrial and Research Roadmap aimed at delivering a focused implementation plan until 2020, within a longer term horizon of actions (2025 and beyond). Timeline for proposed actions is like that; Short Term: 2013-2016; Medium Term: 2017-2020 and Long Term: 2020-2025 and beyond ("NANOfutures," n.d.)

European Aeronautic Defence and Space Company (EADS) prepared a Nanotechnology Roadmap For Space Applications in 2010. Roadmap was established in the following topics: Composite structures, Thermal protection modified with nano fillers, Propulsion, Sensors (Gas detection, Sensors miniaturization) and Coating. The mentioned Roadmap covered the years 2010-2020 (EADS, n.d.).

As mentioned above, many countries prepared nanotechnology roadmaps. Scientific and technological efforts are directed towards a common goal for the benefit of society. Countries allocate more resources to nanotechnology in order not to stay behind from this technology race.

1.4. Nanotechnology Application Areas, Approaches, Tools and Products

In parallel with the advancement of technology, there are also important developments changes in the field of nanotechnology. In this sense, new application areas, different approaches, new tools and products are emerging. Nanotechnology now has a very efficient use in many different products and processes. Nanotechnology offers different solutions to many different problems, especially in the field of military technology.

1.4.1 Application Areas

It is accepted that, among the converging technologies, nanotechnology is regarded as critical technology of today and near future in terms of strategic, economic and technological efficiency. As a result of applied researches, nanotechnology is now used in many commercial products. It is possible to see that nanotechnology applications and nanotechnological products can be found in many areas.

For example in medicine; mini robot that circulates among the blood cells and transmits the drug only to a certain cell, in the field of health; shoe sole that removes foot odor, in the environmental field; non-polluting wall paints or fuel pipes reducing environmental pollution by 20 percent, etc. Such practices have begun to enter into daily life of people. It is possible to find products containing nano-materials in almost all areas from electronics to defense, from communication to medicine, from cosmetics to decoration, from automotive to food and textile. It is foreseen that nanotechnology will have a potential to overcome many problems that may be encountered in the coming years, as well as open up new horizons on many issues such as climate change, environment, renewable water resources, access to decreasing energy reserves, cancer diagnosis and treatment (Bozkurt, 2015).

Nanotechnology, which experienced its first stages in 1997, the US and Europe took up it to their agenda in the 2000s and they increased investments in nanotechnology. It has also an important place in the EU framework programs. Some countries have developed national nanotechnology policies and issued nanotechnology incentive laws. It is stated that nanotechnology, which is about to complete transition period of twenty years, will greatly increase application areas and product diversity within the next ten years. Especially large companies are investing in nanotechnology. It is predicted that nanotechnology will be in every area of life in 2025. Many exciting products using nanotechnology have already been developed like artificial photosynthesis, self-charging, tumor therapy, CD, nanotechnological cloth, battery, varicose veins, miniaturized writing, Nokia's nanotechnological phone and Intel's smallest processor namely Atom (Bozkurt, 2015).

It is expected that more production opportunities will increase the quality of life of people with less cost. Thus a healthier and safer life will be offered to people. Thanks to this technology; from high-speed computers to the gigantic memory devices, from the transport of micro-organisms to the diagnosis and treatment of diseases by nano-robots placed in the vessels, from the manufacture of micro-sensors, micro-machines and optoelectronics components to the use of nano-assisted glasses to provide better visibility in cars, many striking examples can be seen in practice (Bozkurt, 2015).

While producing long-lasting paints, drugs that show fast effect and golf balls that can go further with the help of nanotechnology currently, cars, airplanes, robots and space vehicles will be produced and long and safe journeys can be made with very little energy consumption in the following period. Nanotechnology processed silver can prevent the growth of bacteria or make their life difficult. The process, called nano silver, acts as a vaccine and nano-silver coated surfaces do not pass to bacteria. In this way, it will be possible to create bacteria-free and germ-free environments. This feature is very useful for hospitals and kitchens (Bozkurt, 2015).

As mentioned above, it is possible to come across nanotechnology applications in many different sectors and fields. The applications produced by using nanotechnology and the sectors they belong to are given at the Table 1.3.

Table 1.3 Some Nanotechnology Applications

Sector/Area	Product
Textile	Water-repellent fabrics, non-flammable and impact resistant surfaces, surface treated textile products, smart clothes
Energy	Fuel cells, solar cells, capacitors, materials providing efficient energy conversion or storage
Cosmetic applications	Sun protectors, lip creams, skin creams, toothpastes, materials with different effects of color and surface
Food and beverages	Food packaging methods that increase shelf life, storage sensors, additives, fruit juice additives
House staff	Ceramic coating on iron, catalyst on odorifier, glass, ceramic, floor and window cleaning materials
Sport materials	Boat materials, materials preventing glasses from fogging, pollution preventing agents in boats, tennis racket
Automotive industry	Light construction materials, paint coating materials, catalysts, sensors
Chemistry industry	Fillers for paints, nanocomposites based coatings, paper impregnation, adhesives, magnetic fluids
Engineering applications	Protective coatings for machine and other tools, antiblocking coatings, coatings for strengthening plastic parts, oil-free gear applications
Electronics	Displays, laser diodes, glass fibers, optical switches, filters, conductive and antistatic coatings, memories with higher capacity and processors, foldable imaging units

Table 1.3 (cont'd)

Construction	New generation composites, heat insulation, fire retardants, surface functional building materials, various coatings, flooring materials, paints, light and strong concrete
Bionanotechnology, medicine, health	Chemotherapy drugs, diagnostic kits, drug delivery systems, active agents, contrast agents, prostheses and implants, antimicrobial agents and coatings, cancer treatment agents, live cells, natural like tissues
Defense industry	Armor coating, smart uniform, smart ammunition, robot systems, sensors, unmanned air vehicles, satellites, network systems
Environment	Waste purifier filters, green energy
Agriculture	Effective fertilizers, agricultural vehicles

Source : It is created by using (Özgüz, 2015) and (Denkbaş, 2015) articles.

On the other hand, one of the most important project groups in the field of nanotechnology worldwide, has been the studies of early diagnosis and treatment group based on nanotechnological approaches in medicine and health sciences. The most intense of these studies is the development of nanodiagnostics, which can be the main solution for many diseases, especially cancer and nano carrier, which will be used in the early diagnosis and treatment. Another important area is information technology and energy field. There have been very important developments at these two interconnected areas in recent years and thanks to nanotechnology, these developments are happening at a dizzying speed. More developments such as memory growth, rapid thinking systems, automation technologies and the development of intelligent systems, the globalization of the world, and accessibility are taking place in a very short time, especially in the information sector (Denkbaş, 2015).

1.4.2 Approaches (Structural-Molecular)

According to (Lele, 2009), nanotechnology can be divided into two main categories as the structural and molecular. Structural nanotechnology means developing existing items with nanotechnology. Molecular nanotechnology term refers to designing new materials by using more radical processes. It is also indicated that structural nanotechnology is suitable for top-down approach and molecular nanotechnology is suitable for bottom-up approach.

1.4.2.1 Top-Down

Top-down means taking a material block and in order to get the desired small structure from it, doing some processing like dividing/shaping/fragmentation of the material. This is not different from the approach of the scientist who deals with bronze or stone in the bronze age. In fact, it is such a process which turns molten metals into more advanced, specially shaped materials. The smallest structure that can be achieved is limited to the dimensions of the devices available in this method (Wilson, et al.,2002).

Top-down means bringing the larger particles into nanoscale by grinding them with mechanical or chemical methods. The lower limit is about 100 nm for this process (Özgüz, 2015).

This method is like a sculptor's study. Sculptor takes a marble piece and performs various operations on it and a sculpture emerges at the end. This is an example for top-down approach (Köksal & Köseoğlu, 2014).

1.4.2.2 Bottom-Up

This application is the chemical synthesis method, called the bottom-up approach. In this method, the limit is at molecular levels. It can be expressed as a few nanometers. The approach that will carry nanotechnology forward is synthesis method. Besides, self assembly may also be regarded as the most important future research area for nanotechnology (Özgüz, 2015).

Bottom-up methods arrange atoms and molecules in nanostructures; in other words, nanoscale materials are assembled from smaller molecules and atoms. Here, innovation lies at the precise control of the material's size and resulting properties. Dendrimer and liposome technologies are derived from well-established bottom-up synthetic techniques, which are built to scale using chemistry and self-assembling lipids, respectively (Mazzola, 2003).

1.4.3 Tools and Products

There are various devices used for the development and investigation of nanoscience and nanotechnology. A Scanning Probe Microscope (SPM) is a term that encompasses a number of newly developed microscope technologies. Atomic Force Microscope (AFM) and Scanning Tunneling Microscope (STM) are among the best known types of SPM (Wilson et al., 2002).

A Magnetic Force Microscope (MFM) measuring magnetic forces, a Friction Force Microscope (FFM) measuring friction forces, a close-field optical microscope that increases the resolution of optical microscopes by a factor of ten, a surface temperature microscope and a Scanning Hall Device Microscope that extracts the surface magnetic field map were developed by using similar methods. Hence, they measure the physicsal interaction between a probe and a surface, this microscope family is called Scanning Probe Microscopes (SPM). One of the members of the SPM family, the Scanning Hall Device Microscope is able to perform the surface magnetic field mapping when a very small nano – Hall sensor is approached to the surface and does not affect the magnetic field and directly measure the magnetic field intensity. With this microscope, resolution up to 50 nm can be achieved and very sensitive magnetic field measurements can be made (Oral, 2005).

These devices may be regarded as an attempt to fill a very important gap in the nanotechnology field. Detailed information about these devices which has very important place in the field of nanotechnology, is given below.

1.4.3.1 Scanning Tunneling Microscobe (STM)

The Scanning Tunneling Microscope (STM), which can capture atomic photographs, was invented in 1981 by Gerd Binnig and Heinrich Rohrer in IBM laboratories in Switzerland. The inventors of this important discovery won the Nobel Prize for Physics in 1986. The working principle of the tunneling microscope is actually quite simple. A metal needle, which is sharpened as an atom at its tip, is brought close to the surface, when the needle approaches the surface 0.3-0.4 nm, the electrons begin to jump from the needle (the needle does not touch the surface). In this case, called tunneling, the current, namely the number of electrons flowing from the needle to the surface during unit time, is an exponential function of the distance between the needle and the surface. This function changes so fast that if the needle is closer to the surface by 0.1 nm, the tunneling current increases tenfold (Oral, 2005).

The first STM was produced in 1989 under the scope of two master's thesis in Turkey. Some parts of this STM were supplied from the scrapers and it was made entirely in Turkey, from the feedback circuit to the inspection software. The first STM working in ultra high vacuum in Turkey was also produced at Bilkent University in 1993 under the scope of a PhD thesis. With the help of these powerful microscopes, it was even possible for the first time to display atoms one by one on the surface then arrange atoms/molecules as requested on the surface one by one, experiment on one atom and even play football with them (Oral, 2005).

1.4.3.2 Atomic Force Microscobe (AFM)

The Scanning Tunneling Microscope, a device shows that the atoms are handled for the first time, has an important role in this field. Atomic scale imaging was previously possible with electron microscope, but the simplicity of STM's operation and structure has enabled nanoscience and nanotechnology to become widespread. STM is later replaced by Atomic Force Microscope (AFM). This device has more general applications because it can display the insulating surfaces (Köksal & Köseoğlu, 2014).

The only drawback of STM's was that they could only display atoms on conductive and semi-conductive surfaces and not work on insulators. Binnig made this change in 1986, which removed this restriction. Binnig developed atomic force microscope (AFM) which is a sensitive device that can measure the force between surface atoms and needle with a single atom at its tip (Oral, 2005).

1.4.3.3 Graphene, Graphite, Fullerene and Carbon Nanotube

The beginning of discoveries in the field of nanotechnology has revealed the graphene technology. Lv et al., (2011) stated that graphene technology is a rising star and it can be used in various applications. They put forth this result by using their bibliometric studies. Graphene is described as one atom thick, flat and leafy material. When gathering up many of leaves, grafite is formed. Carbon Nanotubes are obtained by converting graphite to elongated cylindrical structure. These Carbon Nanotubes are durable 100 times more than steel and it is envisaged to be used in the manufacturing of such products as strong composites, sensors, and hydrogen storage units (Tegart, 2004), as well as an artificial skin for robots (Ouellette, 2003). The enlarged version of the graphene is shown at Figure 1.3.

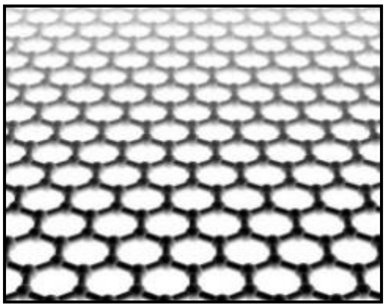


Figure 1.3 Example of Graphene.
Source : (The Nano Age, n.d.)

Graphene was discovered in 2004 by Russian scientists Andre Geim and Konstantin Novoselov. Since then, a different feature has emerged each day. Graphene is a two-dimensional carbon allotropic in the appearance of a honeycomb with carbon atoms arranged in a hexagon. An allotrope is a structure that is formed by the arrangement of atoms of an element differently in space. The graphene forms the structure of graphite, fullerenes and carbon nanotubes, which are other allotropes of carbon. Graphite is formed by overlaying graphene sheets, Fullerene is formed by converting the graphene sheet into a spherical form, Carbon nanotube is obtained by converting the graphene sheet into a cylindrical form (Arseven, 2010). The Picture of fullerene is shown at Figure 1.4.

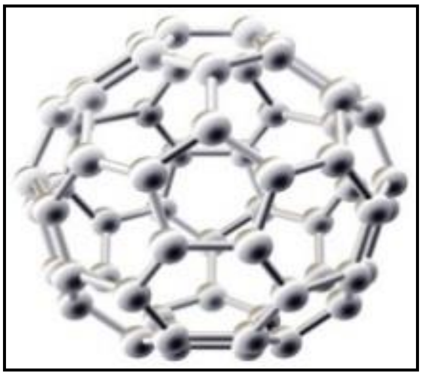


Figure 1.4 Example of Fullerene.
Source : (The Nano Age, n.d.)

Graphene's unique combination of superior properties makes it a credible starting point for new and potentially disruptive technologies in a wide range of fields. Consisting of a single layer of carbon atoms, it is stronger than steel, but still light and flexible. Electrons move up to 100 times faster in graphene than in silicon. Graphene is also transparent and combines electrical and optical features in an exceptional way. These unique properties can be exploited in several industrial areas, to the point where graphene can ignite a technological revolution. The material has the potential to impact several current challenges within, for example, the areas of sensors, ICT, energy, multifunctional materials and life science (Ghavanini & Theander, 2015).

Once the estimated market shares of graphene-based products are examined in the near future, the importance of graphene once again emerges. Market share of graphene-based products for 2017 is about $ 50 million, but by 2024 it is expected to increase by eight times to reach $ 400 million. The related graphic is shown at Figure 1.5 (Ghaffarzadeh, 2014).

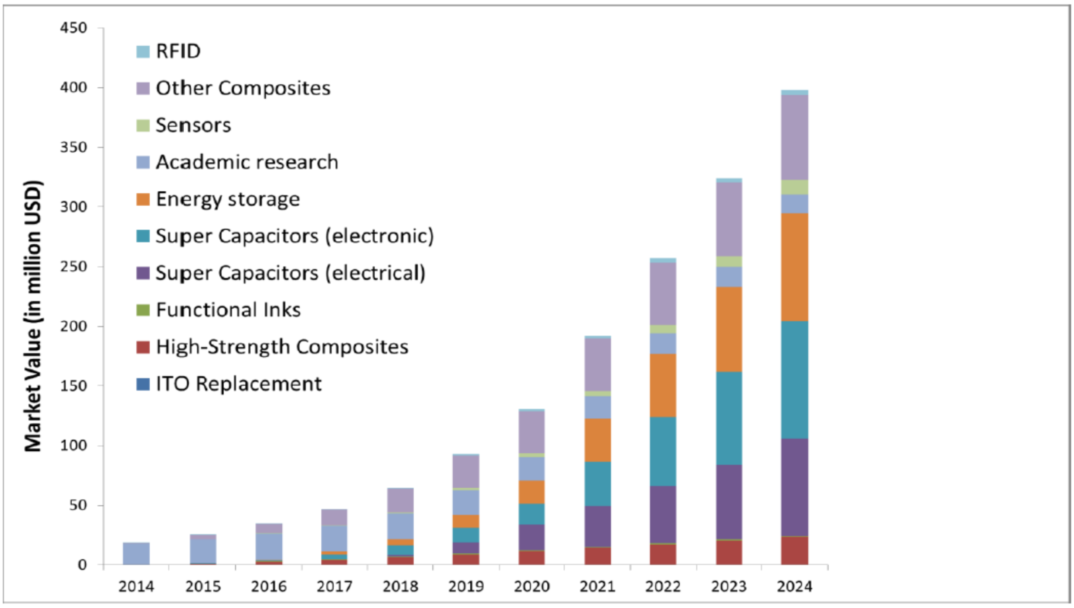


Figure 1.5 Market Forecast for Graphene in Different App. Between 2012-2018. Source: (IDTechEx, n.d.).

Due to the rapidity of electron mobility, graphene has become an alternative material to silicon for electronic circuits. IBM researchers produced a transistor that contained graphene in 2011 for the first time. This allows the graphene to be used in super-fast computers, super capacitors capable of fast charging and other electronic devices. Since the atoms are arranged very tightly, even the smallest atom, helium, can not pass through it. This tight lattice structure makes graphene an excellent sensor. The fact that the entire volume is open to external environment surrounding it allows rapid identification of the molecules attached to its surface. It will be possible to detect even a single gas molecule with a graphene-based sensor in the future. Since the graphene is chemically inert, it can remain intact in ionic liquids within the body. This feature of graphene will play an important role in the development of biological structures such as tissues, organs and drug delivery systems. In addition, due to this stable structure, it will be possible to protect metals against corrosion by coating them (Open Science, 2012).

Graphene can be obtained by many different production methods. The prominent ones of them can be sorted as micromechanical separation of graphite sheets (Exfoliation), Chemical Vapor Deposition (CVD), Graphene oxide reduction and Epitaxial Growth (Bedeloğlu & Taş, 2016).

Major applications of graphene include electronic systems, medicine, food, biotechnology, environment, composite materials, energy storage and heat systems, optical systems, sensors, basic sciences researches, nanotechnology, space and aviation technology and defense industry. Camouflage, armor technology and sensors can be sorted as prominent applications of graphene in defense industry and/or military applications. Detection of chemical agents and determination of explosives are aimed at the warfare with sensors made by graphene. Research on graphene-based materials that can change the color of their environment in real time is being done. With this technology, it is aimed to camouflage military vehicles in real time on the radar.

Chinese Academy of Sciences, Shanghai Ceramic Institute has obtained foam from graphene as a result of intensive study. The foam is remarkable because it is incredibly light and very solid. One of the materials that can be used in armor technology is the spongy (foam) material which is obtained from the graphene. The spongiform, containing ninety-nine percent air, is resistant to one-ton impact in one

cm^2 area. The material that can be shrunk to five percent of its size, can be back to its original position with its elastic structure and this process can be repeated thousands of times, but is not subject to deformation, offers different facilities for every field. With this material, special uniforms for soldiers or special armor for tanks and armored vehicles will be able to be produced (Aykanat, 2014).

There is another issue that indicates the importance of the graphene. The European Commission (EC) selected two projects (Human Brain Project and Graphene Project) within the scope of the EU 7th Framework Program ICT (Information and Communication Technologies). The Graphene Flagship is, along with the Human Brain Project, the first of the European Commission's Future and Emerging Technology (FET) Flagships, whose mission is to address the big scientific and technological challenges of the age through long-term, multidisciplinary research and development efforts. With a budget of €1 billion, the Graphene Flagship represent a new form of joint, coordinated research on an unprecedented scale, forming Europe's biggest ever research initiative. The Graphene Flagship is tasked mainly with bringing together academic and industrial researchers to take graphene from the realm of academic laboratories into European society in the space of 10 years, thus forming economic growth, new jobs and new opportunities. The Graphene Flagship is coordinated by Chalmers University of Technology, Gothenburg, Sweden. The basic consortium includes over 150 academic and industrial research groups in 23 countries. In addition, the project has a growing number of associated members that will be incorporated in the scientific and technological work packages from the Horizon 2020 phase (European Union, n.d.).

Given that the above mentioned issues related to graphene which is subjected to intensive researches on it, are taken into consideration, it is expected that it will be indispensable material for both military systems and daily life as well in the future.

Another milestone for nanotechnology products is the discovery of fullerenes as a molecule of carbon with great potentials for application in electronic and materials engineering (Smalley, 1996).

Today, carbon forms a large family with other forms. The first one of them is C_{60} called the soccer ball or the fullerene. Fullerene has currently more than thirty different forms together with nanotubes. There are sixty carbon atoms in its structure. Therefore, C_{60} term is used (Wilson et al., 2002). The sphere-shaped fullerenes are called buckyballs. The fullerenes consist entirely of carbon atoms and can be in the form of a sphere, ellipsoid (similar to Earth's shape) or tubes. The names of the cylindrical ones are carbon nanotubes. Picture of carbon nanotube is shown at Figure 1.6.

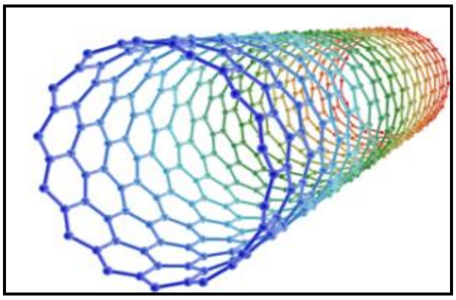


Figure 1.6 Example of Carbon Nanotube.
Source : (IDTechEx, n.d.)

Buckyball is like a dome built by Buckminster Fuller. Spherical carbon molecules were observed by Richard Smalley and Harold Kroto with the carbon spark discharge method and with their observations they won the 1996 Nobel Prize for Chemistry (Wolf & Medikonda, 2012).

It was discovered experimentally for the first time by Iijima in 1991 that carbon could form a tube-shaped structure. The tube obtained by "arc-discharge" evaporation method of graphite is a structure formed by rolling of the graphite sheet by cylinder shape. There are several different methods applied to produce carbon nanotubes. These methods are called as "arc method", "laser method" and "chemical vaporization method" (Erkoç, 2014b).

CHAPTER 2

MILITARY TECHNOLOGY TRENDS, CHANGING CHARACTERISTICS OF WAR, MILITARY APPLICATIONS OF NANOTECHNOLOGY, NATIONAL DEFENSE STRATEGY AND PLANNING OF TURKEY

Along with the developing technology, it is seen that there are major changes in war as well as in every other area. As a result of technological developments, the complexity of the theatre of war increased each day. When wars are analyzed from past to present, it can be seen that time, place, vehicles, weapons and equipments are changing continuously at a considerable rate. In addition, instead of classical wars, a new form of war has emerged currently, in which warfare are often dominated by irregularities. There is a trend towards a war environment where weapons, vehicles and equipment that have never been used before are exercised with conventional systems. However, it is also very difficult to predict the methods used in today's wars.

In this chapter, military dimension of nanotechnology and types of technologies that are being used in the military are examined. Section 2.1 focuses on military technology trends, foresight for environment and structure of the war in the future. In this sense, generations of wars, classifications of wars and nanotechnology applications used in military subjects are viewed. In Section 2.2, changes in nanotechnology in the future and the effects of these changes on war have been examined. In Section 2.3, The situation of the Turkish defense industry has been revealed. Historical development of the Turkish defense industry, Turkish defense industry’s market size, organizations/companies/institutions etc. have been mentioned. Finally, in Section 2.4, National Defense Strategy and Planning of Turkey is explained briefly.

2.1 Military Technology Trends and Changing Characteristics of War

The changing characteristics of warfare have been discussed in detail by (Burmaoglu & Sarıtas, 2016). They discussed how the motivations, shapes and sizes of wars have changed drastically over time. A number of definitions have been provided in the literature from Clausewitz (1968) to a more recent one by Kaldor (2010). The main observation is that whereas the broad conception of war, 'violence' has remained the same across time, the 'means' and 'ends' of wars have been fundamentally changed. These changes are mainly due to the transformations in Social, Technological, Economic, Environmental, Political and Value (STEEPV) systems in wider contexts as well as in concepts and technologies used in wars. Across the three generations of warfare mentioned with the move from 'tactics of line and column' to 'artillery' and 'blitzerkrieg' (Lind et al., 1989), war concepts and technologies have been the main distinguishing factors.

Within the scope of these changes, the warfare in the future will be characterized by the increasing reliance on the effective special forces, wars in urban areas, use of air defense and missile units as well as increasing instances of cyber war, hybrid wars, and use of robots, unmanned air vehicles, mass destruction weapons and space usage. In order to address these new challenges, countries should make use of high-technology equipment and applications, where nanotechnology is expected to play a crucial part, for instance for the production of lightweight and strong materials for multiple purposes from uniforms to armors.

The September 11, 2001, attack on the United States bears the characteristic of the new era. Nowadays, conflicts in various parts of the world give information about the new form of the war. Regarding this issue, according to the US National Defense Strategy (NDS) Document, published in 2005; "The military superiority of the USA has distracted its enemies from traditional methods. The way to fight with asymmetric methods has been chosen".

In this document, threats were classified as Traditional, Irregular, Catastrophic, and Destructive. The Traditional challenges are posed by states employing recognized military capabilities and forces in well-understood forms of military competition and conflict. Irregular challenges come from those employing “unconventional” methods to counter the traditional advantages of stronger opponents. Catastrophic challenges involve the acqusition, possession and use of weapons of mass destruction (WMD) or methods producing WMD-like effects. Disruptive challenges may come from adversaries who develop and use breakthrough technologies negating current US advantages in key operational domains.

The same situation can be seen in the struggle of Turkey with terrorist organizations. Features such as suicide attacks, assaulting with explosive devices, hand-made explosives, using explosives in large amount in attacks, and variability in the nature of the targets reveal that wars are planned in the new period without any rules and with uncertain boundaries. It is also seen that the character of the war is changing day by day. The wars in the world have been examined and various classifications have been made by many researchers.

In this context, Lind (2004) historically divided the wars into categories. Lind et al., (1989) developed the framework of the first three generations during the 1980s and published the Marine Corps Gazette in 1989: “The Changing Face of War: Into the Fourth Generation.” Today's wars are defined as the Fourth Generation War. The mentioned generations of wars according to Lind (2004) are shown at Table 2.1

Table 2.1 The Generations of Wars

Period	Explanation	Prominent Feature of the Period
The First Generation Warfare	From 1648 to 1860:The First Generation of Modern War. Previously, many different entities had fought like families, tribes, religions, cities, business enterprises etc. Wars were formal and the warfare was orderly. Distinguished features of "military" from "civilian" are uniforms, saluting, careful gradations or rank. Later around the middle of the 19th century, the battlefield of order began to break down. The problem ever since has been a growing contradiction between the military culture and the increasing disorderliness of the warfare.	Line and column tactics Culture of order
The Second Generation Warfare	Developed by the French Army during and after World War I. Firepower is outstanding feature, most of which was indirect artillery fire. The goal was attrition, and the doctrine was summed up by the French as, "The artillery conquers, the infantry occupies." Centrally-controlled firepower was carefully synchronized, The commander was like a conductor of an orchestra. Preserved the culture of order. The focus was inward on rules, processes and procedures. Obedience was more important than initiative Discipline was top-down and imposed.	French Army Fire power Attrition Obedience Discipline World War I
The Third Generation Warfare	Developed by the German Army. Tactically, in the attack a Third Generation military seeks to get into the enemy's rear and collapse him from the rear forward: instead of "close with and destroy," The motto is "bypass and collapse." In the defense, it attempts to draw the enemy in, then cut him off. War ceases to be a shoving contest, where forces attempt to hold or advance a "line;" The military culture and tactics were changed. Orders themselves specify the result to be achieved, but never the method ("Auftragstaktik").	German Army Blitzkrieg Surprise&mood Non-linear Initiative World War II Self-discipline, not imposed discipline

Table 2.1 (cont'd)

Period	Explanation	Prominent Feature of the Period
The Fourth Generation Warfare	The state loses its monopoly on war. Actors are non-state opponents such as Al-Qaeda, Hamas, Hezbollah, Iraq Sham Islamic State (ISIS), PKK/PYD and the FARC. Fourth Generation war is also marked by a return to a world of cultures, not merely states, in conflict. This generation has emerged as a result of powerful states attempts to keep relatively weak countries under their control after the Cold War Era. It is seen in this period that weaker parties use asymmetric methods of warfare against powerful states.	Enemy is non-state opponents Asymmetric methods of warfare A kind of attack that it's time, place and method is indeterminate

Source : Prepared by using (Lind, 2004)'s article.

Vietnam, Afghanistan, Iraq and Syria wars are good examples for the fourth generation. The Fourth Generation War is defined as conflicts involving the elements listed as complex and long-running, using terrorist tactics, non-national or exceeding the national borders, directly rapes the enemy's culture, as it is in the psychological warfare, which is carried out in great detail and particularly manipulating the media, using all current political, economic, social and military networks, including the all actors of the networks. The war takes place in the form of low-intensity conflicts by using these methods or other new methods never used before (Lind, 2004).

Regarding the future, (Lind et al., 1989) and Hammes (2005) propose a 'Fourth Generation Warfare', as mentioned above, which can be seen as a twilight zone- between war and peace, between civilian and military, between tactics and strategy. Future of warfare is assumed by Hoffman (2006) as a world of asymmetric and ethnopolitical warfare in which machetes and Microsoft merge, and apocalyptic extremes wearing Reeboks and Ray Bans dream of acquiring mass destruction. In addition these adversaries will not remain low-tech. Instead opponents will be capable of what could be called "advanced irregular warfare", with access to encrypted command systems, manportable air defense missiles, and other modern lethal systems. They will not need formal networks and have cellular structures with greater autonomy. In brief, Hoffman (2006) proposed that new kind of war may be called as 'complex irregular warfare' of which organization is very similar with distributed network structures.

Irregular warfare is defined with another term as 'asymmetric warfare'. In the cases, where the opponent party is not a nation and their capabilities are limited, an asymmetry emerged between the sides involved. Due to this characteristic, this phenomenon has been called as "asymmetric warfare" (Grange, 2000), which is described by Arreguin-Toft (2001) as how the weak win wars. Due to the fact that the opponents are not organized as a formal operational forces they may be distributed in largely populated urban areas or rural areas with difficult geographical conditions. This new asymmetric war context brings additional demand for increased flexibility, mobility and networking of smaller and more distributed forces.

There is a greater demand for the seamless flow and diffusion of information between military units and other actors involved in wars. This vast amount of information naturally requires ‘computerization’ and a ‘network structure’ for the communication with the soldiers in the theatre and dissemination of information to wider public.

Although the war phase is currently called the fourth generation, the new generations of wars will be seen in the future. It is possible to say that by looking at the past. While in the first three generations the country's armies were fighting with each other, in the fourth generation war one of the parties has become a non-state organization. **Maybe the fifth generation war will take place entirely among non-state organizations or It could be in the form of a war of non-state organizations supported by the states.**

Regarding this issue, the changes in the war is shown in Table 2.2 through the phases defined in different ways. According to this, wars are categorized as phases different from the periods or generations. Although the researchers give different names to this phase, the fact that they are trying to be explained with these theories is the birth of the war phenomenon and the development in the history of humanity.

Toffler used "wave" for phases, Hanle used the word "period", Van Creveld called it "age", and Lind et al. used "generation" term. In parallel with social and technological developments, many significant changes took place in the last three hundred and fifty years in terms of the sides of war, its objectives, the warfare, and strategies. Now the war has emerged from the monopoly of the state and transformed into processes in which non-state actors are involved (Gürcan, 2011).

Table 2.2 Classification of Wars As Periods (Gürcan, 2011)

Theorists	1.Stage	2.Stage	3. Stage	4. Stage	5. Stage
Lind, Nightengale, Schmitt, Sutton (1989)	Before Nation-state wars	1.Generation Classic wars (1648- 1830) Peak: Napoleonic Wars	2.Generation Overall Industrial Wars (1830-1918) Peak: World War I	3.Generation Maneuver Wars (1918-1948) Peak: 1991 The Gulf War	4.Generation derivatives of unconventional Warfare (from 1948 to today, especially after 9/11) Peak: Iraq and Afghanistan war
Martin Van Creveld (1991)	Tool age	Machine age		Systems age	Automation age
D.J. Hanle (1989)	Medieval Age (Physicsal skills)	Classical Period (group skills)	Early Modern Period (technical skills)	Late Modern Period (management and administration skills)	Nuclear Period (social skills)
Toffler (1993)	First Wave Agriculture society	Second Wave Industry Society		Third Wave Information Society	
Arquilla and Rondfelt (2000)	Sword Period	Mass and Industrial Wars Period		The Maneuver Wars Period	Conflicts resembling warfare derived from each other Period
Qiao Liang and Wang Xiangsui	Limited Medieval Wars	Limited empires and nation-states wars (Peak 1991 The Gulf War and Ground-air Combat Doctrine)			Unlimited post-modern wars

In relation to the recent wars, unlike Lind's classification, (Hoffman, 2007) introduced a new term: "hybrid war". Accordingly, this type uses multiple war types simultaneously in a way that it will best suit the conditions. Hybrid war means the idea of using all forms of attacks against the enemy in order to get the superiorty. Israeli-Hezbollah war in 2006 is one of the most important example of hybrid war. Hezbollah militants have learned both traditional and unconventional war techniques and have applied them in the same area of operations.

According to the experiences of war in Afghanistan, Iraq, Kosovo and Syria in the last fifteen years, it can be said that wars will be much more complex in the future and that those with high technology will put pressure on the enemy. Therefore, in recent years, theories and concepts such as an impact-based approach, a comprehensive approach, hybrid warfare, cyber threats and multiple futures have been put forward to understand the nature of war. These concepts show that a new form of war has begun to emerge, with unknown boundaries, unknown methods, and unknown scope, rather than the traditional battlefield.

At this point, Turkey's fight against terrorism has revealed crucial data for the future of the warfare. Terrorists, in the urban warfare, can delay the progress of the units with a sniper weapon for a long time, avoiding the close-contact. It provides the opportunity to conceal and cover mostly residential scene makes it difficult to identify the terrorists. Hand-made explosives used by terrorists in large numbers cause increase in casualties. In addition to that, detonating the explosives they placed in the buildings or roads, terrorists can cause more damage to the soldiers. They can restrict the movement of armored vehicles by using rocket launchers and anti-tank weapons that they have in various ways. In order to neutralize the elements that the terrorist has taken advantage of, detecting and neutralizing them from the air has come to the forefront in the urban warfare. It has become a great risk to put troops in narrow streets and between buildings where land vehicles can not enter. In such places, the insertion of troops into the territory appears to be the last movement style to be considered.

Prior to this, it is necessary to direct the fire support units, helicopters, aircrafts, armed Unmanned Aerial Vehicle (UAV)s and drones to the specified targets. At the same time all kinds of tools, weapons, equipment and materials used in the warfare should be used at night as it is used in daytime. However, by using these methods, armies can be successful in the urban warfare in today's conditions. In this way, it is very important to have weapons, vehicles and equipments that use high technology primarily to get out of a war environment with minimum loss and successfully.

Likewise, it sets out important aspects of the future warfare characteristics where Turkey launched its operations on August 24, 2017, named Euphrates Shield Operation lasted six months and Olive Branch Operation lasted two months against terrorist organizations living at the northern part of Syria. In the new era, wars will be carried out with more different elements. As mentioned in the urban warfare, technology is used extensively in these operations. It has become possible to see civilian companies operating in the field of logistics, telecommunication and communication, technical service and spare parts, and factory workers who produce military vehicles and materials, while military units have previously only been involved in the warfare. In fact, this type of warfare is a laboratory for manufacturers and companies. The manufacturer has the opportunity to experiment with the product and to get immediate feedback.

Among the military systems that use technology extensively in these operations are; UAV, armed UAV, Manned Surveillance Aircraft System, fighter aircrafts, helicopters, mortar/howitzer detection radar, armored vehicle systems, operation center, smart phones, internet, air and misilse defense systems, new generation cannons, communication and satellite systems.

In addition, the development of technology and its use in warfare also greatly increases the cost of war. As the operation progresses, the base stations to be set up for communication and internet, tow, stinger, howitzer, anti-tank munitions, defective armored vehicles, the precision and classical ammunition of aircrafts and personnel involved in warfare increase the cost very much. When a calculation is made considering that the average price of an artillery shell is 1.000 USA Dollars; during the operation, more than a total of 126 million USA Dollars is spent on only the artillery shell (assuming an average of 700 artillery shells have been thrown daily). This amount is just related to the artillery branch. If one consider the other units' expenses, the cost of the war will be very large amounts.

Also in the scope of the changes that will be seen in the future warfare; the issues such as increasing efficiency of special forces, use of artificial intelligence, UAV and WMD, the need for fighting in settlements, the use of air defense and missile units, robots, cyber warfare etc. are considered to be in advanced. The fact that such technology-intensive wars also indicate that in the future, wars will take place in space. Frankly speaking, it is very important to have high technology to compete with other countries in these matters.

In addition to the aforementioned issues, military losses in the wars of the last fifty years have emerged as an important problem to be solved for the armies of the future. Casualities and injuries are seen as a factor affecting the result of the war. The US casualties in Iraq and Afghanistan wars are shown in Table 2.3. In this context, Turkish Prime Minister Binali YILDIRIM declared on March 30, 2017 that a total of 216 days in the Euphrates Shield Operation of Turkey, while 67 Turkish soldiers were martyred, 245 soldiers were wounded and became veterans. It was learned that the Free Syrian Army (FSA) units that carried out the operation together with the TAF gave about 600 martyrs during the operation ("Milliyet," n.d.-a). İsmet YILMAZ, Minister of National Defense, declared in 2014 that about thirteen thousand people (5.347 soldiers) had been killed in the fight against terrorism in Turkey.

Table 2.3 The US Casualties at Last Thirteen Years

War	Casualities	Injuries
Iraq War	4523	32.223
Afghanistan War (Between 2001-2017)	2403	17.674

Source : ("iCasualties," n.d.).

The matter of casualities and/or injuries of soldiers in warfare stands as an important problem to be solved. The death or injury of a warrior negatively affects the psychology, morale and motivation of other warriors. The issue of the warriors being out of war affects directly the result of the war. There is also a need for systems that can perform the required tasks under difficult terrain and climatic conditions in hazardous areas in a warfare. The need for the production of high-tech systems/platforms, that can be used in the field of personnel, intelligence, operations and logistics, which are expected to replace soldiers in battlefield, is now felt more and more. As a result of these needs, firms, institutions and universities have begun to work intensively on this field. Consequently, armies have started to use robots in battlefield for various purposes in recent years. Therefore, these robots will be able to overcome the shortcomings mentioned. Already today, various robots are used effectively in fields such as medicine, construction, transportation, food and agriculture.

There are pioneer institutions/companies worldwide in the production of robots that are planned to be used for military purposes like Boston Dynamics Company from USA, Festo Company from Germany and Carnegie Mellon University from USA.

Boston Dynamics, which was bought by Google in 2013, has produced many kinds of robots. They built advanced robots with remarkable behavior: mobility, agility, dexterity and speed. It is possible to see the properties of the produced robots in Table 2.4 (Boston, n.d.).

Table 2.4 The Properties of The Robots Produced by Boston Dynamics

Name	Features	Explanation
Spot Mini	A small four-legged robot that comfortably fits in an office or home, weighs 25 kg. SpotMini is all-electric and can go for about 90 minutes on a charge, depending on what it is doing. It is a nimble robot that handles objects, climbs stairs.	SpotMini is the quietest robot that this company has built.
Atlas	The world's most dynamic humanoid, uses balance and whole-body skills to achieve two-handed mobile manipulation.	Atlas keeps its balance when jostled or pushed and can get up if it tips over.

Table 2.4 (cont'd)

Name	Features	Explanation
		Atlas keeps its balance when jostled or pushed and can get up if it tips over.
Handle	It combines wheels and legs to provide agile high-strength mobile manipulation. Handle can pick up heavy loads while occupying a small footprint, allowing it to maneuver in tight spaces.	All of Handle's joints are coordinated to deliver high-performance mobile manipulation.
Spot	It takes the lessons learned developing BigDog, Cheetah and LS3, and rolls them into a quiet four-legged robot with extraordinary rough terrain mobility and super-human stability.	It carries a 23 kg payload and operates for 45 minutes on a battery charge.
LS3	It was designed to go anywhere Marines and soldiers go on foot, helping carry their load, carries 182 kg of gear and enough fuel for a 32 km mission lasting 24 hours, automatically follows its leader using computer vision, so it does not need a dedicated driver, travels to designated locations using terrain sensing, obstacle avoidance&GPS.	LS3 was funded by DARPA and the US Marine Corps. Boston Dynamics assembled an extraordinary team to develop the LS3, including engineers and scientists from Boston Dynamics, Carnegie Mellon, the Jet Propulsion Laboratory, Bell Helicopter, AAI Corporation, and Woodward HRT.

Table 2.4 (cont'd)

Name	Features	Explanation
RHex	A six-legged robot with remarkable mobility on rough terrain. Independently controlled legs produce specialized gaits that propel it over rough terrain with minimal operator input, traverses rock fields, mud, sand, vegetation, railroad tracks, telephone poles, and stairways.	RHex's remarkable terrain capabilities have been validated in government-run independent testing. It was developed with funds from DARPA and the US Army Rapid Equipping Force.
WildCat	It is the fastest free running quadruped robot in the World, running at 32 km/h. The previous record was 21 km/h, set in 1989 at MIT.	WildCat development was funded by DARPA's Maximum Mobility and Manipulation program.
BigDog	It has four legs that are articulated like an animal's, with compliant elements to absorb shock and recycle energy from one step to the next. BigDog is the size of a large dog or small mule. BigDog runs at 10 kmh, climbs slopes up to 35 degrees, walks across rubble, climbs muddy hiking trails, walks in snow and water, and carries up to 150 kg loads.	Development of the original BigDog robot was funded by The Defense Advanced Research Projects Agency (DARPA).

The Festo company from Germany has produced the Bionic Kangaroo in 2014, which can move on two legs. With the BionicKangaroo, Festo has technologically reproduced the unique way a kangaroo moves. Like its natural model, it can recover the energy when jumping, store it and efficiently use it for the next jump ("Festo Company," n.d.).

Carnegie Mellon University's latest robot is called Snake Monster, however, with six legs, it looks more like an insect than a snake. DARPA sponsored this work through its Maximum Mobility and Manipulation (M3) program, which focuses on ways to design and build robots more rapidly and enhance their ability to manipulate objects and move in natural environments ("Carnegie Mellon University," n.d.).

These robots, mentioned above briefly, were produced with the foreseeable or anticipated needs of the battlefield of the future. Many of the projects were sponsored by DARPA or other defense-related public institutions. It would be beneficial to have more similar projects funded by public for our country. In addition to producing robots for military purposes, manufacturing robots for civilian purposes has also developed in the world recently.

There were five big markets representing 75% of the total sales volume in 2015 worldwide for robot production. These were China, the Republic of Korea, Japan, the United States, and Germany. Sales volume was 70% in 2014. Since 2013, China has been the biggest robot market in the world with a continued dynamic growth. With sales of about 68,600 industrial robots in 2015 – an increase of 20% compared to 2014 - China alone surpassed Europe's total sales volume (50,100 units) ("Executive Summary World Robotics 2016 Industrial Robots," 2016).

The military applications of robotic technologies are unmanned systems, especially UAV, which have increased in usage in the last 20 years. These systems are used extensively in military operational tasks such as reconnaissance, surveillance, armed patrol, precision guided offensive, search and rescue. It is observed that the use of UAV and unmanned sea, land systems are increasingly favored by the countries. Unmanned systems have now changed the operational doctrine, strategy and tactics of the armies and security forces, and have played a decisive role in the methods of warfare. In addition, the production of unmanned systems is being carried out by more and more countries due to the ease of access to technology items, particularly ICT, and low cost of materials (Mevlütoğlu, n.d.).

So far, an evaluation has been made according to the classification of the wars, periods of the wars and estimates of future warfare conditions. Some inferences have also been made about future wars. At this point, when the military aspect of the subject is examined in the context of nanotechnology, very important issues can be reached. Moreover, nanotechnology has great effects on inter-related war strategies and sets of inter-related core skills such as protection, engagement, detection, operation, communication&info. collection for troops (Caygill et al., 2012).

According to (Kharat et al., 2006), by using nanomaterials, nanobot and nanotechnology at producing mass destruction weapons, armies would have a great power to defeat the enemy in only one war.

In this sense, several categories of potential nanotechnology applications in defense sector were identified. Analysing nanotechnology applications related to defense sector, (Kharat et al., 2006) listed nine categories: (i) Armament System, (ii) Nanorobots, (iii) Sensor and Delivery System, (iv) Space Elevators, (v) Intelligence Equipment System, (vi) Micro-electromechanical Systems (MEMS), (vii) Nano-structred Platforms, (viii) Aerodynamics and Propulsion Systems, (ix) Explosives.

In addition to this classification, some researchers evaluated that future military nanotechnology application would fall into six categories: (i) Micro-sensors, (ii) Nano-computers, (iii) Smart uniforms, (iv) Daisy cutter, (v) Super termites, and (vi) Mini atomic bombs (Kharat et al., 2006).

Lele (2009) examined nanotechnology and its applications in the field of military by looking at electronic/computer/sensors, bio-defense, marine applications, space and other defense applications, conventional weapons, ammunition, space wheather forecast.

Altmann & Gubrud (2004) stated that troops would guide missile weapons, micro-sensor network for patrols and guards with flying mini-robots and water carrier device which can collect water in any environment. Mentioned systems are equipped with the information and instructions that can be communicated with tactical command center upon protected network. Uniforms that help to jump over six-meter wall and bulletproof at the same time, can regulate the body temperature and can track necessary signals from the soldier’s body. These systems aim at increasing the durability of troops. With bio-controlling, troops can stay on the operation fields and can not feel any sleeplessness. As a result, starting from this intuition chemistry, medicine, materials science, electronics and many other disciplines will contribute to the creation of this super heroes. When examining some applications based on nano-products, it can be roughly classified as illustrated in Table 2.5.

Table 2.5 Classification of The Nanoapplications in Military Fields

Category	Applications
Soldiers	- Drug delivery systems to be able to directly intervene in situations that cause diseases and epidemics at basic level - Chemical bio-sensors - Implants help to the soldier's bodies and their ability to act - Gained invisibility feature camouflage (Cai et al., 2007) ; (Srinivas, 2017) - Ultra-strong lightweight body armor (Pinault et al., 2005) - Long lasting lithium batteries for warfare devices - Necklaces for search and rescue (war tags) (Tiwari, 2012) - Nanobots that creates themselves (Drexler, 2004)
Vehicles	- Vehicles fighting autonomous - Discovery tools in millimeters - Bio-millimetric- reliable engine and nano-coating for more powerful armor - Crash-resistant vehicles made by using carbon nanotubes - Chameleon style camouflage (Michalet et al., 2005)
Weapons	- Lighter weapons - Stronger and lighter ammunition - High energy density explosives - Harmful substances carried by nanoparticles as biological weapons
Sensors	- Stronger biological and chemical sensors - Small in size and long lasting sensors - The quantum dots instead of organic dyes used in biosensors for portable biological detection devices - Internet of Nano Things (Nayyar, Puri, & Le, 2017)
Logistics	- Nano RFID sheets for safety labeling (Verma, 2012) - Hydrogen storage systems for energy - Low cost solar cell and battery (Petersen & Egan, 2002) - Water purifier aragonite filters - Nano food

As can be seen, nanotechnology applications have potential to be explored in a wide range of military field, as well as in other fields.

2.2 Changes in NT in the Future and The Effects of These Changes on War

Bowman & Hodge (2006) consider nanotechnology as a new technological revolution and indicate that it has a potential that can help to make progress on capabilities of military, biotechnology, agriculture, medicine, materials, environment and healthcare. Globally, more than 120 corporations produced nanotechnology applications in 2002. Nowadays the number of the companies working on this field show an increase far beyond the expectations. Bowman & Hodge (2006) divided the developments in nanotechnology into categories according to three generations. With reference to this classification, first-generation nanotechnology applications are atomic force microscope, simple nano-scale components and composites. Bowman & Hodge (2006) stated that second-generation applications can be revealed within 5-15 years. First and second generation nanotechnology applications can be used for scientific tools, electronic, agricultural, nano-medicine, chemistry, cosmetic, materials, food science, environment, energy, military and security purposes. The third generation advances in nanotechnology can be contrary to the first and second generation and it is estimated to be long-time period. This stage can be considered as science fiction. As Drexler mentioned, robots that clone/copy/match themselves can be witnessed in the third-generation.

With regards to defense, potential nanotechnology applications involve enhanced sensors, power converters, nanorobotics, nanoelectronics, memory storages, propulsions and explosives. R&D studies on these topics are increasing at a rapid rate worldwide. Many programs are initiated and jointly studied by the countries and universities. Special and big budgets are allocated to development of military nanotechnology (Kharat et al., 2006).

Former Israeli Prime Minister Shimon Peres stated at the Netherlands-Israel Military Applications of NT Conference inaugurated on April 15, 2004 that:

> Nano-uniforms manufactured for American troops would be lighter than cotton, but it would protect against bullets and gas and it can regulate body temperature and make soldiers stronger. He stated that one soldier can raise 120 kg with one hand and this uniform will be ready within 3 years.

Similary, following the order of the Indian Prime Minister A.P.J. Abdul Kalam in 2004, scientists worked on ultra-small computers (nano-satellites, nano-tools, smart clothes and shoes etc.) by using nanotechnology. The Prime Minister stated that after getting success in the software industry, now India should be a leader in the nanotechnology field too. These developments have revolutionary potentials within the future combat concept (Altmann & Gubrud, 2004).

There are many applications produced for military purposes in nano-scale and nanotechnology that have big potential to be studied in a wide range in the field of military. Some features of nanotechnology applications are given at Table 2.6 comparatively that Tiwari (2012) and Wang et al., (2012) mostly mentioned. It can easily be said that nanotechnology is used widely in the context of military.

Table 2.6 Features of Nanotechnology Applications

	Subject	Features
(Tiwari, 2012)	Nanomaterials activate some functions of materials in order to make uniforms and equipment more robust and lighter.	Lightness, adaptive structures, reduced vibrations, hidden nanotechnology and filter.
	Nano-technological applications that can be used in the battlefield	Armored vehicle, Nano-fiber (Nanolif), Nano-foods, Nano-machines, Nano Energetic Materials.

Table 2.6 (cont'd)

	Subject	Features
	Future NT applications in the battlefield	Electrochromic camouflage, Fabrics, Nano sensors, Condition monitoring, War tags (by using smart nanotechnological products alloyed with RFID), Artificial muscles, Treating bone fracture without drug and gypsum for military use in terrain, Non-metal nanotechnology composite materials.
	Research areas related nanotechnology in the future	**Nanosensors**: Nano Air Vehicle (NAV) aims at an extremely small (less than 7.5 cm wing span), ultra-lightweight (less than 10 grams) air vehicle system, designed for indoor and outdoor urban military missions **Smart dust**: weighs not more than 10 grams and can carry a payload of up to 2 grams. It will help protect the lives and enhance the operational effectiveness of soldiers and first responders in case of disaster. **Nanopoisons**: NT, with its ability to trigger specific brain functions, will provide a whole new menu of poison options. As an example, The obesity poison will cause a person to eat themselves to death, and favourite the "frontal lobotomy poison," that will make a person incapable of being angry or mean.

Table 2.6 (cont'd)

	Subject	Features
	Contents of first aid kits	Nanofoods, nanodrugs, nanobandage, nanowater purifier, nanoweapon and power supply, war tags with RFID.
(Wang et al., 2012)	Properties of nano-weapons systems	System-miniaturization, Very smart weapon systems, Low cost weapon systems, Greatly enhanced performance of weapons and equipments, Enhanced power of weapons and ammunition types.
	Nano-material applications in the context of military modernization	Stealth Materials, The usage of protective cover, Improving the Application Performance of Military Energy, Military antibacterial materials, Applications of Nano-weapons in military modernization, Distributed battlefield sensor networks, Toxic Chemical Warfare Agents Alarm Sensor. High-performance identification friend or foe, The use of nanotechnology in the production of micro-bionic device (Sparrow satellites, mosquitoes missiles, flies aircrafts and ants soldiers.)

Source: (Wang et al., 2012) and (Tiwari, 2012).

Most of the features mentioned in Table 2.6 are not widespread at this time. But in order to be ahead in the future, it is necessary to design and produce new tools today. By inventing new materials, it will be possible to stay in the race.

Some of the applications given in Table 2.7 may sound like dreamwork to readers, but as Einstein said “imagination is more important than knowledge” (Viereck, 1929). In the more near-term, nanotechnology is expected to be used for military purposes and also for all activities such as advanced computers, clothes for warfare and tools.

Advanced computer systems can be used in controlling operation and logistics. Small and inexpensive sensor systems can be produced in large quantities. Guide systems integrated ammunition and missiles can be developed. Nano-lif composites can give support for producing non-metal weapons and ammunitions. The materials having more heat resistance will contribute to the production of more efficient motors. Some autonomous systems may be in smaller size. Furthermore, some systems can be used as monitoring, communication, extended senses and drug delivery.

Countries are paying attention for nanotechnologies not only for peacefully purposes, but also for the preparation of war in every field of technology such as metallurgy, explosives, internal combustion and aviation. Many country’s armies currently aim to achive nanotechnology-based armament.

Nanotechnologies may play an unpleasant role here in the development of different kinds of weapons. The most dangerous applications of nanotechnology in the field of military are nano-bombs. Nano weapons and weapon systems have important advantages such as ultra-miniaturization, intelligence and high performance. Nanotechnological weapon systems will lead to significant changes in a number of areas such as operational command and combat models.

Nano-enabled smart bullets, bombs and missiles are already under production. Self-replicating viruses may give lethal damage to a city, country or a community. Armies are trying to learn the way of using nanobots and nanotechnology for producing mass destruction weapons all over the world. Powerful armies are facing with danger of extinction without a fight.

The soldiers cannot know any time when they have poisoned by nano-poison. Nanoparticles can harm lungs massively. Particles come up from diesel machines, power plants and waste incinerator damage to the lungs of people significantly. Nano-materials can be used for the production of nanorobots, explosives, propellants, MEMS/NEMS, smart clothing systems, smart materials, aerodynamics and propulsion, sensors and power converters. Use of nanotechnology in the future is expected to increase exponentially in the field of microsensor, nanocomputer, smart clothings, daisy cutter, mini atomic bombs and super termites (Kharat et al., 2006).

If nanocomputers have artificial intelligence features as well as mechanical abilities, flying robot soldiers can be produced easily which can fly hundreds of kilometers per hour (Hall, 2005). In this context IBM's computer named "Deep Blue" has defeated the world chess champion Gary Kasparov in 1997. Similarly at famous competition program, Jeopardy, computer Watson has defeated all competitors in 2011. And lastly AlphaGo developed by Google has defeated the champion of GO. These results indicate that mentioned technological developments are not fiction.

Tiwari (2012) mentioned about nanotechnology for in-capacitative agents as shown in Table 2.7. This table describes the importance of nanotechnology for the future. In the future, neutralizing individuals will come out as a crucial issue instead of killing them.

Nanotechnology science and research have been given importance by the governments and other organizations currently worldwide. Metallurgy, explosives, internal combustion, aviation, electronics and nuclear energy issues are given importance by countries not only for peaceful purposes but also for war preparation.

Table 2.7 Nanotechnology For in-Capacitative Agents (Tiwari, 2012)

Tool	Exlanation
Nano Mind Erasers	Neutralizing a person’s memory can often be a more powerful defense than killing them.
Nano Needles	Invisible to the human eye, nano diameter needles will be shot like clusters of bullets from great distances to “pin” people to a wall or freeze their physicsal movement. Nano needles, because of their tiny diameter, will be the ultimate non-lethal weapon, leaving no visible wounds and causing no permanent damage. This may be used as arrest intruder without harming or killing him.
Water bullets	As a different kind of non-lethal weapon, self-contained water balls, formed around an elevated surface tension containment system, will be used to knock people down, and temporarily rendering them harmless.
Desynchronized Energy Fields	Binary power, created by the intersection of two otherwise harmless beams, has the ability to disrupt the energy fields in an individual. A person with desynchronized energy fields will feel extremely fatigued, and pushed to a more extreme level, will drop unconsciously to the ground.

Nanotechnology has become an interdisciplinary field where private, public and other organizations attach much importance to it. While the budget allocated to the nanotechnology R&D worldwide was 12.4 billion dollars in 2006, this figure reached to the level of trillions of dollars after 2010's. The investments show us the importance of nanotechnology. Therefore, many countries have begun to establish nanotechnology R&D institutions (Whitman, 2007).

According to Wang et al., (2012), in the future, wars between countries will be mainly in the form of science and technology rather than being like a conventional war. Nanotechnology is expected to play an important role in this new way of competition. Nanotechnology will certainly affect military trends in the future. In particular, revolutionary changes are expected to be seen in the structure of wars, such as the new form of access to information (satellites, reconnaissance aircraft, the usage of high-tech weapons), the new connotations of the human/machine combination, and the protection and invisibility of the operational command platform. In the future warfare, giant and miniature weapon systems are expected to operate simultaneously. They will accomplish very important tasks together. It will be possible to witness that the small systems and microns are defeating the giants, in other words, ants eat elephants.

Besides a number of favorable aspects of nanotechnologies, there is still not sufficient discussion and research about their side effects. Various units are searching military applications of nanotechnology in the world and their impacts. For example, Military Nanotechnology Institute, a major research center in the US, undertakes research for understanding nanotechnology impacts and protecting soldiers by reducing their vulnerabilities. If nanotechnologies will be developed in a number of application areas and its use is not regulated, they have unexpected negative consequences (Shipbaugh, 2006).

With regards to warfare, Altmann & Gubrud (2004) describe what needs to be done to eliminate the negative aspects while taking the advantages of the positive aspects of converging technologies, including nanotechnology, biotechnology, information technology and cognitive technology:

- Technologies can be approved by reviewing international humanitarian laws with controlling of existing weapons and disarmament agreements. Especially biological weapons agreement could be strengthened with an additional authentication protocol.

- All kinds of space weapons should be banned. Special rules can be determined for carriers and small satellites used as unarmed.

- Autonomous killer robots should be banned. The decision of hitting a target must be given by a human being.

- Except for medical purposes, body implants should be used for ten-year renewable term.

It may also be useful to establish a nanotechnology hub or nanotechnology network center at international level, where participation is mandatory, to monitor and control the development of nanotechnology worldwide.

In fact, the use of nanotechnology is more complicated issue than the use of nuclear weapons. It requires more analysis and consideration to be dedicated on it (Shipbaugh, 2006).

It is envisaged to replace the currently used systems and subsystems with nanotechnology in the coming years. In addition to the positive aspects of nanotechnology, there is not much information about the side effects or negative aspects of nanotechnology yet.

There are many lessons to take out from the wars, but two of them are very important related to recent wars. Two important strategic lessons have been drawn from the wars of Iraq, Yugoslavia and Afghanistan, where the superiority of the Western armies is seen. Firstly a ridiculous situation arises when the effects of the cruise missiles are compared with the costs of these missiles. Because there is the possibility of destroying some targets by spending less. Secondly the use of weapons with less radioactivity is acceptable to both military and civilian authorities (Gsponer, 2002). It can be said that the use of nanotechnology in the 4th Generation Nuclear Weapons and in the weapon systems planned for battlefield use will be appropriate in the light of the principles determined above.

Altmann (2008) states that nanotechnology is a new technological revolution. It describes materials and systems that are getting smaller and more powerful. Some scientists evaluate nanotechnology within converging technologies. According to Altmann (2008) a few general observations can be done related to nanotechnology. Nanotechnology will allow many hostile systems and interactions that are characterized by small size, low cost and easy availability. Stability becomes more difficult to maintain if the number of actors increases. With respect to nuclear and in particular to conventional war, one big problem is whether one state could successfully deter or defend against a coalition of attackers. Complexity strongly tends to increase, and stability would become questionable, if nanotechnology would put dangerous weapons not only into the hands of states, but even into the hands of non-state actors. Second issue is that in arms control verification becomes more difficult if the size of the treaty-limited items decreases, and if their number increases. All together, nanotechnology, applied for weapons and hostile uses, will greatly increase complexity with regard to international security. Altmann (2008) explained military usage of nanotechnology like that:

> Nanotechnology could be used by armed forces in practically all their activities. Small but powerful computers will be built into arms, war dresses, vehicles etc. Larger computing systems will be applied for war management and logistics, increasingly taking over tasks that used to be reserved for humans. Small, cheap sensor systems could be found in high numbers. Small missiles will become possible, even small munitions could be equipped with guidance systems. Nano-fiber composites could allow metal-free small arms and ammunition. Similar materials will make vehicles and aircraft lighter and more agile, more heat-resistant materials will lead to higher efficiency in engines. In all media, autonomous vehicles will become possible, to be used for reconnaissance and communication as well as for combat. Some autonomous systems may have very small size—centimetres, later millimeters, and even below. NT could be used for implants in soldiers' bodies by providing neuron contact, bio-compatible materials, small computers and power supplies. Such internal systems could be used for monitoring, communication, expanded senses, or drug release. On the other hand, sensors and filtering/neutralizing materials based on nanotechnology could be used for better protection against chemical or biological agents.

In fact, nanotechnology can be used in every field for military purposes. Actually it can be dual-use. It is important to ensure that these technology-intensive products do not fall into the hands of bad people. It is necessary to keep these technological materials under control. The party holding these materials is advantageous if these conditions are fulfilled.

There is an idea that nanotechnological weapons may be bacteria-like replicators, fed from the soil in the enemy's borders, and eventually transformed into soil or it can realize the desired destructive effect. While smart bombs and missiles are present today, smart bullets can be produced through nanotechnology. If nanocomputers have artificial intelligence features as well as mechanical abilities, flying robot soldiers can be produced easily which can fly hundreds of kilometers per hour. They can be virtually invisible due to the phase-sequential optical fibers. Their movements can reach a speed that the human eye can not follow or see them (Hall, 2005).

In fact, in order to prepare for war in the future, nations will only need a common nano manufacturing infrastructure. This manufacturing system can produce such robots, weapons suitable for robots and vehicles when needed. In a very urgent situation, the army can be produced within an hour. A coarse phase-sequential optical texture can focus the light to the desired target. If roofs of buildings are covered with this texture solar light collector, radar, optical camera, spot light and if enough slope is given to this system, it can be used as street lamp. So, when needed many roof of buildings are used in coordination, it may also be a laser-like anti-aircraft (Hall, 2005).

In the twentieth century, the most multiplicative factor among the causes of disasters that would happen to mankind was war. Technology has obviously contributed to the lethality of the war. The question to be asked at this point is that: Will nanotechnology make wars worse? Or will it increase the possibility of war? In the end, nano weapons can not kill more than hydrogen bombs. Moreover, since the emergence of nuclear-powered intercontinental ballistic missiles, a remarkable event has occurred. Other countries refrain from fighting against countries that have such weapons (Hall, 2005). Having such weapons comes out as a deterrent force.

The question that comes to mind in this case might be as follows. How can be the armament when nanotechnology is widely used in manufacturing systems? With the widespread use of nanotechnology, the entire country can be filled with fly-sized aircraft. In this case, it will be more difficult for criminals and/or terrorist groups to hide. Currently, unmanned aircrafts are equipped with missiles that are launched from the air. These missiles can be used to hit sensitive targets. As Tiwari (2012) mentioned, unmanned nano planes can carry needles in various species and chemical or biological agents may be given to the people at doses that are lethal, disabling, or painfully convulsive (Hall, 2005).

According to Shipbaugh (2006), the development of nanotechnology exposes a variety of possibilities for both beneficial opportunities and adverse outcomes as a result of big and small nations applying this technology to military strategies. The use of nanotechnology in war is a more complex issue than the problem of nuclear weapons use and more analysis is required on this issue. The effects of nanotechnology can arise in three different ways in future wars. Pacifism (mainly supported by defense-oriented nanotechnology), Just War (Targets benefit from offensive-defensive nanotechnology) and Realism (If the offensive nanotechnology dominates, the destructive effect is increased).

In the future, nanotechnology can be a factor that exacerbates or exterminates war, such as the role played by nuclear weapons. Nanotechnology can change the balance with technology-oriented revolution potentials in the direction of defense or offense for military forces and the battlefield.

Table 2.8 shows the uncertainties in the future use of nanotechnology for offense and defense.some evaluations can be done according to this table.

Table 2.8 The Uncertainties in The Future Use of Nanotechnology For Offense And Defense (Shipbaugh, 2006).

Defense-related Technologies Non-lethal weapons Protective materials Stimulating sensors	Incentives trend International coalition Peace
Offense-related Technologies: Distribution / Transmission platforms Lethal weapons Sensors that detect the target	Detracting / Aggravating trend International conflict War

According to Table 2.8, while defense related technologies can have consequences for reducing the risk of conflict, offensive technologies have features that can increase the risk of conflict.

2.3 The Situation of Turkish Defense İndustry

Defense industry is a group of corporations owned by private and public organizations, in particular military sectors that develop and produce all kinds of strategic and tactical attack and defense weapon systems and military equipment in the military sense (Şimşek, 1989). In this section, a brief information has been given about the companies/institutions that make up the Turkish defense industry and history of the Turkish defense industry.

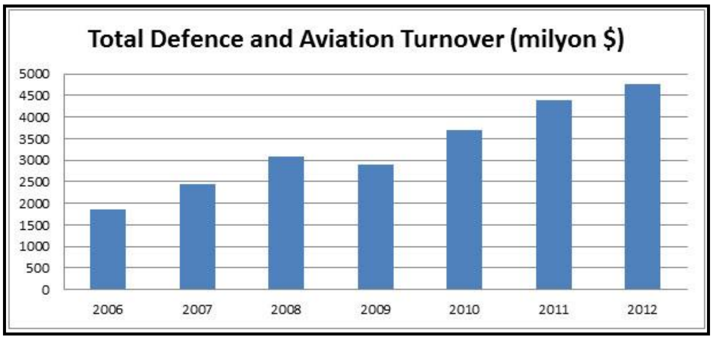
When looking at this issue primarily from the perspective of historical development; the first initiative to establish a defense industry in Turkey dates back to the period of the Ottoman Empire. Until the seventh century there was a strong defense industry but after that defense industry could not keep up with the technological developments in Europe since the 18th century and totally lost its impact starting from the World War I. Thus, there was no significant defense industry infrastructure during the first years of the Republic.

In fact, defense industry is a part of the overall industrialization and development. The government of Turkey intensely decided to support and guide defense industry during “The First Five-Year Industry Plan” period (1934-1938). After that military facilities became a part of the Machinery and Chemical Industry Corporation (MKEK), which was formed as a State Economic Enterprise in 1950. However, development of weaponry and military equipment was kept on the agenda by the Research and Development Department formed in 1954 under the Ministry of National Defense. Later on, this name was changed to the R&D and Technology Department. The importance of a strong defense industry has once again emerged in the Cyprus Operation. Turkish Armed Forces Foundation was established in 1974 and several investments, though limited, were initiated. The Foundation formed enterprises such as Aselsan, Havelsan, Aspilsan with the help of the donations. After that Undersecretariat for Defense Industries (SSM) was born in 1985 under Law No:3238. (SSB, n.d.-a). With an arrangement made in 2017, the SSM is linked to the Presidency of the Republic of Turkey. SSM has achieved great success in the field of defense industry. Later on, its name is changed as “Presidency of Defense Industry”.

As can be seen in the Table 2.9, the Turkish Defense Industry capacity has showed a significant increase in recent years. Total defence and aviation turnover representing the sector size was $ 4.756 billion in 2012 including all defense and aerospace sales, reached $ 5,076 billion by the end of 2013 according to the SSB records.

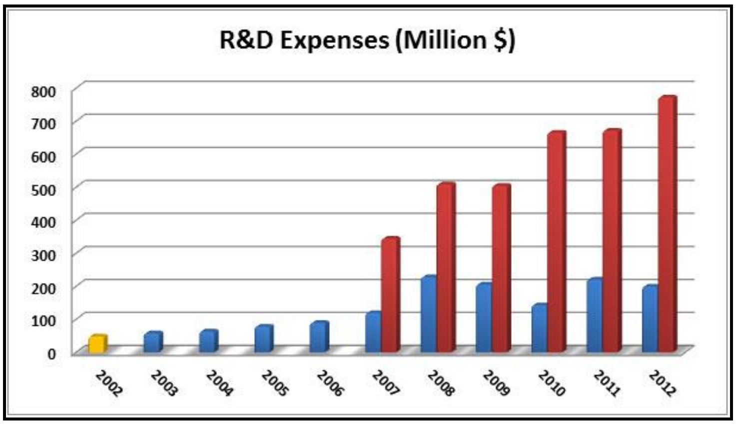
Another indicator of this issue is R&D expenses. The figures for the R&D expenditures which are the driving force of the level of design competence reached by the defense industry can be seen in the Table 2.10. Total R&D expenses was $ 772 million and R&D expenses from equity was $ 200 million in 2012.

Table 2.9 Total Defence And Aviation Turnover



Source: (SSB, n.d.-c).

Table 2.10 Total R&D Expenses



Sources: (SSB, n.d.-c).

The Turkish defense industry consists of public and private sector organizations. The public sector is composed of Supply Maintenance Centers, Shipyards, military factories, Machinery and Chemical Industry General Directorate and affiliated factory directorates. Public partnership organizations consist of the companies affiliated to the Presidency of Defense Industry (SSB) and the Turkish Armed Forces Foundation (Aselsan, TAI, Havelsan, Roketsan, İşbir, Aspilsan). The private sector corporations, which are divided into two group according to the capital structures, consist of firms with domestic affiliates and foreign partners having part of the capital. The public institutions of the sector are mainly established to meet the needs of the Turkish Armed Forces (TAF). The production of goods and services for civil use is limited. The level of the defense sector's ability to respond to TAF needs and the export capacity differ according to the sub-sectors. The level of national capabilities on land and sea platform production technologies is relatively advanced to the areas of guided weapons and aircraft (SSB, 2009).

Companies operating in the defense industry can be classified according to various criteria. Defense industry firms are divided into three groups according to their role in the production process: Main contractor, sub-contractor and parts / material manufacturer. There are five different categories according to ownership status of the companies as military based, foundation based, the Machinery and Chemical Industry Corporation (MKEK), Private sector initiatives, Associatons.

When we looked at the issue in the context of associations operating in the defense industry, various associations emerged. Defense Industry Manufacturers Association, (SaSaD) is one of them. SaSaD was established by 12 companies in 1990 with the support of Ministry of National Defense. SaSaD is the association for producers of defense systems and equipment for domestic and international markets. In January 2012 civilian aerospace manufacturers were included to the scope of the association and the name became "Defence and Aerospace Industries Manufacturers Association". As of 2017, SaSaD has 113 principal members and 75 special members in the communication network in 10 sub-sectors of defence industry: Land Platforms, Naval Platforms, Aerospace, Informatics, Electronics, Electrical Equipment, Weapons, Ammunition, Rockets and Missiles, Research, Development and Engineering, Materials, Mouldings and Parts, Uniforms – Footwear. With 3,39 Billion US Dollars of annual turnover and 817 Million US Dollars of export (2011 figures), Turkish defence industry has reached to a considerable financial size together with a high level of technology (SaSaD, n.d.).

Defense and Aerospace Industry Exporters' Association (SSI) is another organization founded in 2011. Comprising a large number of sub-business segments such as defense and security systems, software, road, air, and sea vehicles and their equipment, electronic warfare systems, support systems and logistical services, R&D, engineering, and manufacturing services, the defense industry is a key strategic sector which constantly grows and bodes well for our country’s future. Having achieved a constant growth trend in the 2000s, national defense industry have had a positive performance in the past couple of years in spite of the global crisis. The turnover of companies in the defense industry market was US$ 2.319 billion while the share of Turkish suppliers providing goods for the industry was 45.2 %. The industry kept its growth momentum in 2010 as reflected by a total turnover of US$ 2.733 billion and a 52.1 % of goods used by the industry was purchased from Turkish suppliers. The national defense industry has reached the phase of development of products within the country and built significant infrastructure in terms of system integration (SSI, n.d.).

The Turkish defense industry is leaping both on the basis of products and on the basis of firm diversity. In addition to the companies engaged in production and R&D, companies providing internationally military training, procurement activities and consultancy services were established after 2010. This sector is also a new opportunity for the Turkish Defense Industry. There has been an increase in the number of firms operating in the field of military training and consulting. Iraq, Syria, Afghanistan and some African countries can be seen as an opportunity for firms offering defense training and consultancy services.

2.4 National Defense Strategy and Planning of Turkey

In this section, national defense planning of Turkey is described in the main lines briefly. Every state has to take all the essential measures against the potential threats to its security. Due to this requirement, states seek to determine the challenges and opportunities through monitoring regional and global environments and prepare national security systems.

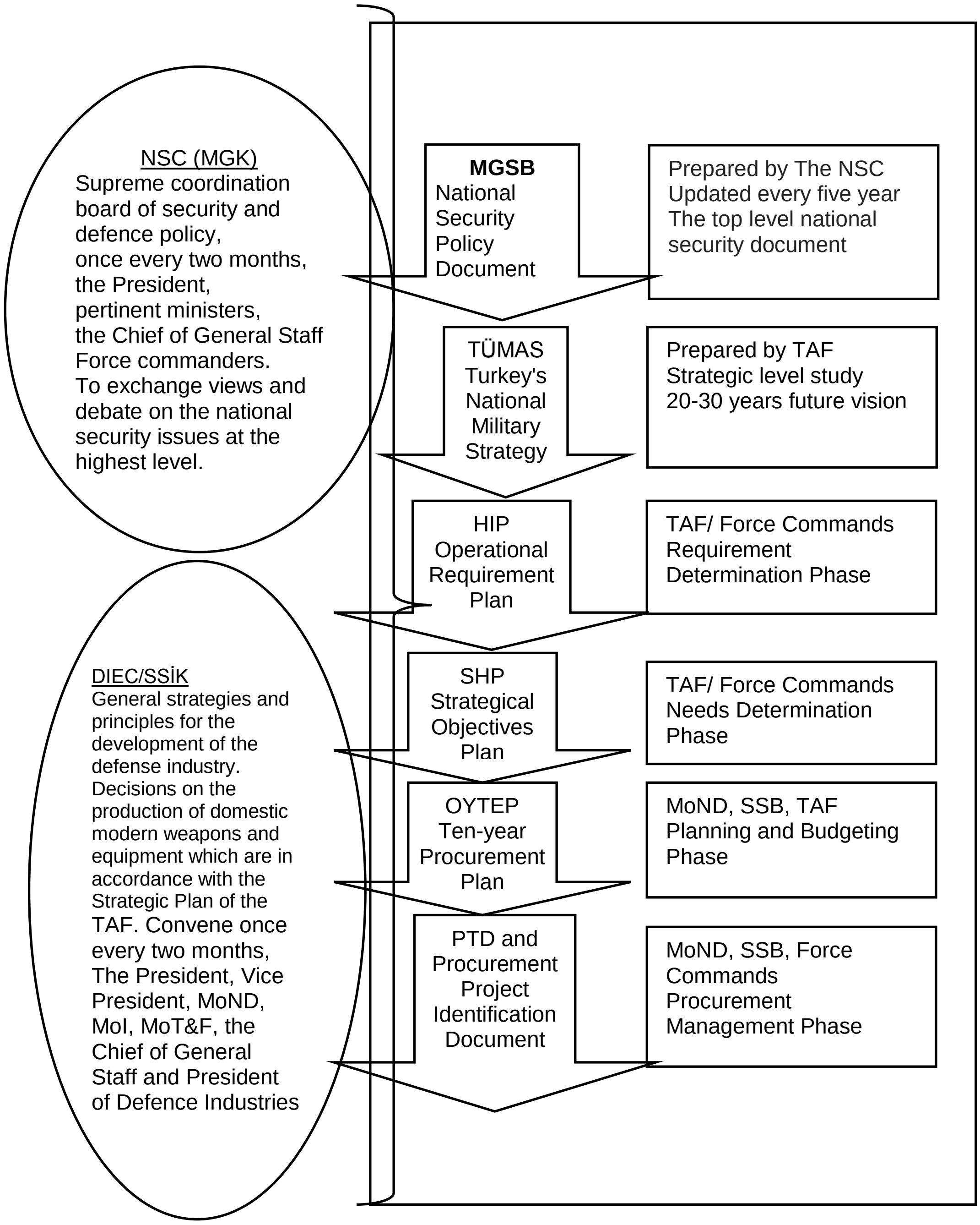
The top-down approach has been adopted in national security planning in Turkey. National defense planning is carried out by The National Security Council (NSC) at the top level in Turkey. The NSC, under the chairmanship of the President, is composed of the Deputy President, the Ministers of Justice, National Defense, the Interior and Foreign Affairs, the Commander of the Turkish Armed Forces, the Commanders of the Land, Naval&Air Forces. Depending on the agenda of Counsil, concerned ministers and individuals can also be invited to the meetings of the Council for consultations. In the absence of the President, the NSC is headed by the Deputy President. The NSC is the supreme coordination board which meets once every two months on a constitutional platform. Council meetings provide an opportunity to exchange views and debate on the national security issues at the highest level. Though it shows changes according to countries, defense planning principles basically consist of certain steps.

Starting point of defense planning activities in Turkey is the preparation of the National Security Policy Document (MGSB). Studies on the preparation of the National Security Policy Document are carried out by the Secretariat General of the NSC. MGSB is updated every five years by the Secretariat General of the NSC. Turkey's National Military Strategy (TÜMAS) document is created by Turkish Armed Forces General Staff in accordance with MGSB. This document specifies the needs, views and prospects of the TAF in the military context at strategic level.

Within the scope of 20-30 years future vision, national military objectives are determined. According to the principles of TÜMAS, each force commands prepares Operational Requirement Plan (HIP). The HIP draws the framework of operations that are foreseen (where, how, and what to do). In fact, HIP defines the systems that the force commands will need in the operation areas.

After that, Strategical Objectives Plan (SHP) is shaped in the direction of HIP. The SHP document is the basis for the Ten-Year Procurement Plan (OYTEP). OYTEP includes all systems, subsystems and services that each force command plans to procure over a ten-year period. Then prioritization is done on the issues involved in OYTEP. After that, Project Identification Document (PTD) is prepared. National Defense Planning System of Turkey is shown at Table 2.11.

Table 2.11 National Defense Planning System



The purpose of supply, number of needed units, the supply model, the technical requirements, etc. are determined in the PTD. After all these activities, the PTD is sent to the SSB and then the procurement project officially begins. The SSB works together with the requirements authority to make the necessary preparations. SSB manage the procurement process in the context of the decision of the SSİK (Defense Industry Executive Committee), via the Request for Information (RFI), the Request for Proposal (RFP) documents etc., SSB conduct contract negotiations with the company which is selected according to the decision of SSİK and then SSB performs the procurement (Mevlütoğlu, 2016).

At this stage, it is necessary to give some information about the SSIK which has an important role in the procurement process. SSİK is set to undertake decisions on the production of domestic modern weapons and equipment or, where required, through overseas procurement which are in accordance with the Strategic Plan of the TSK. It is ratified by Law No. 3238, the main decision making body of the system is the Defence Industry Executive Committee (SSIK). SSİK is chaired by the President of Turkey, the Committee consists of Vice President, the Commander of TAF, the Minister of the Interior and the Minister of National Defense, Minister of Treasury and Finance and President of Defence Industries. The Committee undertake decisions on defence industry product exports, offset, and bilateral trade. Also SSİK coordinate the defense industry and related organizations and determine the principles of the use of the Defense Industry Support Fund (SSDF). SSDF is an important resource for the realization of defense projects.

Thanks to effective coordination and collaboration in defense industry, many important projects have been completed successfully in recent years. At the same time, domestic product usage rate in defense industry is increasing day by day. Thus, external dependence of the defense industry decreases. It is obvious that by making effective and decisive defense planning, it will be possible to strengthen the defense industry and armed forces of Turkey.

CHAPTER 3

NANOTECHNOLOGY STUDIES IN TURKEY AND IN THE WORLD

Studies on nanotechnology began to increase after 1980s worldwide. After the 2000s, this tough race between the developed countries has been accelerated. With intensive investment, Japan, the EU, and the USA are the three biggest actors in NT. It is easy to see that situation by looking at the R&D investments of developed countries. Turkey has started to study more in this field since 2000s like the other developed countries. Research centers and NT departments have been opened in universities and there have been significant increases in the number of publications. More researchers have begun to work on this field. Therefore, the number of patents has also increased. Now, it is possible to say that there is a public awareness about nanotechnology.

By the way, the first international research organization located in Europe, named International Iberian Nanotechnology Laboratory (INL). That is specifically active in nanotechnology field. It was founded in Portugal in 2005 to develop nanotechnology in Portugal and to cooperate internationally with other countries. Advantages such as sufficient research budget, utilizing other centers' experiences, and benefitting from the international partners' infrastructures enabled INL to gain an outstanding status in Europe and in the world. The center is situated in the city of Braga and has more than 200 researchers, and it has four research priorities for the development of nanotechnology like that; Nanomedicine, Nanoelectronics, Nanomachine and manipulation at nano-scale and Monitoring environment, safety, foodstuff quality control. INL is important because it is the first in nanotechnology field (Statnano, n.d.-a).

In this chapter, nanotechnology studıes in Turkey and in the World are examined. Section 3.1 focuses on Nanotechnology in Developed Countries. In this sense, nanotechnology studies in USA, Germany, Japan, China, South Korea, and European Union (EU) have been viewed. The status of nanotechnology have been tried to be revealed in these countries. In Section 3.2, Nanotechnology Studies in

Turkey have been examined. Analysis was performed especially in the context of research centers and private sector studies. In Section 3.3, According to Vision-2023, Status of Nanotechnology in Turkey has been viewed. In Section 3.4 Nanotechnology Studies in the Ministry of National Defense and in the Turkish Armed Forces have been examined. Section 3.5 focuses on analysis of the nanotechnology subject of the Defense Industry Vision prepared by the SSM.

3.1 Nanotechnology in Developed Countries

Coccia et al., (2012) studied the current trends in nanotechnology research according to macro subject areas between 1996-2008 for China, Europe, Japan, South Korea, the US and Canada. As a result of this research, it has been found out that the studies of Materials Sciences are in a downward trend, whereas the studies in chemistry and medicine are significant rise. For the year 2008, it is stated that there are approximately 130 nanotechnology research centers in China, 150 in Europe, 100 in Japan. As stated in Chapter 3.2, the number of nanotechnology research centers in Turkey is far below developed countries.

Many countries, particularly the United States, China, Russia, Germany, Japan, the European Union, South Korea, Israel, Taiwan and the United Kingdom are making considerable investments in the field of nanotechnology. According to a statement made by NNI, only the US nanotechnology investment in 2015 was worth $ 1.54 billion and it was estimated that this investment amount would be around $ 100 billion worldwide for 2015. It is also expected that the mentioned investments will continue to increase rapidly in the future.

Because the coming years, as happened in the past industrial revolutions, are considered as a period in which it is expected that the developments will take place exponentially. The best example of such rapid progress is the developments experienced in mobile phones. While mobile phones become smart on the one hand, they are reduced in weight, diminished in size and made more ergonomic on the other hand. The price of it has also increased in proportion to the properties it has (Denkbaş, 2015). The more technology improves, the quality and the price of the product are increasing so much.

In this sense, the R&D expenditures (% of GDP) of some countries covering the six years from 2009 to 2014, including Turkey, are shown in Table 3.1 as an indicator for R&D activities. South Korea is the leading country in the world in shares allocated to R&D. According to Table 3.1, Japan and Germany are among the countries that have the largest share of the R&D expenditure after South Korea. It is necessary for Turkey to allocate more R&D budget to make further improvements in this area. Technologically advanced countries's R&D expenditures (% of GDP) is over 2 per cent.

Table 3.1 The R&D Expenditures (% of GDP) of Some Countries

	Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
1	South Korea	3.29	3.47	3.74	4.03	4.15	4.29
2	Japan	3.36	3.25	3.38	3.34	3.47	3.58
3	Germany	2.73	2.71	2.80	2.87	2.83	2.87
4	USA	3.82	2.74	2.76	2.70	2.73	-
5	China	1.68	1.73	1.79	1.93	2.01	2.05
6	UK	1.74	1.69	1.69	1.62	1.66	1.70
7	Russia	1.25	1.13	1.09	1.13	1.13	1.19
8	Turkey	0.85	0.84	0.86	0.92	0.94	1.01

Source : (Statnano, n.d.-b)

3.1.1 Nanotechnology Studies in the USA

The USA is one of the major countries in the world where nanotechnology studies were planned and put into practice as a government policy. It could have some indicators such as institutional structuring, opening training programs, investments etc. We can better explain this situation firstly by looking at R&D spending. The USA's R&D expenditure (% of GDP) is 2.73 for the year 2013 as shown in Table 3.1. This rate is well above the world average. For Russia this ratio is 1.13 and it is 0.94 for Turkey in 2013. It shows the importance given to R&D studies by the US.

The US Government, at its top levels, recognized nanotechnology as a very crucial field of research. For this reason, National Nanotechnology Initiative (NNI) was established in 2000. The NNI is a program to define, follow up, and invest R&D in nanotechnologies across the full range of US government agencies. This institution has quickened funding for nanotechnology R&D from about $116 million in 1997 to $961 million in 2004 with about 27% of that total allocated through the Department of Defense (DoD) (Hernandez et al., 2005). The 2019 Federal Budget provides more than $1.4 billion for the National Nanotechnology Initiative (NNI), affirming the important role of nanotechnology (NNI, n.d.).

In the context of nanotechnology research in the USA, according to the (PCAST, 2005); The National Nanotechnology Advisory Panel (NNAP) was established to coordinate these studies. As mentioned in the report:

> The National Nanotechnology Advisory Panel (NNAP) was created by the United States Congress in the 21st Century Nanotechnology 21st Research and Development Act of 2003 (P.L. 108-153), signed by President Bush on December 3, 2003. The Act required the President to establish or designate a NNAP to review the Federal nanotechnology research and development program. On July 23, 2004, President Bush formally designated the PCAST to act as the NNAP.

The organizational chart of the NNI updated in 2015 is shown in Figure 3.1. NNI is managed by National Science and Technology Council’s (NSTC) Committee on Technology (CT). Committee consists of senior executives of the units and R&D departments of the Federal Government's. Subsequently, the Nanoscale Science, Engineering and Technology (NSET) Subcommittee was established by the NSTC. The NSET Subcommittee is structured to coordinate the federal government's multi-unit nanoscale R&D programs, including the NNI.

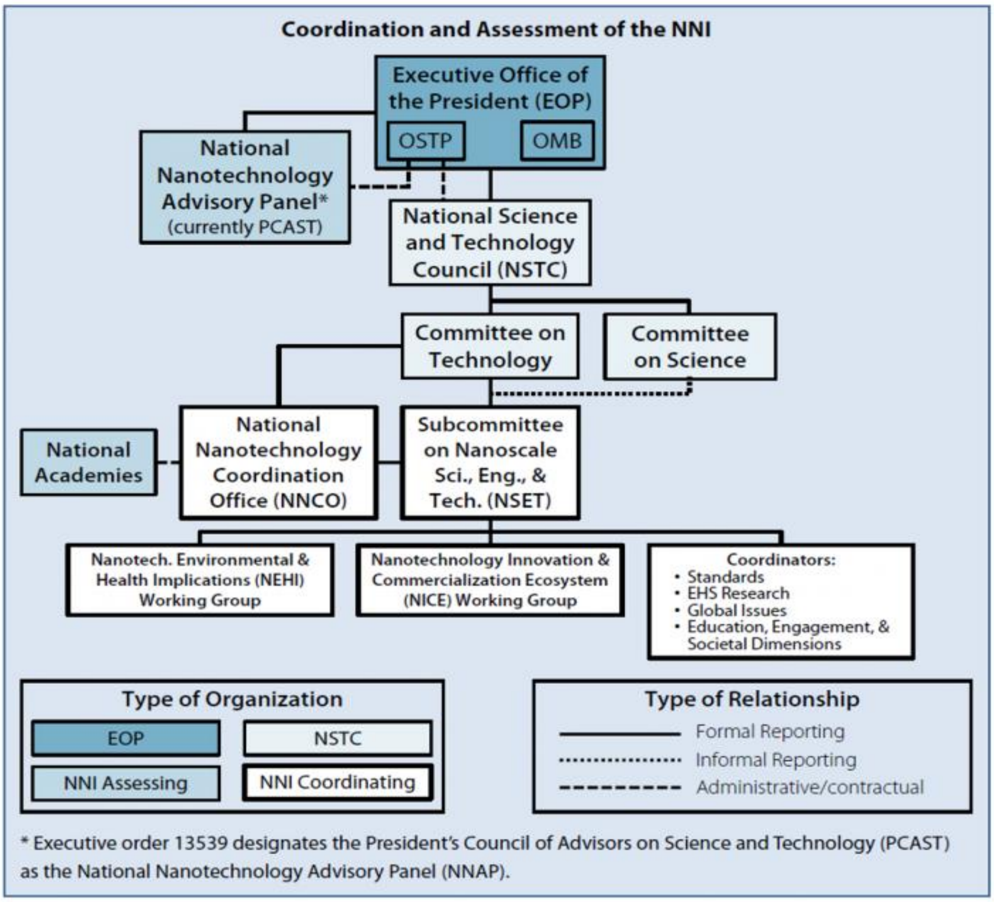


Figure 3.1 The Organizational Chart of the NNI
Source: (Nano.gov, n.d.)

Dong et al., (2016) mentioned about the aims of National Nanotechnology Initiative (NNI). It shows that the main purpose is to gain the ability to use NT in all sectors firstly in the world:

> The NNI established four goals: (1) to advance a world-class nanotechnology research and development program; (2) to foster the transfer of new technologies into products for commercial and public benefit; (3) to develop and sustain educational resources, a skilled workforce, and supporting infrastructure and tools to advance nanotechnology; and (4) to support responsible development of nanotechnology.

It can be said that NNI has been systematically working since 2000 to realize these goals. Of course it is a necessity to allocate resources in order to realize the objectives. The 2017 Federal Budget allocates more than $1.4 billion for the NNI, confirming the crucial role of NT. Cumulatively totaling nearly $24 billion since the establishment of the NNI in 2000, the President's 2017 Budget supports NSET

R&D at 11 agencies. Another 9 agencies have NT-related mission interests or regulatory responsibilities. Federal institutions with the largest investments are shown at Table 3.2. and NNI Budget is shown at Table 3.3 for 2015-2017 (dollars in millions). According to Table 3.3, NSF allocates the most money to NNI.

Table 3.2 Federal Institutions with the Largest Investments for NNI

Agency	Activity Area
National Science Foundation (NSF)	Fundamental research and education across all disciplines of science and engineering
National Institutes of Health (NIH)	Nanotechnology-based biomedical research at the intersection of life and physicsal sciences
Department of Energy (DOE)	Fundamental and applied research providing a basis for new and improved energy technologies
Department of Defense (DOD)	Science and engineering research advancing defense and dual-use capabilities
National Institute of Standards and Technology (NIST)	Fundamental research and development of measurement and fabrication tools, analytical methodologies, metrology, and standards for nanotechnology

Source : (NNI, n.d.).

Other agencies and agency components investing in mission-related nanotechnology research are Department of Homeland Security, Food and Drug Administration, Environmental Protection Agency, National Aeronautics and Space Administration, National Institute for Occupational Safety and Health, Consumer Product Safety Commission, Department of Transportation (including the Federal Highway Administration), and the U.S. Department of Agriculture (including the National Institute of Food and Agriculture, the Forest Service, and the Agricultural Research Service) (NNI, n.d.).

Table 3.3 NNI Budget, by Agency, 2015-2017 (dollars in millions)

Agency	2015 Actual	2016 Estimated	2017 Proposed
CPSC	2.0	2.0	4.0
DHS	28.4	21.0	1.5
DOC/NIST	83.6	79.5	81.8
DOD	143	133.8	131.3
DOE	312.5	330.4	361.7
DOT/FHWA	0.8	1.5	1.5
EPA	15.1	13.9	15.3
DHHS (Total)	385.8	405	404.4
FDA	10.8	12	11.4
NIH	364	382	382
NIOSH	11	11	11
NASA	14.3	11	6.1
NSF	489.8	415.1	414.9
USDA (Total)	21.1	21.5	21
ARS	3	3	3
FS	4.6	4.5	4
NIFA	13.5	14	14
TOTAL	**1496.3**	**1434.7**	**1443.4**

Source : (NNI, n.d.)

Hernandez et al., (2005) stated that as of 2005, with the increase in the number of nanotechnology-related projects in the Ministry of Defense, Small Business Innovative Research (SBIR) program has become remarkable. From 2000 to 2005, over 5400 SBIR solicitations were offered by agencies of the DoD. In 2005, about 7.5% of all SBIR solicitations were nanotechnology related. It appears that there is indeed increasing interest since 2001 in DoD agencies in nanotechnology oriented research. At the same time, Lockheed Martin, a major defense and aerospace company, had 28 active R&D projects focused on nanotechnology in 2005. Lockheed Martin company used nanotechnological military applications in the fields of electronics/photonics, sensors, energy and high performance structural materials.

Currently, 2692 products manufactured by 463 companies in the USA. These companies are working in the field of nanotechnology in order to invent new materials related nanotechnology (Statnano, n.d.-a).

After the NNI, Institute for Soldier Nanotechnology (ISN) was founded in 2002 to meet the needs of military systems using nanotechnology. ISN was established within the Massachusetts Institute of Technology (MIT) with a budget of $ 50 million. Due to the need of soldier protection and survivability and Army's demand, The ISN emerged. It was planned as a university center for basic research on nanotechnology. The ISN is a team of MIT, Army and industry partners working together to discover and find solutions for soldiers needs. The ISN's working style has been explained in detail at their web page like that (ISN, n.d.):

> The ISN's mission is complex and difficult—and it won't be solved by cutting-edge nanoscience alone. Army research partners are vital to the ISN Mission. They collaborate on basic and applied research, provide guidance on the Soldier relevancy of ISN projects, and participate in transitioning (i.e., technological maturation and scale-up of the outcomes of ISN basic research). The ISN is sponsored through the U.S. Army Research Office (ARO). MIT scientists work closely with scientists from the ARO and other science and technology communities within the DoD to exchange ideas and share experience with what does and doesn't work. The Army also keeps the ISN in contact with the customer—the individual soldier. Several times a year, MIT researchers travel to Army bases to observe soldiers in training, talk with them one-on-one, and see how current equipment works. It's also a chance to get a first-hand taste of the soldier's challenges, by wearing bulky night-vision goggles or carrying a 40-pound rucksack for an hour. Industry partners are critical to the ISN Mission, helping turn innovative results of basic research into real products and scale them up for affordable manufacture in industrial quantities. Membership in the ISN Industry Consortium is open to companies who provide a critical core competency for ISN research and an appropriate level of cost-sharing.

The ISN is composed of Soldier, MIT, industry, some other DoD units and also other government agencies. The ISN has had substantial interactions and collaborations with a number of the Army's sister services and other US government units. The ISN is a large family with approximately 50 faculty members, more than 150 graduate students and postdoctoral associates, 15 staff members at ISN Headquarters, visitors from industry, the government, and academia. It is a good example of using nanotechnology for soldier demands (ISN, n.d.).

The USA is effectively involved in nanotechnology studies with all government, military, industry and private institutions. Scientists and researchers are working hard to keep up with the speed of nanotechnology, which is constantly evolving. The

USA, one of the leading countries in terms of nanotechnology studies worldwide, is expected to continue its study actively and intensively in the next years (Özer, 2008). Especially due to the emerging threats worldwide in the field of security, it is considered that the USA will speed up the nanotechnology studies for the development of military systems and other technology fields.

3.1.2 Nanotechnology Studies in the Germany

Germany is a well-developed country in the middle of Europe. It is possible to see that situation by looking at R&D spending. The Germany's R&D expenditures (% of GDP) is 2.87 for 2014 as shown in Table 3.1. This rate is well above the world average. It shows the importance given to R&D studies by the Germany. Like USA, Germany is one of the countries that act fast in nanotechnology studies.

Companies such as Nanoplus, Infineon, Biomers, Daimler Chrysler, Cleancorp Nanocoatings, Schott, Carl Zeiss, Magbetec, Siemens, Osram, Nanopool, Degussa, BASF, Bayer, Metallgesellschaft and Henkel have come forward with nanotechnology studies.

Germany has organized the educational infrastructure for nanotechnology. Germany has focused on nanotechnology studies since 2000 with great budgets. In this sense, Federal Ministry of Education and Research (BMBF) fulfills a very important task. BMBF is coordinating R&D activities and plans in Germany. When examining nanotechnology trainings in universities, it is possible to encounter the following examples as shown at Table 3.4.

Table 3.4 Nanotechnology Activities in German Universities

Activity	Explanation
NanoClub	Started in 2002, at the Technical University, RWTH Aachen, with the aim of networking the RWTH's interdisciplinary research activities in the field of nanosciences and nanotechnology. It also provides an effective platform for regional, state, federal and European activities. It enables to cooperate with participants from industry, the Jülich Research Centre and numerous Fraunhofer institutes.
The Centre for Functional Nanostructures (CFN)	Established in 2001, the CFN is funded by the German Research Foundation (DFG), the State of Baden-Württemberg, and the Karlsruhe Institute of Technology (KIT). In 2006, the CFN also became a "Cluster of Excellence" in the German Excellence Initiative. Currently, about 250 scientists in 5 interdisciplinary CFN research areas collaborate to work in 17 projects, divided into 88 subprojects. In addition, 4 "CFN Young Scientist Groups" are fully funded by the CFN (KIT, 2018).
The Institute of Solid State Physics and the Centre of Nano photonicss	Founded in 2004. The Institute of Solid State Physicss is at Berlin's University of Technology (TU Berlin). It is one of the largest training centres for semiconductor technology in Germany. The project received a total of approximately 5.4 million euros in funding.
The Centre for NT, CeNTech	Located in Münster University, aims to initiate spin-offs in the field of NT and support companies in the nano sector. It is involved in extending training and further training measures.

Table 3.4 (cont'd)

Activity	Explanation
The Centre for NanoScience (CeNS)	Located at Munich University (LMU), promotes interdisciplinary research and teaching in fields dealing with objects and functions on the nanometre scale. CeNS promotes cooperation between different scientific disciplines by pooling knowledge, technologies, facilities and resources.
The Master's course in "nanobiophysics"	Organized at Dresden's University of Technology (TU) enables students who already have a first degree in a physicsal or technical subject (usually physicss or biophysicss) to pursue interdisciplinary training in the field of molecular and cellular biophysics with special emphasis on nanotechnology. Training focuses on scientific basic principles and current methods in molecular cell biology and biochemistry, biophysics and NT.
The Centre for Nanointegration	Founded at the University of Duisburg (CeNIDE), pulls together and promotes cooperation in NT among the university's departments of physicss, chemistry and engineering as well as external partners in research and industry. The centre offers unique fabrication facilities for nanoscale materials, and a newly established "Nanoengineering" study programme.

Source: (BMBF Report, n.d.) and (KIT, 2018).

Within the scope of nanotechnology studies in Germany, nanotechnology competence centers have an important place. BMBF called for establishing CCNanos in 1998. The numbers of competence centers were six at the beginning but later numbers of these centers increased to nine and spread throughout the country. Locations and tasks of Nanotechnology Competence Centers in Germany are shown at Table 3.5.

Table 3.5 Nanotechnology Competence Centers in Germany (Harms, n.d.).

Center Name	Activity field
CC NanoChem e.V. – CC Chemical NT, **Saarbrückenƒ**	Nanoparticle technologies for industrial applications, Surface technologies for innovations in all areas, Nanomaterials for Life Sciences,
CeNTechGmbH -Center for Nanotechnology, **Münster**	Investigation of new materials and nanoscale structures, Formulation of micro fabrication processes to reproduce biological and biochemical systems
ENNaB–Excellence Network NanoBiotechnology, **Munich**	Network of research groups of excellent young scientists and enterprises of the region, Connection between institutional basic research and economic application,
INCH -Interdisciplinary NanoScience Center **Hamburg**	Interdisciplinarity is in the foreground, Inquiry of complex problems in NS and NT
NanOp -CC NanoOptoelectronics, **Berlin**	Application of lateral nanostructures, nanoanalytical methods and optoelectronics,
NanoBioNete.V. –CC Nanobiotechnology, **Saarbrücken**	Focuses on nanobiotechnology, Mainly regionally oriented on Saarland/Rhineland-Palatinate
NanoMat -Network Nanomaterials, **Karlsruhe**	Super-regional network of 31 partners 8 enterprises, 9 universities, 12 research institutions, one assurance
UFS -CC Ultrathin Functional Films, **Dresden**	6 research groups, advanced CMOS, new devices, biological molecular layers for medicine and engineering,
UPOB e.V. -CC Ultra-precise Surface Figuring, **Braunschweig**	Production methods, metrology, sensor technology and materials for macroscopic products

There are some applications showing us the situation of nanotechnology, R&D and innovation in Germany. One of them is “The High-Tech Strategy”. The others are “NanoInitiative–Action Plans 2010, 2015 and 2020”. At the beginning of 2011 the Federal Government presented “Action Plan Nanotechnology 2015” in order to ensure through a common platform the opportunities for NT through safe, sustainable and successful use. After that, “The Action Plan Nanotechnology 2020” was prepared covering the Federal Government’s inter-departmental support strategy for NT in the period 2016–2020. The Action Plan 2020 is associated with the 2015 Action Plan and the Nano Initiative - Action Plan 2010.

All these studies were made to coordinate and orientate R&D activities and NT efforts effectively in Germany. The federal government made the 'Hightech-Strategy' as a detailed strategy in 2006 for all major parts of research and innovation in Germany, covering relevant research, education, innovation and technology transfer topics. This strategy has triggered the federal government investments up to € 27 billion between 2006 and 2013. The strategy has been updated in 2014 (EC, n.d.).

The BMBF has been funding nanotechnology R&D for over 20 years. Although when funding first started, the projects were still very basic, as funding strengthened they were able to become increasingly relevant to real applications. Nanorisk research has been heavily funded from as far back as 2006. BMBF funding was also pioneer in this field. BMBF research funding in 2011 accounted for around 222 million euros of project funding including innovation-supporting measures. A total of 26 BMBF advisers across all departments were involved in funding of some 1700 individual projects. 43% of the funding went to industry and 57% to public research institutions. The New Materials and Nanotechnology sector accounted for the largest share of this funding, at almost 40%. The BMBF employed some 18 million euros of this funding in 2011 on around 170 projects in preventive and supporting research through NanoCare, NanoNature and accompanying innovation measures.

The other federal ministries involved in the Interministerial Steering Group released around 45 million euros for nanotechnology R&D in 2011. That means, the federal ministries expended totally over 266 million euros in support of nano projects in 2011. This included around 26 million euros on preventive and risk research together with accompanying measures, equating to almost 10% of the total federal ministry funding (Nano.De-Report, 2013).

Due to the research policy of the EU and the BMBF, the number of firms oriented to nanotechnology products also have increased. The BMBF has allocated budget for NT projects since the beginning of the 1990s. The USA and Europe have roughly the same number of nanotechnology-related companies. Nearly half of them in Europe are German firms. Finally, it can be said that Germany is first in rank in Europe in nanotechnology studies. A good financial policy has contributed significantly to Germany’s development. With about 440 million euros in public funds, Germany is a powerful country in Europe (DaNa2.0, n.d.).

3.1.3 Nanotechnology Studies in Japan

Japan is also a well-developed country in the East Asia. R&D investments of Japan is very high according to other countries. The Japan’s R&D expenditures (% of GDP) is 3.58 for 2014 as shown in Table 3.1. This is a ratio which generated great difference. It shows the significance given to R&D studies by Japan. Like USA and Germany, Japan is a country that understands the importance of nanotechnology for future. Companies such as Fujifilm, Fujitsu, Nikon, Topcon, Hitachi High-Technologies, and Nanophoton stand out with nanotechnology studies.

Japan has a world-leading position in publicly funded nanotechnological research. Many nanotechnology research programs have been established in both practical and basic research areas. Two of the most important nanotechnology research institutes in Japan are the Joint Research Center for Atom Technology (JRCAT) and the Institute of Physics and Chemistry Research (RIKEN) (TÜSİAD, 2008). According to the report (CRDS-FY2015-XR-07, 2016),

> Extra-large research complexes for industry, academia, and government are being established overseas one after another, including Albany NanoTech (USA), IMEC (Belgium), MINATEC (France), Fusionopolis (Singapore), and Nanopolis Suzhou (China). These research complexes are developing their activities on a global scale. In Japan, the Tsukuba Innovation Arena - Nanotech (TIA-nano) is currently expanding its funding and the numbers of participating researchers and research projects.

For building advanced science and technology-based nation, basic plans have been prepared since 1996. The S&T Basic Plan is a comprehensive plan prepared by the Japanese government in accordance with the Science and Technology Basic Law, enacted in 1995, in order to promote S&T in Japan over a five-year term, based on a ten-year forward outlook. Aim of the plans and some other informations are given shortly in Table 3.6. In the Third Basic Plan (FY 2006-2010) eight promotion areas were determined. These areas were Energy, Monodzukurı (manufacturing) technologies, Infrastructure, Frontier (outer space & oceans), Life science, IT, Environmental sciences, Nanotechnology&materials. The last four areas were announced as priority promotion areas including nanotechnology. Nanotechnology&Materials Area consist of five sub-areas and 29 key R&D subjects (CRDS-FY2015-XR-07, 2016).

Table 3.6 Information About Basic Plans in Japan

Plan No.	Aim, key policies	Budget
First Basic Plan (FY 1996-2000)	Increasing R&D budget, structuring a new R&D system	17 trillion Yen
Second Plan (FY 2001-2005)	Prioritization of R&D on national/social subjects, doubling competitive research funds	24 trillion Yen
Third Basic Plan (FY 2006-2010)	Further reform of S&T systems, leading to higher performance, strategic prioritization of R&D themes	25 trillion Yen
Fourth Basic Plan (FY 2011-2015)	Enhancement of basic research, Fostering of STI person, S&T Policy as the national strategy, taking an important role in “New Growth Strategy”, Promotion of STI in two growth areas: Green Innovation&Life Innovation	
Fifth Basic Plan (FY 2016-2020)	Acting to create new value for the development of future industry and social transformation, “Society 5.0 – Another Perspective”, the road to that super-smart society.	

Source : (Baba, 2010) and (Cabinet Office Report, 2015).

The top levels of the government are actively involved in science and technology organizations in Japan, Science and technology R & D studies in Japan are conducted under the coordination of the Ministry of State for S&T Policy, especially with the active participation of the Ministry of Education, Culture, Sports, S&T (MEXT) and the Ministry of Economy, Trade and Industry (METI).

Science and Technology Administration in Japan is shown in Figure 3.2. The main related ministries are as follows.

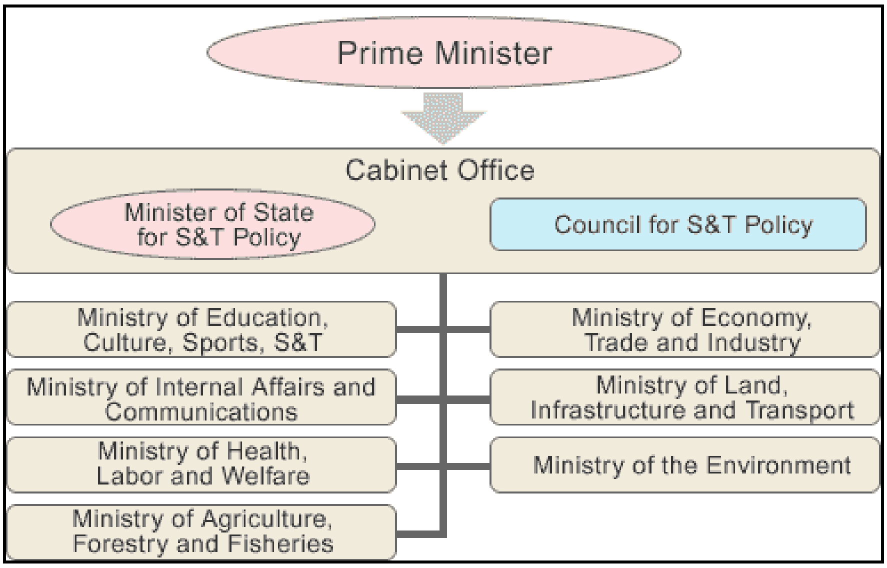


Figure 3.2 Science and Technology Administration in Japan.
Source : (Cabinet Office, 2017)

Counsil for S&T Policy (CSTP) and Ministry of Education, Culture, Sports, S&T (MEXT) are main actors in Japan for executing science and technology activities. Basic research, generic technologies and long term challenge for industrial use subjects are under their responsibility. Council for S&T Policy (CSTP) unit is coordinator for all these studies (Takemura, 2006).

Japan started the science and technology foresight studies in 1970 by preparing the technology road map. Technology foresight studies have been used as an effective tool in the design of science and technology policy. One of the leading countries in science and technology studies is Japan. Japan has already organized its institutional structure for science and technology studies. Science and technology policy is related to many ministries in Japan. It is a fact that as a result of the coordinated studies of the ministries, Japan has come to a very good point in nanotechnology studies worldwide.

3.1.4 Nanotechnology Studies in China

Kostoff (2011) stated that China shows rapid growth in nanotechnology and nanoscience according to Science Citation Index (SCI). China has passed the USA in 2009 in nanotechnology and nanoscience research output. Thus, China's rapid increase in the number of nanotechnology researchers and the number of nanotechnology and nanoscience studies shows that the industrial ability to provide China's national development in the future will also increase. This situation does not only increase China's ability in this area. It also increases its commercial and military capabilities.

China, the most crowded country in the world, is a developed country in Asia. R&D spending of China shows that situation to us. China’s R&D expenditure (% of GDP) is 2.05 for 2014 as shown in Table 3.1. This ratio is above the world average. Since 1999 to 2006, China’s spending on R&D has increased by more than 20 per cent each year. It shows the importance given to research and development studies by the China. Companies such as Arknano, NaBond, Nano-group Holdings, Tipe, Scientz, XP Nano Material, XF Nano Materials, and TitanPE Technology Inc. draw attention with their nanotechnology studies.

President of China Hu Jintao announced the objectives on January 09, 2006 for science and technology studies for the year 2020 like that “By the end of 2020, China will achieve more science and technological breakthroughs of great world influence, qualifying it to join the ranks of the world’s most innovative countries” (Wilsdon & Keeley, 2007).

In January 2006, China’s Science and Technology Congress assembled to confirm a new Medium to Long Term S&T Development Programme. This Congress set preferences for the next 15 years and approves the goal of increasing investment to 2 per cent of GDP by 2010 and 2.5 per cent by 2020 (Wilsdon & Keeley, 2007). This situation is shown at Table 3.7.

Table 3.7 R&D Spending Targets in the Medium to Long-Term Plan of China
Source : (Wilsdon & Keeley, 2007).

	R&D spending (all sources, US$ billions)	**% of GDP**	**Central government (US$ billions)**
2004	24.6	1.23	8.7
2010	45.0	2.00	18.0
2020	113.0	2.50	not known

The Medium to Long-Term Plan included 68 priority aims spread across 11 key areas of importance to China's economy and development, 16 special research projects, eight 'cutting-edge' technology areas: biotech, IT, new materials, advanced manufacturing, advanced energy, marine technologies, lasers and aerospace, eight 'cutting edge' science challenges, including cognitive science, deep structure of matter, pure mathematics, earth systems science, four major new research programmes in protein research, nanoscience, growth and reproduction, and quantum modulation research. New measures being introduced to pursue these goals include increasing R&D expenditure on science, combining and coordinating military and civilian research organisations and the management of these, new fiscal incentives to support innovative start-ups, introducing a new evaluation system for benchmarking research institutes and researchers and a new national strategy on intellectual property rights (Wilsdon & Keeley, 2007).

According to the World Bank records, R&D expenditure (% of GDP) of well-developed Asian countries in 2014 (Japan, South Korea and China) is shown at Figure 3.3 in order to make a comparison. China is the last among these three countries. South Korea's R&D spending was twice as much as China's R&D expenditure in 2014.

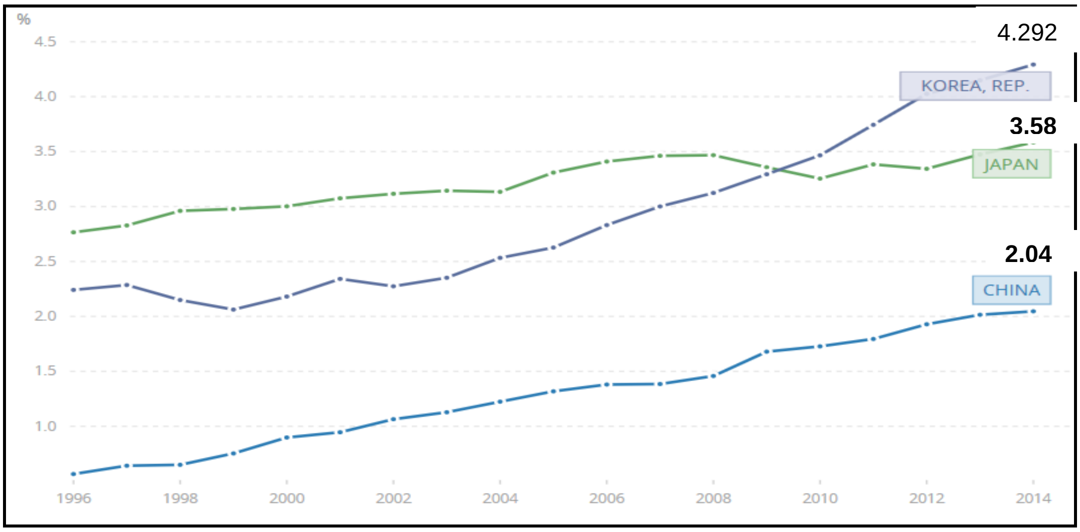


Figure 3.3 Research and Development Expenditure (% of GDP)
Source : (The World Bank, n.d.)

There are some key institutions in Chinese science and innovation policy. State Council is in charge of the highest level and is in the position of coordinator for all science and innovation activities. Under this Council, there are six ministry-level organisations that deal with science and innovation. One of them is Ministry of Science and Technology (MOST) created in 1998 out of the former State Science and Technology Commission, MOST has the primary responsibility for science and technology policy and strategy. It finances a large amount of research, primarily through special programmes. It also administers technological development zones and oversees international collaboration. Commission of Science, Technology and Industry for National Defence (COSTIND) formed in 1982, this influential but secretive body oversees defence-related R&D and military applications of commercial technologies. Ministry of Education (MOE) is responsible for education policy and management of higher education institutions. It also oversees state key laboratories and research institutes in universities, and has established various initiatives to promote the commercialisation of scientific research.

Chinese Academy of Sciences (CAS) formed in 1949, It is China's most prestigious science organization, and its academicians (yuanshi) are the elites of science. Following recent reforms under its 'Knowledge Innovation Programme', CAS had an important role in providing policy advice and scientific input to government. Chinese Academy of Engineering (CAE) created in 1994, CAE was involved in policy advice and development. Unlike CAS, it does not run its own research institutes. National Natural Science Foundation of China (NSFC) was set up in 1986 to promote and support scientific research. Its budget in 2005 was US $337 million, which is around one-fifth of the government’s total investment in research. In May 2006, it was announced that the NSFC’s budget would increase by around 20 per cent a year until 2010 (Wilsdon & Keeley, 2007).

China's five-year NNI program was launched in 2001. The budget for this programme is planned to be met by the MOST, MOE, CAE and NSFC. China has ranked third in the number of publications on nanotechnology after the USA and Japan in the ten-year period from 1991 to 2001. Between 1985 and 2001, there were 956 nanotechnology patents issued in China. It was 1165 between 2009-2011 (TÜSİAD, 2008). China's number of patents in 2015 was realized as 393.

The National Center for Nanoscience and Technology (NCNST) of China is an important organization for nanotechnology studies. It was co-founded by CAS and MoE. It is a subsidiary non-profit organization of CAS which enjoys full financial allocations with a status of independent non-profit legal entity. The center was officially founded on December 31, 2003, with CAS, Peking University and Tsinghua University as its initiators and co-founders, located in Zhongguancun-Beijing (NCNST, n.d.).

Six cities in China; Beijing, Shanghai, Tianjin, Shenzhen, Shenyang and Guangzhou had become invention patents centers. In addition to these cities, Dalian, Wuhan and Binhai New Area have come to the forefront. They are developing distinctive niches. In this context, it can be said that the whole map of China’s innovation system may change in 2020 and in the following years.

MOST prepared an important plan, in 2001, enabling national nanotechnology development strategy, covering 2001-2010. This plan identified China's nanotechnology general objectives and strategies. According to the plan; the development of nanomaterials has been shown in the near term, bionanotechnology and nanomedical technologies in the medium term and the development of nano electronics and nano particles in long term targets. Like this ten-year programme, five-year programmes were prepared after 2000s. Like every other country in the world studying nanotechnology, China gives much emphasis on nanotechnology

R&D study for the defense industry. In this sense, intensive studies have been undertaken to create intelligent nanomaterials, nanosensors, micro-motor technology, micro and nano aircrafts and satellites for the development of new defense systems. Nanotechnology is expected to make a significant contribution to the social and economic standarts, defense effectiveness and capability of China, which is rapidly advancing to become a superpower (Özer, 2008).

3.1.5 Nanotechnology Studies in South Korea

South Korea introduced Nanotechnology Initiative Law in 2001 and planned to use $ 4 billion for NT research and aimed to train twenty thousand nanotechnology specialists until 2015. R&D spending of South Korea is very attractive. South Korea's R&D expenditure (% of GDP) is 4.29 for 2014 as shown in Table 3.1.

South Korea is in the first place in the world according to the amount of budget allocated to R&D in 2014. This ratio is above the world average or OECD average. Since 2012 this ratio has not fallen below 4. It shows the importance given to R&D studies by South Korea.

Companies such as Seron Technologies, ABC Nanotech, Nano Co, Nanopoly, Nanux, and NTbase draw attention with their nanotechnology studies.

According to OECD (2015) Science, Technology and Industry Scoreboard South Korea is in a good position just as indicators show;

> Gross domestic expenditure on R&D (GERD) in the OECD area grew 2.7% in real terms from 2012, to reach USD 1.1 trillion in 2013. As a % of GDP, GERD in the OECD area remained unchanged with respect to 2012 at 2.4%. This recent growth has been driven by a strong increase in business R&D, while R&D expenditures in government institutions fell in 2013. China's reported expenditure on R&D continued to converge with the OECD average. Among countries covered in the OECD Main S&T Indicators publication, R&D intensity was highest in **Korea** following a period of fast growth. The fast growth witnessed in China and Korea was driven principally by their business sector, while the R&D intensity in this sector in the OECD has barely changed over the period.

South Korea is ranked first in Total R&D (GERD), Especially the increase trend after 2010 is very striking. High investments in R&D enable to develop in every field of life for a country. South Korea, which launched nanotechnology investments in 2000s, is among the top three in the world in R&D statistics from 2010 to today (OECD, 2017a).

South Korea was chosen the most innovative country in the world, second was Sweden and the third one is the USA according to Bloomberg Rankings in 2014. Nanotechnology Policy in South Korea established in accordance with the Nanotechnology Development Promotion Law (enacted in December, 2002).

This policy was developed and implemented by the National Comprehensive Development Plan for the Nanotechnology (NCDPN). The third phase NCDPN was established in 2011. In this plan, 30 future core technologies in 5 fields were chosen in order to improve NT for responding to the needs/demands of future society.

Since 2000, many improvements have been made to develop nanotechnology in South Korea. Research centers were opened, plans have been revised and new plans have been put forward. In 2008 and 2014, Nanotechnology Roadmaps were prepared and put into practice.

Various research centers were opened such as NT Industrialization Support Center, National Nanofab. Center, Center for Nanostructured Materials Technology, Center for Nanoscale Mechatronics & Manufacturing, Nanoparticles Application Center especially between 2002-2004. Nanotechnology Initiative Law, introduced in 2001, was revised in 2005 and 2011 and re-evaluated (Lee, 2014).

Detailed information on various nanotechnology programs implemented in Korea are given in Table 3.8. According to this, it can be said for South Korea that commercialization of convergence technologies for the post-2020 period has been identified as a target and selling these products to foreign markets has been described as a goal.

Table 3.8 Selected Nanotechnology Programs of MSIP
(Ministry of Science, ICT and Future Planning) (Lee, 2014) and (KAST, 2017)

NAME	FUNCTION	DURATION	BUDGET
Nanomaterial and Technology Development programme	Fundamental research on nano materials, nano devices, nano process, nano tools etc.	5-7 years	$0.5-1 M/year
Pioneer Research Center	High-risk and high-profit converging technology in Nano	6 Years	$1 M/Year
Global Frontier Programme	Innovative technology which can overcome the limits of existing technologies	9 Years	$15 M/Year
Nano Convergence 2020	Commercialization of NT-based convergence technologies and cretion of new industrial fİelds	2-9 Years	Upto several M$/year (need-base)
Korea NT Research Society (KoNTRS)	-Promote joint projects, networking, and information exchanges between corporations and scholarly researchers in NT, -Improve mutual collaboration among members and contribute NT policy, research, scholarly activities, and early industrialization,	Majör Activities: -KNI and NT Road Map, -Nano Korea Symposium -Domestic&Global Networking and Collaboration, -Nano Convergence (New journal started in 2014 with Springer), -NT Education Programs including e-Nano School -Knowledge Sharing with Public	
National NT Policy Center (NNPC)	-Help Korea to become a world-class NT country through NT information collection and analysis as well as national NT policy NT policy and strategy development, -Advance into a world-class research institute exclusively for nano policies	Major Functions: -Support for the national NT policy -Collection and analysis of NT information -Support for international cooperation and network establishment,	

Table 3.8 (cont'd)

NAME	FUNCTION	DURATION	BUDGET
Korea Infrastructure Organization for NT (KION)	-Constructing a mutual cooperation system for preemptive response to the NT paradigm shifts and consumer demands, -Providing and sharing integrated information on attained technology, equipment, service, and usage, etc.	Major Activities -Providing effective support for domestic NT research and development via close collaboration amongst domestic Nano-infrastructure.	Members of KION: Ubiquitous IT Cluster, Korea Printed Electronics Center (KPEC), (NCNE) Korea Advanced Nano Fab Center (KANC) National Nanofab Center (NNFC), (NCNT)
NT Research Association	Help private sector for commercialization of research outcomes in NT, Networking of government, academia, research institutes and private sector,		
Nano-Convergence Foundation (NCF)	Creation of new markets &industry through commercialization of NT	Commercialization of research outcomes, Bringing-up nanotechnology corporations including start-ups	
The Korean Academy of Science and Technology, (KAST)	It is the highest intergraded think-tank for science technology.	KAST contributes to national development by promoting science and technology (KAST, 2017).	

3.1.6 Nanotechnology Studies in European Union (EU)

In this section, EU’s S&T policy studies are examined in general. It was determined that framework programs were the basis of S&T studies in Europe during this review. Nanotechnology studies have also been included in these framework programs.

The requirement for the European Union to start working on S&T goes back nearly fourty years and precedes the Single European Act of 1986 that transferred competencies for a common European R&T policy to the EC, concluding the implementation of the Framework Programmes (FPs) (Marimon & Carvalho, 2008).

In order to understand the general framework of the EU's S&T policy, it is useful to look at the basic foundations of this policy. First of all, the decisions taken by the Council of Europe in the Spring Meeting of 23-24 March 2000 in Lisbon are striking. At this meeting, the Council decided to have a knowledge-based economy until 2010 and follow a strategy for realizing that goal. This strategy was called as the "Lisbon Strategy". In the implementation of this strategy, great importance has been given to research activities which are the main source of information production and which lead to use information. The second mainstay of the EU's current S&T policy is the decisions taken by the Council of Europe at the Spring Meeting in March 2002 in Barcelona. At the Barcelona meeting, the Council set a target for investment in R&D and decided to raise the R&D expenditure (% of GDP) to 3%. It also predicted that two thirds of R&D expenditure would come from private sector investments. In summary, the objective and general framework of the EU's S&T policy is set out in the Europe Council's Lisbon (2000) and Barcelona (2002) meetings. The strategy to be followed is decided at these meetings. Decisions to support this strategy have been taken at subsequent meetings of the competent bodies of the EU (Göker, 2006).

In fact, the EU's science and technology policy is best reflected in framework programs. They are the most effective means of implementation of the EU's agreed science and technology policy. The budget for the last programe, 7th Framework Programme was approximately fifty-three billion Euros, covering the 2007 - 2013 implementation period. This budget, as a support mechanism, will give an idea of the extent and importance of framework programs. It is envisaged to use two instruments for coordinating research programs not included in Community programs. The first instrument is ERA-NET developed under the 6th Framework Program. The main theme of EP6, covering the years 2002-2006, was the strengthening of the European Research Area (ERA) structure and bases. The second tool to be used to ensure co-ordination was the participation of the Community in the joint national research programs. In addition, for increasing synergies between inter-governmental structures such as EUREKA (It is an intergovernmental initiative established in 1985 to support activities to develop new products, new production methods and services throughout Europe), COST (An intergovernmental structure established in 1971 to coordinate scientific and technical research in Europe) and framework programs or ensuring that they complement each other, the needed support is provided (Göker, 2006). The term “ERA” has made its official appearence in the Lisbon Treaty like that;

> The Union shall have the objective of strengthening its scientific and technological bases by achieving a European Research Area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry, while promoting all the research activities deemed necessary by virtue of other Chapters of the Treaties.

Such a role for the ERA had received a clear positioning in Community priorities as in the March 2008 EC's results the ERA was placed at the core of the "fifth freedom", namely the free action of knowledge, ideas and researchers in Europe (Marimon & Carvalho, 2008).

The outcome of the EU's science and technology study also reflected in R&D spending. But the rate of increase is not too high. They could not reach the % 3 R&D expenditure target, decided in the 2002 Barcelona meeting. In 2015, EU’s (28 countries) Gross Domestic Spending on R&D was 1.96. Between 2012 and 2015, OECD R&D expenditure (% of GDP) is more than EU spending. This situation is shown at Table 3.9.

Table 3.9 Gross Domestic Spending on R&D Total, (% of GDP), 2012 – 2015

	2012	2013	2014	2015
EU (28 countries)	1.92	1.93	1.95	1.96
OECD Total	2.32	2.35	2.38	2.38

Source : (OECD, 2017b).

The framework programs, mentioned above, first started in 1984. The Seventh FPs finished in 2013. Meanwhile, for the first time, Turkey participated in the 6th framework program. Each framework program lasted an average of four years. At the beginning, the programe budgets were low but especially the budget of the seventh program has been increased too much. This situation is shown in Table 3.10.

Table 3.10 Budgets of EU Framework Programmes (Vural, 2011).

Framework Numbers	Covered Years	Framework Budget (billion euros)
First Framework Programe	1984-1987	3,3
Second Framework Programe	1987-1991	5,3
Third Framework Programe	1991-1994	6,6
Fourth Framework Programe	1994-1998	13,2
Fifth Framework Programe	1998-2002	14,9
Sixth Framework Programe	2002-2006	19,1
Seventh Framework Programe	2007-2013	53,2

Framework Programs are being implemented to strengthen European R&D" development capacity, to promote university-industry cooperation, to cooperate with EU Member States and other countries within EU policies in various fields. The programs are implemented through a special funding system established to support R&D and innovation activities within a comprehensive scientific framework. Horizon 2020, the EU's new framework for research and innovation, had a budget of around 80 billion euros in the period between 2014 and 2020, after 7th FP.

The European Union's new R&D and Innovation Program "Horizon 2020" consists of three components. First component is Excellent Science including The European Research Council activities, Future and Emerging Technologies, European research infrastructures (including eInfrastructures) and Marie-Skłodowska-Curie Actions. The second component is Industrial Leadership and the third componenet is Social Challenges. Within the scope of industrial leadership; under the Industrial Leadership and Competitiveness, it is aimed to increase employment by creating new business fields, strategic investments in key technologies, private sector investment for R&D and innovative SMEs. Industrial leadership consists of Facilitators and Industrial Technologies. Within this program, 13,5 million euros have been allocated to ICT, **nanotechnology**, advanced materials, advanced manufacturing and processing technologies, biotechnology and space studies (Ministry for EU Affairs, n.d.). The National coordination of the Horizon 2020 Program is carried out by TÜBITAK.

According to a report published by European Commission (EC) in 2013 related to nanotechnology, Horizon 2020 Programme is very important for EU (European, 2013):

> One important point for the Horizon 2020 programme, under the Future and Emerging Technologies (FET) competition, will be a one-billion euros, ten-year sustained initiative dedicated to the investigation and exploitation of the unique properties of graphene. This exceptional nanomaterial possesses such remarkable physicsal and chemical properties that it has been dubbed the wonder material of the 21st century with far-reaching potential in electronics, transport, energy and medicine. The 'Flagship' effort on graphene, which will involve over 100 research groups and 136 principle investigators including four Nobel Laureates, indicates just how important nanotechnology is and will be over the coming decades.

This statement demonstrates the importance and value of nanotechnology for Europe. In the meantime, The Graphene Flagship mentioned in the paragraph is, along with the Human Brain Project, the first of the European Commission's FET Flagships, whose mission is to address the big S&T challenges of the age through long-term, multidisciplinary R&D studies (Graphene, n.d.).

Studies such as the framework programs, the horizon 2020, the human brain project and the graphene flagship stamped the last 40 years of Europe. These important projects are efforts on coordinating and directing science and technology studies in Europe. It can be said that the targets set at the beginning are reached when the output is viewed. With such planned and scheduled work, the European Union can take part in technology race in the future easily.

3.2 Nanotechnology Studies in Turkey

Since the 1980s, inventing materials and tools for nanotechnology use and processing have contributed to innovation in every field worldwide. The promising aspect of nanotechnology has attracted countries into a race. Developed countries acted carefully in order not to lag behind this global technology race by making structural and administrative adjustments since 2000's. Almost all developed countries have attempted to create the National Nanotechnology Programs and R&D Plans. The US NNI, established in 2000, and the Military Nanotechnology Institute, which was established in the USA in 2002, are examples of these studies. R&D studies are being carried out for military applications of nanotechnology in this institute. Countries such as USA, Japan, China, South Korea, Germany, Israel are making important efforts in this field.

Nanotechnology is a new opportunity for the remaining countries in the technology race. If necessary measures are taken, if appropriate structure is realized and if effective mechanisms are installed then it will be easy for developing countries to reach a good point. In this sense, important steps are being taken by Turkey especially after 2000s in nanotechnology, which is given so much importance globally and which is so crucial for the future. Every nanotech. - focused research centers, especially TUBITAK, continue to operate in NT. There are a lot of company using nanotechnology in their products, especially in textile and dye sector.

It is very important for Turkey to use this technology as a new jumping-off point, which is seen as a critical technology revolution in the new century and which is still in its infancy term. It is necessary to invest in NT in order not to miss the global nanotechnology race. Investment in nanotechnology is not in very good shape compared to other countries for Turkey. However, significant institutional structures have been formed for the development of this technology and scientists&universities are carrying out important projects related to nanotechnology and they are trying to give necessary support in terms of infrastructure and incentives.

More than 70 companies used NT in their products in 2015. The Advanced Research Laboratories have been established with the support of the Presidency of Defence Industries (SSB) and very important researches have been carried out. Many universities have established nanotechnology centers. Training programs are started related to nanotechnology. There are also companies in our country that operating applied research in the field of NT. Besides the projects carried out with the support and incentives of TUBITAK and State Planning Organization (SPO), initially at METU, followed by Bilkent University and after that at many universities, training programs and NT centers have been established (Bozkurt, 2015).

Priority areas have been identified in plans made in the last fifteen years for the purpose of managing and directing S&T efforts in Turkey. Documents/plans such as Vision 2023 Strategy Document, Science and Technology Policies Application Plan 2005-2010 and National Science, Technology and Innovation Strategy 2011-2016 are examples of these studies. In these documents, emerging technologies like nanotechnology have been strategically defined for Turkey.

At last decade, 19 centers have been set up in Turkey to carry out researches in this field, and an investment amounting to approximately one billion TL has been invested. Research structuring on NT started in 2005 in Turkey. It can be said that Turkey is in the first three among the most rapidly developing countries in nanotechnology at research level.

A wide variety of studies are being carried out in the field of NT in Turkey. NanoTR Conferences are important in terms of synchronization and coordination of NT studies at the highest level. For this purpose, since 2005, National Nanoscience and NT Conferences (NanoTR) have been held regularly every year. First NanoTR

Conference was held in 2005 at Bilkent University. The annual NanoTR conferences are considered to be the premier scientific event in Turkey in the field of NS&NT, with broad attendance in various areas. The 14th NanoTR conference was held in İzmir, on September, 2018 with 398 participants from 17 countries. Within this context, the NanoTR conference series offer an ideal platform for fertile exchange of ideas which is important for scientific advancement.

When we look at NT studies in Turkey, the result is not very satisfactory but recently it is noteworthy that NT is a breakthrough in university-industry-state units. According to Table 3.10, which shows scientific publications and patent numbers on nanotechnology for the year 2015, Turkey ranks 20th in the publication and 31st in the number of patents. China, the USA and India are in the first three ranks in publications, while the USA, Japan and South Korea are in the top three in terms of patent numbers. It is evaluated that China, which ranks first in the publication, ranks fifth in the number of patents since it can not convert this accumulation sufficiently to marketable product. The number of publications indicates the number of nano-articles with index of ISI, while the number of patents indicates the patents granted in the field of nanotechnology by US Patent and Trademark Office (USPTO).

Table 3.11 NT Related Scientific Publications and Patent Numbers in 2015

Rank	Country	Publications	Rank	Country	Patent Numbers
1	China	46363	1	USA	4365
2	USA	22814	2	Japan	902
3	India	10266	3	S.Korea	839
4	S.Korea	8652	4	Taiwan	500
5	Germany	7943	5	China	393
6	Japan	7086	6	Germany	307
7	Iran	6419	7	France	242
8	France	5446	8	Holland	156
9	UK	4672	9	UK	109
10	Russia	4102	10	Canada	109
20	Turkey	1807	31	Turkey	5

Source : (Statnano, n.d.-a).

In recent years, there has been an increase in the number of publications and patents in Turkey. According to the data of 2014, Turkey increased 13.36% in publications and 66.67% in patent numbers in nanotechnology. However, an increasing number of research centers working on nanotechnology have also been observed. Nanotechnology studies are carried out at nineteen Research Centers. It is expected that there will be significant increases in the number of these research centers and projects carried out in future periods. Table 3.12 lists some of the current research centers and institutes in Turkey.

Table 3.12 Research Centers and Institutes in Turkey

Research Centers	**Explanation**
METU Center For Solar Energy Research and Applications	GÜNAM is a multi-disciplinary center of excellence in the area of solar energy science and technology. There are seven laboratories and one of them is Nano Materials Development Group (METU NANOLAB) (GUNAM, n.d.).
Bilkent University National Nanotechnology Research Center (UNAM).	With 62 laboratories in 9000 m² closed area UNAM is one of the centers of excellence in NT in Turkey. The mission of UNAM is defined as “training experts through a multidisciplinary graduate program and develop new and high technologies based on nanoscience to strengthen the competitiveness of Turkish products in international markets”. It was founded in 2007 (Bozkırlıoğlu, 2011).
Bilkent University Nanotechnology Research Center (NANOTAM)	NANOTAM is dedicated to research on applied nanoscience and nanotechnology with strong emphasis on education and training. NANOTAM is an inter-disciplinary research environment which houses the nanotechnology related research efforts, and cooperates external companies as well as government to solve NT and material based high-tech problems (Bilkent University, n.d.).

Table 3.12 (cont'd)

Research Centers	**Explanation**
Sabancı University Nanotechnology Research and Application Center (SUNUM)	SUNUM is established by The Turkish Ministry of Development and Sabancı foundation with 25 Million Euros investment. The high-tech facility of the Center is designed to support cutting-edge scientific and technological research related to nanotechnologies. SUNUM is the first building in Turkey conforming to both LEED and BREEAM standards. Center became operational in January 2012 (Sabanci University, n.d.).
Koç University Surface Science and Technology Center (KUYTAM)	KUYTAM, which received start-up funding from SPO with additional funding from Koç University, was established in 2010 as the first research center in Turkey on surface sciences. Currently, KUYTAM houses 30 characterization instruments, grouped under the seven laboratories. (KUYTAM, n.d.).
Gebze Technical University Institute of Nanotechnology	Following the establishment of Gebze Technical University in 2014 (formerly named as Gebze Institute of Technology, 1992), In 2003, the NT Research Center was founded with the support of SPO. The research center was one of the firsts in Turkey. As a result of all these efforts, in order to systematize and institutionalize the R&D and educational activities, the Institute of NT was founded at Gebze Tech. University in 2014 with law No. 6562. (Gebze, n.d.).
İstanbul Technical University ITUnano NT Research Center	Being the leading research oriented university, ITU is highly motivated to pursue state of the art research and technology. As research on NT&NS is at high priority in its more than 30 engineering fields, many programs make ITU to have a strong stand in NT&NS R&D (ITUnano, n.d.).

Table 3.12 (cont'd)

Research Centers	Explanation
TUBİTAK Marmara Research Center Institute of Material, Nanotechnology Laboratories	Nanotechnological and Functional Materials Project Group has know-how and R&D competence in the development of functional glasses/glass ceramics/ceramics and piezoelectric ceramics for different end users. The group conducts basic and practical R&D studies with national&international projects (Tubitak, n.d.).
Marmara Univ. NT and Biomaterial Research and Implementation Centre	Marmara University NT and Biomaterial Research and Implementation Center was established in 2007. Aim of the Centre is to produce projects that will contribute to Turkey that is suitable for NT (Marmara, n.d.).
Çanakkale Onsekiz Mart University NANOTRAC	Nanoscience and Technology Research and Application Center (NANOTRAC) was founded in 2009. NANOTRAC is a multidiciplinary reserch center. Researchers are from various departments. They work on various research topics (ÇOMÜ, n.d.).
Erciyes University NT Research Center (ERNAM)	The center has become operational in April 2013 and currently serves to researchers from different fields with several fabrication and characterization laboratories (Erciyes, n.d.).
Atatürk University NS and Nano Engineering Research and Application Center	Nanoscience and Nano Engineering Research and Application Center is one of 26 research centers located at Ataturk University. Center staff are on the path to finding new products by closely following developments in NT (Atatürk, n.d.).

In recent years the number of programmes / studies in NT provided by Turkish universities has also increased. Universities such as METU, Bilkent University, Hacettepe University, Sabancı University, Gebze Technical University, Atatürk University, Dokuz Eylül University, Anadolu University and Istanbul Technical University provide master and PhD programs in nanoscience and nanotechnology.

The first nanotechnology workshop was held in Gebze on July 14, 2012 in Turkey, in order to reveal the current situation in the field of nanotechnology and to develop a strategy for this field. This workshop was the first ring of studies to create a national strategy document in the field of nanotechnology. It was organized by Turkish Management Sciences Institute (TÜSSİDE). The second workshop was held on September 01, 2014. After these studies, The High Planning Council (YPK) of Turkey, headed by the Prime Minister, accepted the "Turkey Nanotechnology Strategy and Action Plan (2017-2018)" at the meeting held on 17 July 2017. This plan has been prepared with the vision of being a country that can meet the global needs by strengthening infrastructure and human resources in the field of nanotechnology. Four targets and 15 actions under these targets are determined in the plan. The need to make nanotechnology widespread in the country has been revealed. This plan is important for our country because it is the first strategy plan related to nanotechnology.

Despite the increase in numbers of scientific publications, patents and nanotechnology research centers, the stage being reached is not enough for Turkey. In this regard, Science, Industry and Technology Minister Fikri IŞIK made a statement on May 01, 2016 as follows:

> The number of R&D centers in Turkey is 250, 26,500 R&D personnel work in these centers, approximately 5.000 projects are executed, there is 1.060 registered patents and close 4.000 patent applications. It is aimed to increase the number of R&D centers to 1000 in 2017. R&D and innovation have become one of the indispensable elements of competition today. Countries supported by active R&D incentives are at the highest levels in the world competition rankings (Milliyet, n.d.-b).

With the figures given by the Minister of Science, Industry and Technology, Turkey ranks 51st on the World Competitiveness list. In the “Global Competitiveness Index 2015 - 2016 Report” published by the World Economic Forum, Switzerland ranked first among the 140 countries in the competition power, Singapore second, and USA third. Germany, Holland, Japan, Hong Kong, Finland, Sweden and the

United Kingdom are ranked in the top 10 in terms of competitiveness. According to the ranking in this report, the countries, in the top ranks, attach great importance to R&D and innovation. Ranking is shown in Table 3.13.

Table 3.13 Global Competitiveness Index 2016-2017, 2015-2016 And 2014-2015 Report.

	GCI 2016-2017		GCI 2015-2016		GCI 2014-2015	
Countries	Rank	Value	Rank	Value	Rank	Value
Switzerland	1	5,8	1	5,76	1	5,70
Singapore	2	5,7	2	5,68	2	5,65
USA	3	5,7	3	5,61	3	5,54
Germany	5	5,6	4	5,53	5	5,49
Holland	4	5,6	5	5,50	8	5,45
Japan	8	5,5	6	5,47	6	5,47
Hong Kong	9	5,5	7	5,46	7	5,46
Finland	10	5,4	8	5,45	4	5,50
Sweden	6	5,5	9	5,43	10	5.41
UK	7	5,5	10	5,43	9	5,41
Turkey	**55**	4,4	**51**	4,37	**45**	4,46

Source : (World, n.d.).

Although Turkey provided a significant improvement in competitive performance in the ranking of the GCI in 2012-2013, Turkey has been going back in recent years in the ranking of GCI. Turkey ranks 55th on the World Competitiveness list 2016-2017. When countries are examined according to their developmental stages, Turkey maintains its position among "Transition Countries from Productivity to Innovation" according to the report of 2015-2016 (Competition, n.d.).

The research centers, working in the field of nanotechnology, have been briefly informed in the previous section. In this section, detailed information will be given about some units which are carrying out important studies on nanotechnology in Turkey. By increasing the number of such centers, nanotechnology can be used more intensively in every field.

3.2.1 National Nanotechnology Research Center (UNAM)

UNAM was established in 2005 with the contribution of SPO to centralize R&D activities in various scientific and industrial fields. UNAM's founding mission is to increase the competitiveness of products, produced in Turkey, in foreign markets through nanotechnological applications and research. At the center, in accordance with the trends and developments in nanotechnology; subjects like nanobiotechnology, nanomaterialization, energy, chemistry, nanotribology, surface coating etc. are included in research topics.

UNAM was established in order not to stay away from the nanotechnology development. It is aimed to start the technology race, with financial, research infrastructure and equipment support of private institutions, SPO and Bilkent University. Materials Science and NT is master of science program carried out at UNAM.

Projects are conducted in cooperation with academic members of universities such as METU, Koç, Sabancı, Ege, Anadolu, Mersin, Kırıkkale, Pamukkale and Turkish scientists working in various laboratories of USA. Private-public-university collaborations are carried out at UNAM and in the context of various projects, with companies such as Roketsan, Arçelik, Güral Porcelain, Korteks, DYO and Atlas Carpets, joint R&D studies are also being carried out. The knowledge and experience gained is shared with science and industry circles in various forms. In cooperation with the Ministry of Industry&Commerce and the Bilkent Cyberpark, the establishment of "Nanotechnology Incubation Center" has been carried out in order to transfer the inventions and new methods developed in UNAM to the industry. In terms of university-industry-public cooperation, the incubation center is very important for Turkey. The Stanford Research Park, established in 1951 by Stanford University students, has allowed the formation of the Silicon Valley. Students studying at this center have established Silicone Valley businesses. Based on this example, UNAM aims to develop and commercialize the inventions obtained by the students and researchers. Finally the goal is marketing the nanotechnology outputs with the help of technoparks (Şahin, 2014).

UNAM has been striving for excellence in science and technology from the day it was established and has aimed to assume a leadership position in the areas of nanotechnology and nanoscience in Turkey. With 9,200 square meters of total space, including state-of-the-art shared facilities as well as 70 specialized laboratories housed in a six-floor building, UNAM is currently serving over 1,250 researchers both on campus and across Turkey. Thus, it is playing an important role in the advancement of science and technology in Turkey (Unam, n.d.).

64 projects were completed at UNAM up to now. There are a lot of on going projects currently. For example, a study is being done for the textile sector, which is very important for Turkey’s economy. Technological support is provided to the textile industry. Studies are being conducted on popular topics such as hydrogen storage, fuel cells, and tribology. In this context, for Turkey, which has a very large reserves of boron, the boron studies are very cucial. Some of the projects carried out in UNAM include the conversion of TNT into fertilizer, the production of electricity from solar energy, the bandages that allow the wounds to heal very quickly, and the self-cleaning carpet with solar energy (Şahin, 2014). These topics can also be used for military purposes. There will be various solutions to the problems that the soldiers face such as energy, survival, first aid etc.

3.2.2 Nanovak R&D Company Operating in Hacettepe Technokent

Nanovak R&D Company, founded in 2006 by Prof.Dr. H.Zafer Durusoy ve Dr. Recep Görür, in order to meet primarily Turkey’s needs in the context of vacuum and thin film coating systems. Nanovak R&D designs and produces vacuum systems, coating systems of vacuum and their parts. Products manufactured by Nanovak R&D can be characterized as private manufacturing. There is no serial production. Products, related to defense industry and NT research sectors are mostly examined. Nanovak is a flexible (Fabless) production company. It doesn’t have factory (Nanovak, n.d.).

Nanovak R&D has focused on nano-production devices worth millions of dollars with purely domestic resources. Prof. Dr. Zafer Durusoy stated that;

> They are active in the defense industry and nanotechnology with the seven-person R&D team and they can cost up these devices to 2-3 times cheaper than their counterparts abroad. Nanovak's products are used in the research laboratories of universities such as ODTÜ, Boğaziçi, Bilkent and Koç, in white goods production and in the defense industry. It is said that the technology developed in the Nanovak R&D, can only be done by countries such as Switzerland, Germany and Israel. Company sell regularly vacuum equipments to two companies in Europe. In 2013, two devices were also installed in the Egyptian National Research Center and six system orders were received from the UK. There is a great demand in the world market because ten different devices were manufactured much cheaper than competitors for research centers (Hürriyet, 2015).

3.2.3 Sabancı University NT Research and Application Center (SUNUM)

SUNUM is engaged in highly effective multidisciplinary research programs in advanced materials, nano-bio technology, nano-medicine, nano-electronics, nano-optics, micro/nano fluidics, micro/nano-electromechnaical systems and renewable energy systems. The multi-disciplinary laboratories of SUNUM houses advanced capabilities and equipment such as atomic resolution imaging and chemical analysis, fast gene sequencing for different cells, deposition of multilayers of few atom thick metals and dielectrics. SUNUM infrastructure is flexible and open to improvements to allow configuration changes to address future needs. The research infrastructure of SUNUM is accessible to all researchers from all academic, public and industrial institutions.

Sabancı University is setting up a genuine example for multi-disciplinary studies by "creating and developing together" strategy and "no departments, no walls" approach. Combined synergistically with the research expertise of the Faculty of Engineering and Natural Sciences, SUNUM allows application oriented research. SUNUM, in collaboration with academic and industrial partners, focuses on human-centric, safety-minded research and applications in advanced structural materials, healthcare, energy, the environment, agriculture, food and defense areas (Sabanci University, n.d.).

Twelve percent of the projects carried out by SUNUM include EU projects and thirty one percent of projects include industry cooperation projects. Three new technology-focused incubators have been established. Nanocomposites stand out as both structural and functional materials. Nanocomposites are used in lighter and stronger structures, aviation and automotive sector. Energy converter and storage materials are other issues focused on by SUNUM. Graphene studies are also very significant for this center. Participating in EU projects is an important objective for SUNUM. Intensive efforts are being made to bring new solutions to health issues. High nutrient grains, drought-tolerant grains, controlled-release natural fertilizers, and long shelf-life packaging are being studied intensely at the center. In the context of nanosafety, environment and water; The Center focused on the effects of nanoparticles on environmental and human health, water, air and soil cleaning (Özgüz, 2015).

3.3 Status of Nanotechnology in Turkey According to Vision-2023

The Supreme Council for Science and Technology (BTYK), has set a new 20-year Science&Technology Policy for 2023 (the first technology foresight study of Turkey) at its meeting in 2000 and TÜBİTAK was appointed for this task. As mentioned before, technology foresight studies were first applied in Japan in 1970. The success of the foresight studies led to the spread of such studies in Europe. As a result of all this, Turkey has started to implement a technology foresight for the first time in 2003.

In an environment where the scientific and technological developments are accelerating rapidly and the need to follow these developments is increasing; the main objective of the Vision-2023 Strategy Document prepared by TÜBİTAK is to create an affluent society with the ability to use technology consciously and capable of developing new technologies and possesses the skill of converting technological developments into social and economic benefits. While the basic elements of this objective are identified as education, health, transportation, agriculture, food, construction, infrastructure, energy, information, communication, defense, aviation, textile and environment, socioeconomic targets, supporting these items have been determined like that; to be competitive in the determined industrial production areas and having serious share from international trade, to improve the community's quality of life, to achieve economic development by providing sustainability in the designated production areas, to strengthen the ICT infrastructure in order to be able to adapt to change in the world.

The basic tools for achieving these goals have been determined as science and technology. In order to gain the ability to carry out the priority technological activities listed above, it is necessary to be able to become competent in the key technologies underlying these activities. These technologies, called "Strategic Technologies", are grouped under 8 main headings: (i) ICT, (ii) Biotechnology and Gene Technology, (iii) Nanotechnology, (iv) Mechatronic (v) Production and Process Technologies, (vi) Materials Technologies, (vii) Energy and Environment Technologies and (viii) Design Technologies. As mentioned in the Document, Nanotechnology is among the Strategic Technologies. Nanotechnology has strategic importance in achieving intended goals. Nanotechnology also has the power to increase the gap between weak and strong countries. Nanotechnology, which is extremely important in terms of national security, development, prosperity and competitiveness, is defined as an area that has the power to radically change human life and economic activities with new products and markets.

It is emphasized in the Strategy Document that nanotechnology, as a strategic technology, should be studied under the headings as: (i) Nanophotonics, Nanoelectronic, Nanomagnetisma (ii) Nanomaterial, (iii) Nanocharacterization, (iv) Nanofabrication, (v) Nano Scale Quantum Data Processing, (vi) Nanobiotechnology in the context of welfare, economy and national security. Nanotechnology roadmaps were prepared for each heading and strategic aims were determined. For example strategic aim of the nanobiotechnology heading was “Development of DNA diagnostic systems” or “Development of nanoscale quantum cryptography systems for commercial and military purposes” for Nano Scale Quantum Data Processing. Within all strategic goals, the phrase "military purpose" took place only in the Nano Scale Quantum Data Processing’s strategic aim (Tübitak, 2004).

As a result, the level of prosperity, economics and national security will be better in the countries that have this technology capacity compared to other countries. For Turkey, which has not been able to catch up with the industry and microelectronics revolutions in time, nanotechnology can be last opportunity.

Turkey's ability to evaluate this opportunity, as underlined by many Technology Foresight Panels, is crucial for the future.

In general, it can be said that the goals of nanotechnology shown in Vision-2023 strategy document can not be easily reached in 2023. However, it is difficult to capture R&D-related targets took place in the strategy document. Vision-2023 Goals and realized values in 2015 is shown in Table 3.14. In addition, the number of private companies studying nanotechnology is increasing day by day. The number of research centers and the number of university programs are raising rapidly. The shares allocated to nanotechnology R&D are increasing every year. NT conferences are held regularly every year at different universities. Researchers attend international conferences on nanotechnology. All these developments point to the fact that the future of NT in Turkey is promising.

Table 3.14 R&D Situation According to Vision-2023 Goals

	Turkey (2015) Realized Value	Turkey (2023) Goals
R&D Expenditure (% of GDP)	1,06	3,00
Business enterprise expenditure on R&D (% of GDP)	0,53	2,00
R&D expenditure per researcher	168,577 TL	280,000 TL
Number of Researchers	122,288	300,000
Number of business enterprise full-time equivalent researchers	66,036	180,000

Source:(Tüik, n.d.) and (Erdil et al., 2016).

Vision-2023 has been prepared with the aim of ensuring social welfare by directing science and technology studies to a common goal. Although the idea of planning in the Turkish economy started with the industrial plans prepared in the 1930s, the first development plan covered the years 1963-1967. Up to now, 10 development plans have been prepared and implemented. The tenth development plan covers the years 2014-2018. Studies are underway to prepare the eleventh Development Plan of Turkey which will cover the years 2019 - 2023. This plan coincided with the last period of Vision-2023 at the same time. Preparing technology foresight study and act in accordance with this plan for post-2023 period is important for social welfare, national security and development. Since Vision-2023 has been prepared, it has made very significant contribution to the development of Turkey's technology structure. Strategic technology areas are better focused thanks to Vision-2023. Because of all these reasons, strategic technology areas should be determined and foresight studies should be carried out for long-term period such as 2040, 2050 and 2071 years for Turkey.

3.4 NT Studies at MoND, TAF and Force Commands

TAF is one of the most structurally affected institutions from the July 15 coup attempt. The change and transformation activities initiated after the July 15 coup attempt changed the defense and security system structurally and functionally. Decisions of the Decree Law issued (KHK) have been subjected to significant structural changes in the defense and security mechanism of Turkey, especially the structure of the TAF. In this scope, the General Command of Gendarmerie and the Coast Guard Command are connected to the Ministry of Interior. Firstly, The Chief of General Staff is attached to the Presidency of Republic of Turkey while the force commands were linked to the MoND. Later on, The Chief of General Staff is also attached to the MoND. TMA, Naval Academy and Air Force Academy were connected to the newly established National Defense University while the military high schools were closed.

Every state needs to take all the necessary precautions against the potential threats to its existence, survival and security. Because of this requirement, states search to identify the challenges and opportunities through monitoring regional and global security environments. In order to fulfill this purpose, the National Security Council (NSC) is formed in Turkey. NSC is the highest unit at the center of defense and security policies. NSC is convened every two months under the chairmanship of the President, In other countries, it is possible to find such structures as NSC. National defense and security - related decisions are then reported to the relevant units of the state for the purpose of applying them. In this context MoND and Force Commands act in accordance with these decisions. New product and system development activities are mostly related to R&D, technology development and project management units of MoND and Force Commands.

The present situation of the national defense and security system of Turkey is generally summarized at the end of the Chapter 2. It is time to take a brief look at the historical background of the Turkish defense industry. In the first years of the Turkish Republic, some investments were made in a way that would constitute the foundation of national defense industry, and significant initiatives firstly were made especially in the arms, ammunition, aviation sectors, and the establishment of the General Directorate of Military Factories. During and after the Second World War, donations and grants provided by the UK and the USA, and military aid, which has increased with the entry of Turkey into NATO, have stopped the development of the defense industry, which has yet to be established. Nevertheless, efforts to develop weapon systems, tools and equipment needed by the TAF were tried to be kept on the agenda together with the R&D Department, established in 1954 within the Ministry of National Defense, but the desired results could not be obtained. As a result of the national reaction to the arms embargo against Turkey, Turkish Armed Forces Foundation (TSKGV) was established in 1974. After that the Foundation formed enterprises such as Aselsan, Havelsan, Aspilsan thanks to the donations. It was soon realized that the actual need for a contemporary defense industry could not be met through the Foundation alone. After all these efforts, the SSM was established in 1985 with the aim of enhancing the development and effectiveness of the defense industry and to meet the needs of TAF faster. Undersecretariat for Defence Industries (SSM) was born under Law No:3238. The R&D and Technology Department of the Ministry of National Defense was closed and linked to the SSM under the name of R&D Department in 2016. The R&D and Technology Department was formed in MoND in 2018 again. Currently, there are two R&D and Technology Departments within the national defense systems.

Until 2016, The R&D activities of the TAF are prepared, followed up and coordinated by the MoND R&D and Technology Department. The R&D Plan, prepared for this purpose, determined the policies, targets and priorities that would guide the national needs of the TAF to meet all of the mandatory national system requirements and the critical system needs of the TAF based on R&D. The National/Critical Systems and Technologies identification activities were carried out in accordance with the R&D Plan and Program through the Technology Panels established within the R&D and Technology Department of the Ministry of National Defense. In order to carry out activities such as providing a harmonious, participatory, and sharing business cooperation between TAF, research institutions, universities and industrial organizations in research and technology activities for ensuring coordination, compiling and storing technological information, providing easy access, mutual information exchange and consultancy services, Technology Panels were established. At the Technology Panels, basic trends and drivers in defense and space technologies were assessed, SWOT analysis was conducted, technological trends for the future were identified and their priorities were listed for National/Critical Systems and Technologies. The final list of national/critical systems and technologies was published to the Chief of Staff and SSB. The National/Critical Systems and Technologies list was updated every two years on Technology Panels. There were nine technology panels including information systems, sensor and electronic systems (containing nanotechnology/NEMS), aviation and space systems, land vehicles, navy vehicles, materials and processes, Chemical, Biologic, Radiologic and Nuclear, weapon systems and energic materials.

After July 2016, radical changes were made in defense and military systems. As mentioned before. The force commands were connected to the MoND. Military factories and shipyards were removed from the Force Commands and connected to the Ministry of National Defense. Nanotechnology studies in the Force Commands are usually carried out within the technical and project management departments. In order to increase the operational capability of the warriors and to ensure that the TAF is strong in all cases, the technological developments that occur domestically and abroad are monitored and controlled by the relevant units of each Force Command. For this purpose, although the name of the organization defined differently by the force commands, for determining needs, conducting R&D, sharing information with the defense industry firms and various private/public institutions, some departments were established in which military and civil engineers work together.

Finally, The SSB was tied to the President with the Decree Law No.KHK/696 published in the Official Gazette no.30280 dated 24 December 2017. Before that, SSB was linked to MoND. In 2018, it has been restructured as the Presidency of Defence Industries by the Decree Law No. 703. With the "Presidential Decree on Defense Industry Presidency no.7" organization, duties and responsibilities have been regulated. Important tasks have been given to the Presidency of Defence Industries in order to "develop a modern defense industry and ensure the modernization of the Turkish Armed Forces".

In the context of defense systems very successful products and applications have begun to emerge as a result of the joint efforts of civilian and military personnel especially in last decade. The NANOAYGIT Project is an example for this. It is one of the biggest projects carried out by TAF in the field of nanotechnology and supported by TUBITAK and carried out by MoND R&D and Technology Department at Bilkent University NANOTAM, finished in 2012. NANOAYGIT Project Director and President of NANOTAM Dr. Ekmel Ozbay said:

> With the achievements of the project, the important infrastructure and know-how gained for the many needs of the defense industry in nanotechnology in Turkey, until recently that nanotechnology is considered as the basic R&D and it is assumed that it will take many years to enter into practice and stressed that nanotechnology came to the point of being "real for TSK" with the completion of the Project.

NANOAYGIT Project has been carried out in four different subjects. First, nanobiosensors sensitive to biological warfare agents and nanosensors sensitive to chemical warfare gases have been developed. Thanks to its nanoscale dimensions, these nanosensors, operating in the ultraviolet wavelength range and made for the first time in the world, have high sensitivity. Improvement of detection time is improved 20 times or more by producing nanosensors sensitive to different biological agents on the same base.

In the second study carried out under the project, ultraviolet nano light sources and nanophotodetectors were designed and produced. These studies, which have been carried out for the first time in the world in the ultraviolet wavelength, have an important advantage in terms of size, weight and power consumption to the TAF’s electrooptic systems of today. These new technologies, also called nanophotonics, will be used especially in missile warning and night vision systems in order to obtain much more precise and remote imaging.

In another study of the NANOAYGIT Project, nanotransistors based on gallium nitride (GaN) have been developed for use in high power radio frequency (RF) systems. It is aimed to use GaN technology, which is in the fast development stage in the world and developed nationally, in both civilian and military areas. GaN nanotransistor technology is expected to be used in Radar, Satellite Transmitter, Jammer and next generation mobile phone systems. This will meet the critical RF integrated circuit requirement of Turkey's communications field.

Finally, carbon based nanotransistors have been developed. With this new nanomaterial named Grafen, which won the Nobel Prize in 2010, nanotransistors and integrated circuits operating at very high frequencies were produced for the first time in Turkey. It is aimed to use graphene-based nanotransistors, which are expected to replace silicon-based transistors used in computers, in both IT and communication technologies (Kasap, 2012).

Another sample successfull study is AB-MikroNano. This company was founded in 2014 in partnership with ASELSAN and Bilkent University. It was founded to produce GaN-based chips that are strategic for defense, space, communications and energy sectors. Turkey will be one of the countries that produces strategic technologies such as air defense radar, electric car, high-speed train and 4G/5G mobile phone systems thanks to the GaN-based chips produced in this facility. Gallium Nitrate is a new semiconductor material that has been extensively studied all over the world in recent years, with the reason for its superior physicsal properties. This facility is located within Bilkent University campus. The nanotransistor technology based on GaN semiconductor material supported by TÜBİTAK and the SSB was developed nationally by ASELSAN and BILKENT (Aselsan, 2014).

3.5 Analysis of the NT Subject of the SSB’s Defense Industry Vision

SSB, established with the law 3238 for the development of modern defense industry and the modernization of TAF, contributes to the utilization of technological weapons and systems by preparing strategic plans and technology map. In this sense, there are some plans prepared in last decade. Crucial information has been given about the strategic objectives in these plans. The role of the defense industry for meeting the needs of TAF are explained in detail. The comparative information about strategic documents prepared by SSB is given in Table 3.15.

Table 3.15 The Comparative Information About Strategic Documents of (SSB)

Document Name and Period	Main theme / strategic purpose	Strategic fields/targets	"Nano" word usage in the plan
Strategic Plan 2007-2011	To meet the system requirements of TAF and the government organizations those promote the national defense and security; to establish and implement the strategy and procedures for the development of defense industry	Indigenous share will be increased to 50% and the exports of defense industry products and services will be realized as at least 1 billion USD in 2011	-
Sectoral Strategy Document 2009-2016	Strategies have been determined separately for each sector.	Land, Marine, Air Vehicles, Electronic Warfare and Sensors, Communication Electronics and Information Systems, Missile, Ammunition and Weapon Systems Sector Strategies	Three times

Table 3.15 (cont'd)

Document Name and Period	Main theme / strategic purpose	Strategic fields/targets	"Nano" word usage in the plan
Technology Management Strategy 2011-2016	Ensuring sustainable and competitive technological competence in the defense industry.	Six different objectives have been identified for the defense industry.	Fifteen times
Strategy Plan 2012-2016	To manage industrialization, technology and procurement programs that will continuously improve the defense and security capabilities of our country.	Four different strategic aims and thirteen strategic targets have been identified for the defense industry.	Seven times
Strategy Plan 2017-2021	Technological Depth and global activity	Speed, Quality and Cost Efficiency in Modernization Projects, Productivity Management for Capability Gain, Combining Technological Innovations with Scientific Accumulations and Experiences and Strategic Human Resources and Strong Corporate Governance	Once

In the plans covering the post-2010 period, "nano" expression has been given more according to the Table 3.15. "Nano" statement used 102 times in Vision-2023. It is assessed that it will be useful to give more emphasis to nanotechnology in the future plans. Strategic goals and objectives have been well defined In these plans. It is possible to come across good practices that guide the defense industry. Many defense industry products were presented to the use of the TAF. Since 2004; Milgem Ship, Altay Tank, Atak Helicopter, Anka and Bayraktar Unmanned Aerial Vehicles, New Type Patrol Boats, Rapid Intervention Boats and National Infantry Rifle are the results of the projects.

Thus defense industry's external dependency is reduced. The indigenous share has increased to 60%. SSB used some methods when doing these successful studies. Excellence network (MÜKNET) is an example for this. MÜKNETs have been formed from working groups consisting of university-industry-research institutions. The main aim of MÜKNET is to maximize the utilization of existing sub-structures within industry, universities and research institutes. One of the 12 areas of MÜKNET is micro and nano technology. Numerous projects are still being carried out in this area, which offers significant opportunities especially for university and industry cooperation. Micro and nano scale system and material technologies require special design and production techniques. In this regard, following the nationalization of the necessary infrastructure requirements, the following subjects are the priorities within the research areas: Strategic Antenna Structures, High Frequency and NT Transistor and Module Technologies, Smart Textile Materials Technologies, Armor Materials Technologies, MEMS and MOEMS Technologies, Short/Medium/Long Wave Infrared Sensor Technologies and Basic Laser Technologies (SSB, n.d.-d).

Currently over 400 projects are being carried out within the SSB. According to the data issued in 2015, total defense and aviation sector turnover reached five billion dollars annually and defense&aviation exports amounted to 1,655 billion dollars. As of 2015, the total expenditure on R&D activities reached 904 million dollars annually. A large increase in the number of large and small scale firms operating in the sector has been achieved, and a great depth of industrialization has been achieved by bringing about 130 defense industry companies at the level of the SMEs. Despite the fact that indigenous share rose from 41.6 per cent in 2007 to 54 per cent in 2011. External dependence on this area still continues. In developed countries this ratio is between 85 and 95 percent.

Within the SSB, Department of R&D & Technology Management follow technological developments and carry out projects with the aim of introducing new products. In this context, Department of R&D & Technology Management conducted a study on nanotechnology within the scope of advanced materials and energy projects named NANOKAP. Aim of the study was that; development of nano based coatings to improve the lifetime and field performance and also reduce the operational costs of the equipment, tools, units and instruments to be used in land, sea, air and space applications. In this Project, Prime/Sub Contractors were Bilkent University, Atatürk University and ROKETSAN A.Ş (SSB, n.d.-b).

SSB has made important contributions to Turkish defense industry up to now. SSB has also been working on the modernization of the TAF since 1985. SSB makes intensive efforts to make the TAF one of the strongest armies in the region and in the world by using the most advanced technology with its strategic plans and technology road maps.

CHAPTER 4

METHODOLOGY

This chapter describes the methodology used in the thesis. Bibliometric analysis, interview and survey were used in a hybrid method. The aim, signifiance, scope, research questions, sub-research questions and statistical methods used in the research are included in this chapter. At the end of the Chapter 4, a nanotechnology roadmap was presented for the Turkish Defense Industry.

The methodology of the present study consists of three main stages. **First stage** is a review of the military nanotechnology literature, which was presented in the Second Chapter. In other words, an overview of nanotechnology, military technology trends, changing structure of the war, military applications of nanotechnology, situation of Turkish Defense Industry and defense planning strategy of Turkey subjects are examined in detail.

The second stage of the study consists of a bibliometric analysis of publications on nanotechnology. Bibliometric analysis means analysis, regulation and discovery of large-scale data by using mathematics and statistical methods in order to identify new patterns of historical data (Daim et al., 2006) and (Norton, 2001). Bibliometric methods contribute to science and technology studies for decades (van Raan, 2004). These methods help to researchers for finding hidden patterns by classifying information like writers, keyword, phrases, organizations, countries, cooperation, references etc. A number of tools are used in the bibliometric studies including counting simple document, word frequency analysis, citation analysis, co-word analysis, cluster analysis and collaboration analysis. Thomson Data Analyzer, The VantagePoint and CiteSpace are among the software programmes used for analysis.

The development of nanotechnology in the world with the publication analysis and outstanding issues were examined in the context of publishing trends such as subject, keyword, author, supporting organizations and research units by analyzing the most cited 50,000 articles from the Web of Science database in the last decade.

In this study, Arora et al., (2013)'s keyword set is used, which is the latest set used by the Georgia Tech University.

After conducting bibliometric analysis, the prominent words of bibliometric analysis were asked to the experts working at three different institutions in order to determine the commercialization time of the featured words. According to the results of the interview, a survey applied to the engineers working at Department of R&D and Technology at MoND in order to detect which NT applications can be used in military systems in the future.

Finally, **the third stage** of the study involves construction of a roadmap for the Turkish Defense Industry. Main strategies and sub-strategies are determined for the defense industry. Finally conclusion and policy recommendations are given at the end of the thesis namely Chapter 5 and Chapter 6.

4.1 Aim of the Research

Nanotechnology, which brings all the scientific fields together and aims cooperation, has emerged as the technologically most radical innovation after the industrial revolution. Nanotechnology points to a field that has potentially radical innovation in many areas from health to defense sector, from daily vehicles to spacecraft etc. In this sense, the Vision-2023 Strategy Document also shows that nanotechnology is of critical importance in the context of welfare, economy and national security for Turkey.

The main purpose of this study is to create a nanotechnology roadmap for the Turkish Defense Industry by focusing on nanotechnological developments based on the world trends and to suggest alternative research strategies in the field of NT. Eventually, it will help to form a basis for R&D and innovation activities in Turkey. The main objectives that should be carried out in order to achieve this basic goal are as follows: to examine the most cited nanotechnology publications by using the Web of Science database with the technology mining applications published between 2005 and 2014 worldwide and to identify 'weak signals' for possible developments in nanotechnology, to detect commercialization time of nanotechnological applications, to find usage of nanotechnological applications in the military systems.

As a result, the gap between the Turkey and the world trends was analyzed and suggestions were made related to alternative research strategies in the light of the compared data.

4.2 Significance of the Research

An in-depth investigation of the nanotechnology is considered to provide a new insight into the strategy of nanotechnology for Turkey and Turkish Defense Industry. Thus, a different interpretation of politics may be uncovered in relation to nanotechnology in terms of information capacity, cooperation and future technologies. Because technology mining practices analyse very high volumes of data to reveal unseen trends in them and weak signals that could lead to change in the future, and alternative research topics can be put in line with these trends. Strategies to be developed in the direction of these alternative research subjects will ensure that defense industry will be prepared to the different aspects of nanotechnology field with innovative approaches. It is not prepared such a road map for the Turkish Defense Industry up to now.

It is stated in the literature that nanotechnology is among the emerging technologies that are likely to direct the future. Rapid developments in nanotechnology and efforts to keep pace with these developments are causing changes in every field. As can be seen in the literature review and recent trends, it can be said that the studies carried out in this area are of a wide variety and even in a way that will force people's dreams.

Important studies on nanotechnology have started to be made in Turkey since 2000s. According to Counsil of Higher Education (YÖK) Thesis Center’s records; the first thesis, in which "Nanotechnology" was written in the title was carried out in 2002 and there are a total of 75 theses conducted in Turkey up to now, including master's thesis and doctoral dissertations passing "nanotechnology" in the thesis title. The first thesis written in 2002 is in the field of mechanical engineering and the it’s name is “Nanotechnology and mesoscopic mechanical engineering”. The first doctoral dissertation was made in the field of textile in 2006 named “Advancing the performance properties of sportswear fabrics by nanotechnological products and the comparison of application techniques” (Higher Education Counsil, n.d.).

Theses are generally concerned with topics such as medicine, chemistry, physics, material science, education, food and textiles. The number of studies that emphasize the importance of nanotechnology in the defense industry and which are expected to give direction to the defense industry is frankly just a few.

4.3 Methodology of the Research

There are many different studies in the field of nanotechnology all over the world. Many things that have previously been seen as dreams, have already been realized. In fact, imagination is the first step in realization. It is important to estimate the situation of Turkey in nanotechnology. Reaching scientific publications and studying national researchers’ efforts enabled to reveal the real situation. It is thought that bibliometric studies which is one of the technology mining methods will contribute to this process at this stage. Norton (2008) defines bibliometric studies as a measurement of text and information. The collection, organization and analysis of large quantities of data via bibliometrics methods makes it possible to identify past and future trends to be observed (Daim & Suntharasaj, 2009). With the road map proposed in this thesis, by using the Web of Science database, it has been defined the fields of scientific and technological developments related to nanotechnology using key words and expressions suggested in the literature. The level of competence in the world and in Turkey in these issues has been revealed on an institutional, personal and subject basis. Clues for strategies on R&D studies planned for the future were also given by using analysis of publications.

After the bibliometric analysis, detailed interviews were held with experts from UNAM, GUNAM and SUNUM. Interviewing is one of the most commonly used data collection techniques in social sciences. There are different types of interviews in the literature. These types are located between structured and unstructured interviews

(Ergün, n.d.). In this thesis, structured interview (standardized open-ended interview) method is used. According to (Ekiz, 2003), structured interviews take place in qualitative research methods. Data were gathered in order to reveal the period of commercialization of prominent keywords on frequency basis for Turkey. All participants were asked the same questions. Both closed-ended and open-ended questions were used. Four of the experts are working at UNAM and GUNAM, located in Ankara and two of the participants are working at SUNUM, located in İstanbul. At the end of the interview, the obtained data and the thesis topic are merged. After the interview, a survey was applied to the engineers working at the Department of R&D and Technology, MoND. In this survey, engineers were asked which nanotechnology applications will be implemented and when in military technologies.

As a result of the analyzes and evaluations made, the Nanotechnology Road Map was prepared for the Turkish Defense Industry. The methods and techniques used in the technology roadmap processes also vary. Technology roadmap is a structured approach that enables mapping the evolution of complex systems development (Phaal et al., 2011). Technology roadmap is a method widely applied in the company and sectoral level in determining strategies, policies and innovation. It is a clear and effective planning tool for future development of the technology highlights (Robinson & Propp, 2008). Technology Roadmap is also a useful tool in an environment where intense environmental change can be seen. In this sense, (Gerdsri, 2007) suggested the Technology Development Envelope concept. The technology roadmap has been made more dynamic, more flexible and more applicable with this suggestion. (Robinson & Propp, 2008) developed the multipath mapping method and suggested that this method aligns the forefront science and technology fields.

However, the conventional technology roadmap models also have some limitations. For example; workshop processes are based on the instinctively knowledge of participating experts that this information sometimes can be subjective and biased. In contrast some new tailored quantitative analysis using objective data such as publications, patents, literature and business data assist in the analysis of the technological innovation that exists. These analysis that based on data can help to reduce bias and subjectivity. A potentially useful method for this purpose is bibliometnc analysis (Saritas & Burmaoglu, 2016). Researchers can reflect the analysis findings to the decision-making process with bibliometric analysis. This method is widely used for the foresight of new technologies and prominent research topics (Shibata et al., 2008) and (Kajikawa et al., 2008).

The methods and techniques used in technology roadmapping process are also varied. Some of the techniques and methods are as follows; brainstorming, survey (Kim et al., 2009), delphi questionnaire (TÜBİTAK, 2003) and (Saritas & Oner, 2004), scenarios (Saritas & Aylen, 2010), SWOT analysis (Lee et al., 2007) ; (Lee et al., 2009), bibliographic analysis (Rödel et al., 2009), (Kim et al., 2009), (Lee et al., 2009) and (Daim & Oliver, 2008), patent analysis (Kim et al., 2009) and (Lee et al., 2009) and Analytic Hierarchy Process (AHP) (Kim et al., 2009).

In this study, survey, interview and bibliometric analysis methods were used in an integrated way. Firstly, a bibliometric analysis was conducted with the nanotechnology publications. (Arora et al., 2013)'s search query is applied from Georgia Technology University. Different preprocessing methods can be applied such as detecting duplicate and misspelled items, time slicing, data reduction and network preprocessing. In the present study duplicates were identified and cleaned by using the VantagePoint Software (VantagePoint, n.d.). After the preprocessing phase data reduction is carried out in order to select the most representative data for the analysis, so it is done after the de-duplicating process. Once the data has been preprocessed a network is built using a unit of analysis, as for example, journals, documents, cited reference, authors, author's affiliation, and descriptive terms or words (Börner et al., 2005). Generally, words are the most common used item for network analysis. These words can be selected from the title, abstract, author's keywords, and body of the document or some combinations of them. In this study author's keywords were selected for co-word analysis. After that, the findings of bibliometric analysis were interpreted by the experts.

The interviews were held face to face through one month period because of the time restrictions and availability constraints of the experts. After verifying bibliometric results with the interpretations of nano-experts, featured topics were also obtained based on the bibliometric results. Then, the results were interpreted with their implications for the defence industry.

Surveys were conducted with military engineers working in the Ministry of National Defense R&D and Technology Department. With this survey it is aimed to understand which nanoapplications will affect the military field in future. Finally, a nanotechnology roadmap for the Turkish Defense Industry was formed. General strategies and sub-strategies are determined finally. In the context of this thesis, survey, interview method and bibliographic analysis were performed.

The activity of the roadmap creation, mentioned above, is a result of technology foresight, which allows long-term critical decisions to be taken. Technology foresight makes it possible to put forward the role of technology in building a long-term future. Technology foresight determines the critical/strategic decisions that need to be taken in the context of science and technology to enable the realization of the predicted vision of the future of the country (Göker, 2004).

(Martin, 1995) defines technology foresight as a long-term effort to look at science, technology, economy and society systematically and states that the aim of the technology foresight is to identify the emerging generic technologies and strategic research areas that can generate the highest economic and social benefits.

There are a number of well-known tools used in technology foresight studies such as technology evaluation, trent analysis, strategic planning, setting priorities, preparation of targeted and functional science and technology budgets, field scans, R&D statistics, patent indicators, and so on that feed each other to create synergistic effects. In this way, foresight studies have taught actors of the study to think systematically for long-term and to look at their own field from a wider perspective and even more importantly to show the ways to overcome limitations specific to their field. Foresight studies in this sense are of particular importance for developing countries that do not have such a culture (TÜBİTAK, 2001).

Outputs of the foresight process can be represented as a set of policies, products, programs, processes, and many other socio-economic activities and networks of cooperation. The most commonly used methods in technology foresight studies in the world are panels, delphi questionnare and scenario methods; there are examples where two or more of these are used together. Strategic document and road map creation activity is carried out after foresight studies (Göker, 2004).

Technology foresight can be expressed as an applied method for understanding the trend of technology development (Wonglimpiyarat, 2007). The use of foresight may provide informational support to assist the public policy making process. Many countries have used foresight method to assess and determine scientific and technological developments which had a significant impact on industrial competitiveness, prosperity and quality of life to promote industrialization (Martin & Irvine, 1989) and (Costanzo, 2004).

The technology foresight emphasizes that technology can be predicted and thus suggests planning for output that is desired in the future. But, there are some limitations for the R&D investments to be considered for the enhancement of science and technology capabilities. In other words, the impact of technology development driven by the inadequate allocation of resources at the national level and the foresight study may not be visible in the output of industrial structures. Policy makers may not be able to contribute to technological capabilities, industrial needs, labor force and other national innovation systems components, due to reasons such as not being sufficiently expert, the misjudgment of priorities, and inability to select technologies properly (Wonglimpiyarat, 2007). Because of all these reasons, a well-organized foresight activity is crucial.

According to (Wonglimpiyarat, 2007), the process of foresight consists of four stages. These stages are respectively pre-foresight, foresight, post-foresight, and implementation&evaluation. It is suggested that the priorities of science and technology should be determined at the pre-foresight stage. Delphi, Brain Storm and Scenerio writing methods are carried out in the foresight stage. The results are disseminated and policies are applied at the post-foresight stage. In addition, proposals can be made to public and related organizations at this stage. In the implementation and evaluation phase, it is evaluated whether the science and technology strategy is harmonized with the Ministry of Industry and Technology and related institutions.

4.4 Scope and Limitations

This study is prepared for Turkish defense industry. In the study, over the last decade (covering 2005-2014), 50,000 articles published in the Web of Science database on which the keyword set could be applied were analyzed by bibliometric method. Interviews were held with six specialists working at UNAM, GUNAM and SUNUM which are the leading units of Turkey in nanotechnology and advanced technology. The survey was applied to engineers in different branches working on military issues at the MoND R&D and Technology Department.

Because of the chosen research approach, the research results may lack generalizability. Therefore, researchers are encouraged to test the proposed suggestions further. Interviews and surveys have limitation with the bounded rationality of participants. The thesis proposed a nanotechnology roadmap for the defense sector with a data-led foresight practice. Performing such a study is considered to be crucial for the armies of developed and developing countries, so that the military sector also avails benefits from this revolutionary technology. Quantitative and qualitative methods were mixed for developing the roadmap.

4.5 Research Questions

There are two basic research questions in the thesis. Six sub-research questions related to basic research questions were identified.

The first question is : When examining the most cited 50,000 nanotechnology publications in the last decade in the world, what kind of structure do nanotechnology researches show? and what are the technology alternatives that these technologies are matched in the defense sector?

The second question is : How can a technology roadmap in the field of nanotechnology be prepared for the Turkish defense industry in the light of the aforementioned trends and developments?

Sub-research questions prepared for these basic research questions and the questions to be answered in the thesis are given ike that; first sub-question : What are the focused areas according to the the most cited 50,000 nanotechnology publications in the last decade in the World? The second sub-question : What can be the commercialization time of nanotechnological products&applications and in which military systems can be used these nanotechnological products&applications? The third sub-question: How can nanotechnology issues be imported into the Turkish defense sector that are focused in the world? The fourth sub-question: What strategy can be proposed for the defense sector in the light of the analysis in predictable, foreseeable and probable time? The fifth sub-question: Which strategies and sub-strategies can be proposed to defense industry of Turkey? And finally sixth sub-question: What kind of a picture is reached when the studies made in Turkey and in the world are compared? What are the differences and similarities between the studies conducted in Turkey and the World's publication trends in the light of the analysis?

4.6 Data and Statistical Method

Theoretical studies related to nanotechnology area were carried out by literature review. National and international studies on publications, laws, regulations and general publications of public institutions and organizations scan have been conducted in order to determine the current status of nanotechnology in Turkey and in the world. In this study, advances in nanotechnology were examined with bibliometric analysis which is one of the technology mining methods.

To achieve this purpose; firstly with the publication analyzes, the development of nanotechnology in the world and the outstanding topics have been reviewed in the context of publications trends; subjects, keywords, authors, supporting organizations and research units by downloading 50,000 articles from the Web of Science database. In this study, (Arora et al., 2013)'s keyword set is used, which is the latest set used by the Georgia Tech University.

Featured topics were obtained from the authors' key words. After bibliometric analysis, interviews were executed. Interviews were held with experts from UNAM, GÜNAM and SUNUM to determine the commercialization time of prominent words. So that data was collected from the experts. Later on, in order to detect the issue, in which military systems can be used nanotechnological products&applications and when, a survey was applied to engineers working at MoND.

4.6.1 Bibliometric Analysis

The process of examining the subject which started with the Lexical Search Query Strategy has been carried out by deciding the Search Query Strategy, removing the data from the database and clearing them for analysis and performing the analyzes and interpreting the findings. The Lexical Search Query Strategy methods are the most widely used research method in the literature of bibliometric analysis studies (Gorjiara & Baldock, 2014, p. 123). Using these methods, it is possible to analyze the information such as the getting the publications from the databases, in which fields the most study conducted, which journals are most frequently published, which subjects are mostly concentrated and the publication trends.

There are many researchers who used the Lexical Search Query Method in the field of nanotechnology. In this sense, (Braun et al., 1997) can be considered the first researchers to use the Lexical Search Query. They analyzed the articles written between 1986 and 1995 in the field of nanotechnology.

One of the Lexical Search Query Strategy Methods used to create a set of keywords was developed by (Kostoff et al., 1997). This method is named as "Iterative Relevance Feedback Technique/Relevance Feedback Search Approach of Simulated Nucleation".

Among the important researchers who have used the Lexical Search Query Strategy Method are Meyer, Debackere and Glanzel. (Meyer, Debackere, & Glänzel, 2010) refers to (Glanzel et al., 2003) for their set of keywords.

The Lexical Search Query Strategy Method, which was expanded and developed by (Porter et al., 2008), is a reference for many articles on nanoscience and nanotechnology. The method was then updated and expanded with the contribution provided by Arora. Developed version of the Lexical Search Query Strategy mainly consists of two steps.

The first step includes a set of eight modular (unitary) components from the broadly inclusive query set, such as nano, to techniques and tools. In other words, eight basic modular clusters are used in the first step. These clusters are, for example; cluster used to scan all articles written on nanotechnology in databases and created with nano, cluster used to scan articles written on various topics that do not include the nano prefix but are presumed to be related to nanotechnology (such as molecul or motor) and Sub-clusters containing the most widely published journals on nanotechnology (such as Digest Journal of Nanomaterials and Biostructures). All modular components are entered in the titles of the articles, in the summary part and in the databases so that the parts of the keywords are scanned.

If the modular word set consisting of eight components is expressed in more detail, the first component is an inclusive query set “nano”. The second component is “quantum”. The third component is “self-assemly”. The fourth component has been created to capture the other articles written on nanotechnology-related terms that cannot be captured while scanning with the nano. For example, although fulleren does not start with nano, it is one of the basic keywords of NT. The fifth component is named microscopy terms. The sixth component is “nano-related”. It provides a scan with a wide range of terms. The seventh component is also called nano-related, but unlike the sixth component, it allows for a narrower scan. The eighth and final component allows you to scan articles specifically related to NT journals. As mentioned above, it is possible to capture articles written on terms which are not directly related to NT but which are not related to nanotechnology.

The second step involves excluding from analysis process. This step is intended to make the nano-scan set clear and precise. (Arora et al., 2013) determined forty keywords for this step. These keywords consist of keywords that have taken the nano prefix but containing nano scale calculations and are not directly related to nanotechnology. Two basic modular components have been created to determine which keywords are excluded from analysis. In the first modular component, articles with specific non-NT terms are removed. In the second modular component, articles with only nano measurement terms are removed.

The other properties of the method updated by (Arora et al., 2013) are like this: this original scanning process consists of mainly two steps. In the first step, the terms / keywords to be included in the scan are determined, in this step, thirty-four new terms have been added to the keyword set used by (Porter et al., 2008). In the second step, a list of updated non-analysis terms was used to remove or delete out of scope and/or unwanted records. All scans have been done in the abstract, title and keywords section of the Web of Science database.

As a result, bibliometric analysis was carried out on the basis of nanotechnology by using the Lexical Search Query Strategy. Moreover, due to the dynamic nature of the method, it has been seen that it needs to be continuously updated and developed in the light of future developments. It can be said that these developments can be done with the inclusion and exclusion perspective.

Keyword clusters of NT have been formed for many years and have been widely used in studies conducted in this field. In this context, the detailed information about (Arora et al., 2013)'s keyword set is given at Annex A. As a result of the evaluations, it was concluded that this keyword set can be used for the thesis study.

"Lexical Search Query Strategy" and "bibliometric equations" are used in the analysis. These equations help to test whether the numerical ratings for publications are consistent and these equations help to understand whether growth rates present a trend or not. The keyword set used in the thesis is presented in Table 4.1.

The most cited 50,000 nanotechnology publications were downloaded from WoS database based on the (Arora et al., 2013)'s search query. When the data parsed with VantagePoint software, a cluster including 130 research areas, 119 countries, 1048 universities and 1906 authors were obtained. Initially, it has been focused on the keywords of the most cited studies in terms of shedding light on the policy development studies and trying to understand what these keywords are concentrated in.

Thus, the keywords used by the authors of the first 1,000 most cited publications in the last decade are clustered by principal component analysis and it was mapped with Aduna Clustering Algorithm shown at Figure 4.1.

Based on the map, 17 main clusters were obtained, among which; "**nanoparticles, nanostructure, self-assembly, drug delivery, graphene, carbon nanotube, nano composites, nanotechnology, electrospinning, quantum dots, nanoparticles, adsorption, gold, mechanical properties, photocatalysis**" came to the fore.

Table 4.1 Keyword Clusters Used in Research (Porter et al., 2008)

Cluster	Keyword Clusters Used in Research
#11	#10 AND #9
#10	Topic=((monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array* or molecul* or polymer* or (co-polymer*) or copolymer* or mater* or biolog* or supramolecul*)) OR Topic=((monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array*))
#9	#8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1
#8	Topic=(TEM or STM or EDX or AFM or HRTEM or SEM or EELS) OR Topic=(atom* force microscop*) OR Topic=(tunnel* microscop*) OR Topic=(scanning probe microscop*) OR Topic=(transmission electron microscop*) OR Topic=(scanning electron microscop*) OR Topic=(energy dispersive X-ray) OR Topic=(X-ray photoelectron*) OR Topic=(electron energy loss spectroscop*) AND Topic=(MolEnv-I) NOT Topic=(nano*)
#7	TS=(SELF ASSEMBL*) OR TS=(SELF ORGANIZ*) OR TS=(DIRECTED ASSEMBL*) AND TS=(MolEnv-I) NOT TS=(nano*)
#6	SO=(fullerene* or ieee transactions on nano* or journal of nano* or nano* or (materials science & engineering C - biomimetic and supramolecular systems) NOT nano*)
#5	Topic=(biosensor*) OR Author=(sol gel* or solgel*) OR Publication Name=(dendrimer*) OR Topic=(soft lithograph*) OR Topic=(molecular simul*) OR Topic=(quantum effect*) OR Topic=(molecular sieve*) OR Topic=(mesoporous material*) AND Topic=(MolEnv-R) NOT Topic=(nano*)
#4	Topic=(pebbles) OR Author=(NEMS) OR Publication Name=(Quasicrystal*) OR Topic=((quasi-crystal*)) AND Topic=(MolEnv-I) NOT Topic=(nano*)
#3	Topic=(((molecul* motor*) or (molecul* ruler*) or (molecul* wir*) or (molecul* devic*) or (molecular engineering) or (molecular electronic*) or (single molecul*) or (fullerene*) or (coulomb blockad*) or (bionano*) or (langmuir-blodgett) or (Coulombstaircase*) or (PDMS stamp*)) NOT nano*)
#2	Topic=((quantum dot* OR quantum well* OR quantum wire*) NOT nano*)
#1	Topic=(nano*)

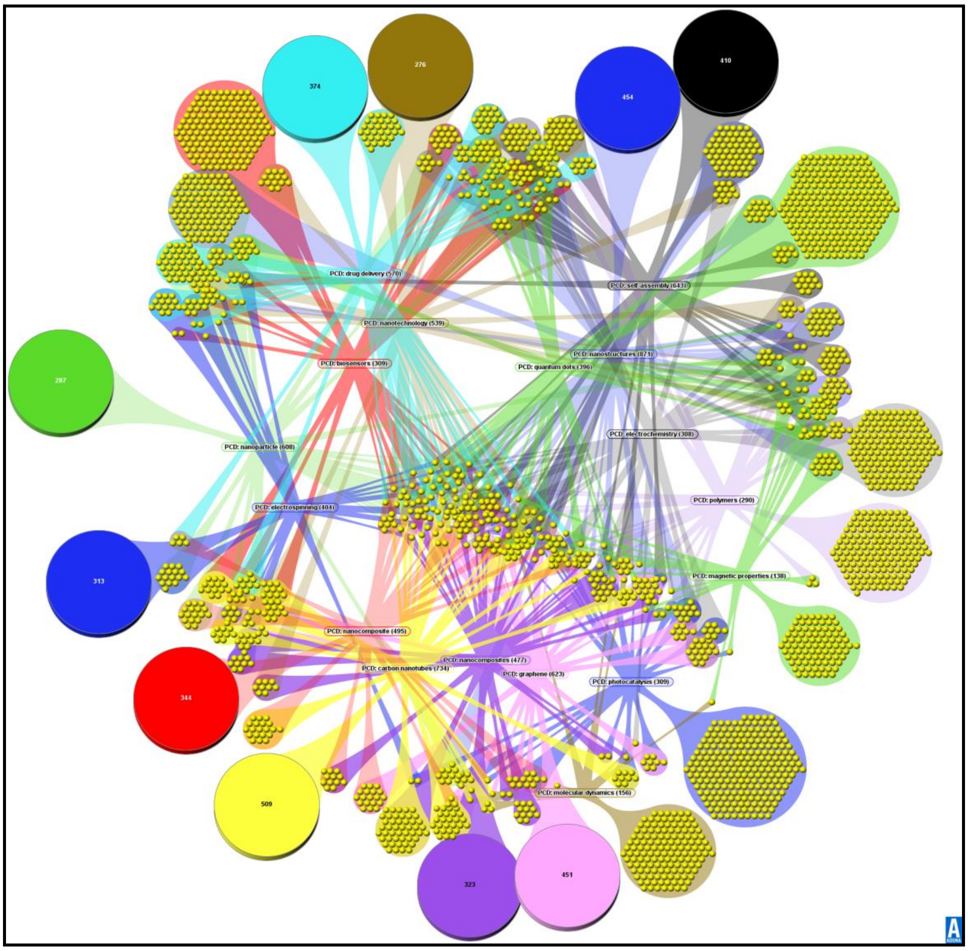


Figure 4.1 : Aduna Cluster Map of Keywords Used by the Authors of the First 1,000 Most Cited Publications in the Last Decade.

When Figure 4.1 is examined, it is observed that 17 main clusters are formed. Some of them address the characteristics of nanotechnology whilst the others refer to the products directly. Polymers, nanocomposites, graphene and carbon nanotubes stand out in the most cited publications at last decade. It is observed that the properties like drug delivery, magnetic properties and self-assembly are located in the research area as well.

In a nationally funded project which was conducted by (Burmaoğlu, 2015), a remarkable presence of graphene, which has an important position in the world literature, was observed. In addition, in the map created by using the most cited publications worldwide, the tools used in nanotechnology (AFM, XRD etc.) can not be seen as a set, they can be seen in the map that created for Turkey. Based on the (Burmaoğlu, 2015)'s findings, Kleinberg's "sudden emergence algorithm" used in his study and by the way a qualitative assessment was considered as more realistic in terms of understanding the field.

The analysis performed on the world data by using Citespace (Chen, 2006) software programme, a sudden emergence of "graphene" and "sheet" terms were observed. It can be said that these terms especially used in the application of nanotechnology. Publication year average, the starting and ending years of sudden emergence can be shown as another important issue in the data obtained in that analysis. When these variables were examined even if the study conducted over the most cited articles of last decade, there seems to be that sudden emerging terms are locating in the energy field in last three or five years. Further development studies of improving the quality of the material seems to take place especially in the existing battery or photovoltaic cells. It can be said that graphene is another application source also.

When the study carried out with Turkey's data in order to make a comparison, there was no one word in common among the sudden emergence keywords of Turkey and the world data. The intensification of sudden emergence term, especially in the context of energy systems in the world, may also be important for Turkey. It is very striking that at some areas where there is high external dependency for Turkey like biotechnology, energy and medicine, there is not enough applications. On the other hand, related to subject of the study researchers are concentrated in energy in the world but this situation that does not show a similar structure in Turkey. There is a failure at reaching the critical density or frequency. This can be considered as an important gap for Turkey that has high energy dependence.

The technology areas mentioned above that help to improve these technological developments are material science, computer science and informatics, biology and engineering science. For example, biopolymers offer new opportunities for designing robust, lightweight, flexible and more difficult to notice unmanned vehicle bodies as an intersection of biology and materials science. In material science, nanoparticles, especially carbon nanotubes (one of the most prominent key words of the most cited first thousand nanotechnology publication's authors), can be used in the construction of mechanical devices at very high frequencies that can be used in the communications infrastructure of unmanned systems. In addition, with the use of nanoparticles and the use of electrically stimulated polymers would enable the production of camouflage-enabled unmanned vehicles.

The high efficiency, solid energy conversion devices to be obtained by bismuth nanoparticles will provide significant advantages in terms of weight and size for unmanned combat vehicles compared to the old ones. Intelligent materials (that combine sensing, control, and response capabilities and adapt to changing environmental conditions) and magnetic storage devices that use magnetic nanoparticles will enhance the cognitive capacity of unmanned vehicles.

In the light of the analyzes and evaluations made, it can be said that nanotechnology studies in the world concentrate on materials such as graphene, graphite, quantum dots, nano-composite, nano-sheet and application fields like biotechnology, energy, material science, chemistry and medicine. An important reflection of this situation can be assessed in the context of military technologies, especially in the context of armor, fuel, batteries and survival materials.

The field of publications based on WoS categories related to nanotechnology at last decade is shown at Figure 4.2. Chemistry, Material Science and Physicss are in the top three. Looking at the areas of nanotechnology publications in the last decade, Chemistry, Materials Science, Physicss, Science&Technology and other subjects, Biochemistry&Molecular Biology, Engineer, Polymer Science, Electrochemistry, Pharmacology and Cell Biology have been among the top ten fields of research in nanotechnology.

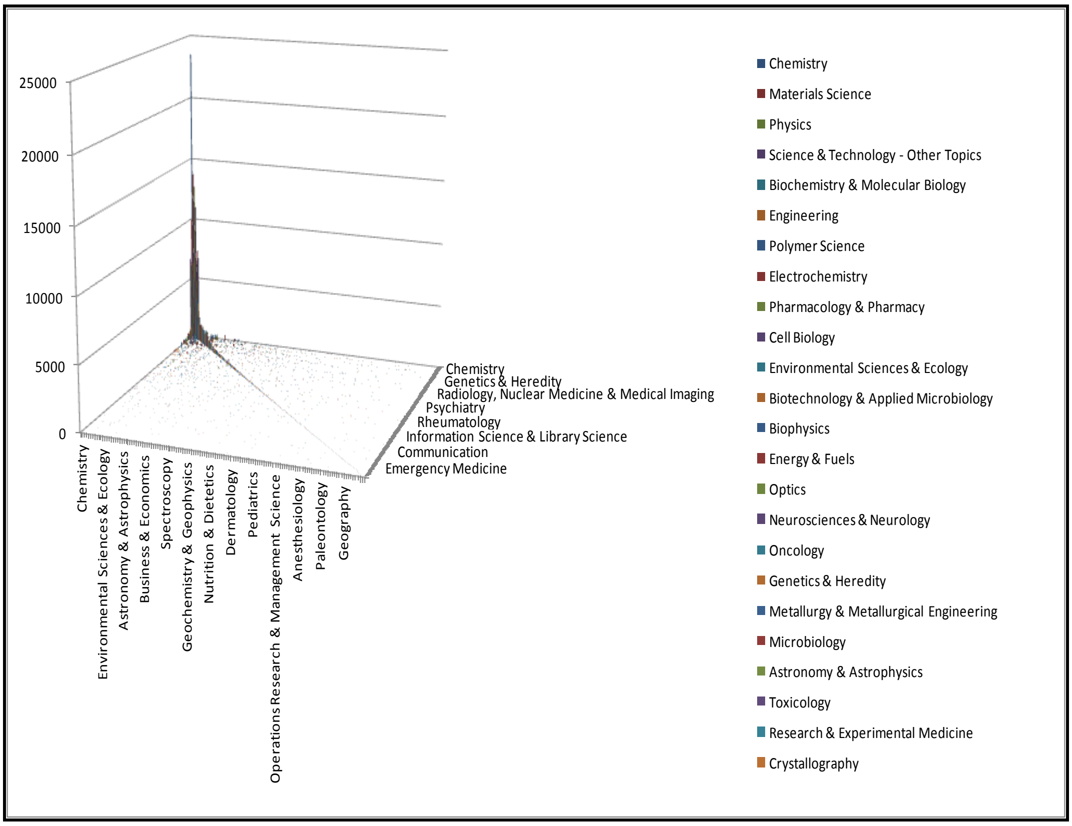


Figure 4.2 The Field of Publications Related to Nanotechnology at Last Decade.

Looking at the country sources of publications on nanotechnology in the last decade, the United States appears to be in the first place. Then comes in turn China, Germany, England, Japan, France, South Korea, Canada, Spain, Switzerland, Italy, Holland, Australia, Singapore, India, Taiwan, Sweden, Belgium, Israel and Denmark. Turkey ranks 31st in this order. Greece is the 29th country, and Iran is the 30th among the neighbors of Turkey. The related information is given at Figure 4.3.

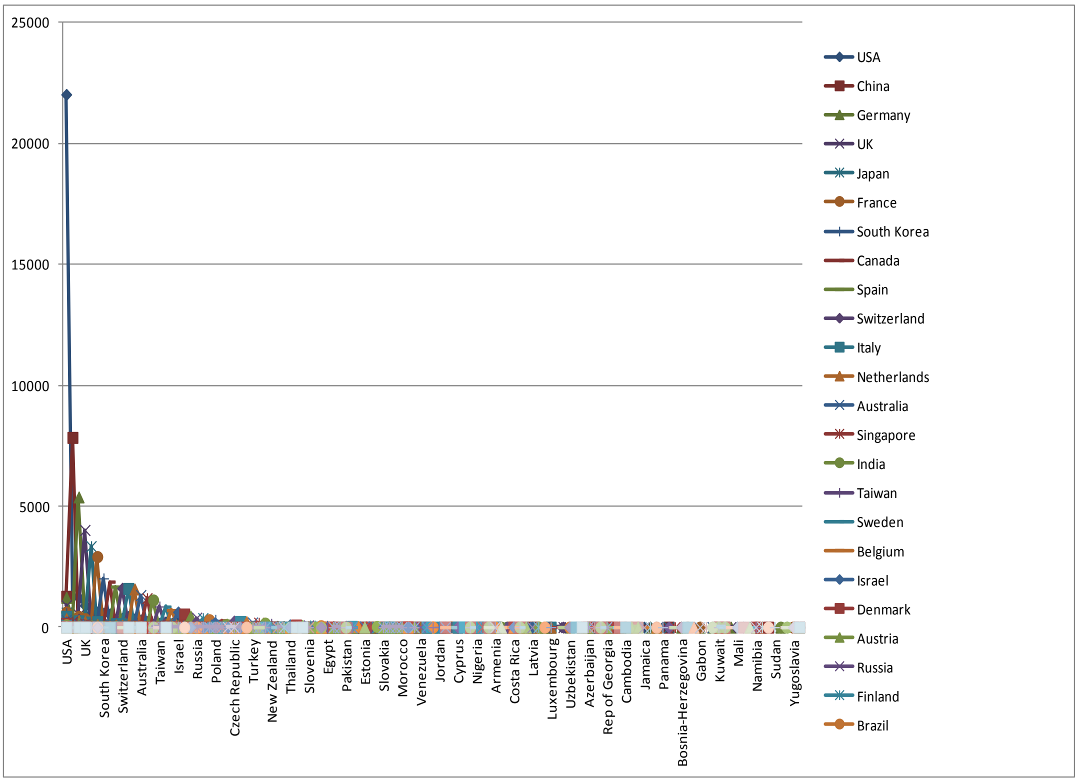


Figure 4.3 The Country Sources of Publications on NT in the Last Decade.

The Chinese Academy of Science is ranked first when it comes to the sources of universities where publications about nanotechnology have been published in the last decade. It is followed by Harvard University, Berkeley University of California, MIT, Stanford University, National Center for Scientific Research in France, Washington University, Singapore National University, Northwestern University, Georgia Institute of Technology. Bilkent University from Turkey is listed as 496th place, ODTÜ 752nd place, ITU 955th place and Hacettepe University place 1004th place.

In the last decade, when the authors who had ten or more cited publications are examined, Michael Graetzel, Younan Xia, Jun Wang, Zhong Lin Wang and Xin-Yi Wang are among the top five authors with over 100 publications on the issue. From Turkey, N. Serdar SARIÇİFTÇİ is listed as 415th place and Ataç İMAMOĞLU 1174th place.

When we look at the publishing years of 50,000 publications on nanotechnology, which have been most cited in the last decade, it is seen that this number decreased until 2014, when the most publication was made in 2005. The publication years is presented in Figure 4.4.

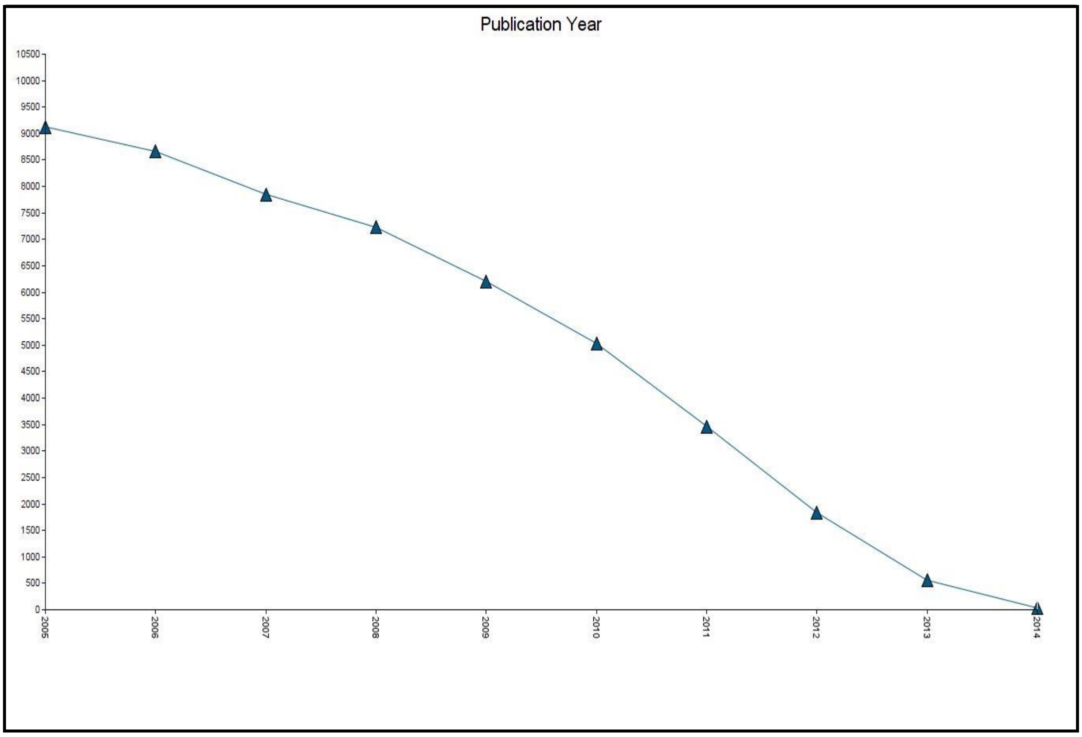


Figure 4.4 Publishing Years of the Most Cited 50,000 NT Publications in the Last Decade.

4.6.2 Interview

Based on the results of the bibliometric analysis an interview was undertaken with the members of Bilkent University National Nanotechnology Research Center (UNAM), METU Center for Solar Energy Research and Applications (GÜNAM) and Sabancı University NT Research and Application Center (SUNUM) personnel. The questions and answers are summarized below:

The first question of the interview is related to the terms of nanotechnology. "Which of the terms (featured words of bibliometric analsis) if used primarily in military technology, contribute to the development of Turkish Defense Industry from your point of view?" 75% of interviewed experts stated that **graphene and nano composites** contribute to the development of Turkish Defense Industry mostly. After that they stated that nanostructure and nano particles also contribute to the development of Turkish Defense Industry.

Looking at the areas of nanotechnology publications in the last decade, according to the result of bibliometric analysis; Chemistry, Materials Science, Physics, Science&Technology and other subjects, Biochemistry&Molecular Biology, Engineer, Polymer Science, Electrochemistry, Pharmacology and Cell Biology have been among the top ten fields of research in nanotechnology. The second question of the interview was related to the areas to be focused on: "Which areas should be focused on for the development of the Turkish Defense Industry for you?" All of them expressed that **Materials Science** is the most important field for developing defense industry. Biochemistry & Molecular Biology, Physics and Polimer Sciences should be also focused on.

The third question of the interview was related to the transfer methodology: "How can nanotechnology issues focused in the world be imported to the Turkish Defense Industry (which transfer methods)?" 75% of the experts stated that by using **university-industry** cooperation method, nanotechnology issues focused in the world can be imported. In addition, half of the experts also stated that **technology transfer** and investment in basic science is important for gaining advanced technology.

The last question of the interview was related to the commercialization time of nanotechnology's sub-areas: "What do you think about the commercialization time of nanotechnology's sub-areas?" Nanotechnology applications such as **nanoparticles, graphene, nanocomposites, carbon nanotube and nano photonics** will be commercialized in predictable time (2017-2020). Methods and process related to nanotechnology like **drug delivery, quantum dots, self - assembly, electro spinning** etc. will be commercialized after 2020 in a foreseeable or probable time according to the experts. Also electrospinning (nanofiber) will be commercialized in 2020-2025 and **two-dimensional non-graphene materials, self-assembly and drug delivery** mostly after 2025.

4.6.3 Survey

Frequency-based featured key words and issues that can be related to the military technologies were asked to the engineers working at MoND R&D and Technology Department. 41 people participated in the survey. Totally 80 engineers were working at this department. This unit is the only department included engineers from different branches working within the armed forces in the field of R & D. In the survey; demographic questions, questions to determine preferences, comments and open-ended questions were asked to engineers.

As a result of the survey; **nano composites, nano structure, nanoparticles and graphene** have been determined to be the most contributing products to the Turkish Defense Industry, **material science** has been identified as the area to focus on and **university-industry cooperation method** has been determined as transfer method.

The first question of the survey, Branches of participants who took part in the survey are listed in the Table 4.2. 46.8% of the participants are physics and mechanical engineers.

Table 4.2 Frequency Distribution of Participants' Branches.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Mechanical Engineer	9	22.0	22.0	22.0
	Chemistry Engineer	7	17.1	17.1	39.0
	Physics Engineer	11	26.8	26.8	65.9
	Computer Engineer	2	4.9	4.9	70.7
	Elc./electronics Engineer	4	9.8	9.8	80.5
	Metallurgical Engineer	3	7.3	7.3	87.8
	Unspecified	5	12.2	12.2	100.0
	Total	41	100.0	100.0	

The second question is related to experiences of participants. When a classification according to professional experience is made, 58.5% of the participants are engineers with 10 to 20 years of experience. This period is important for the acquisition of professional experience. Related information is given at Table 4.3.

Table 4.3 Frequency Distribution of Professional Experience Period of Engineers.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-3 Years	1	2.4	2.4	2.4
	4-9 Years	6	14.6	14.6	17.1
	10-14 Years	11	26.8	26.8	43.9
	15-20 Years	13	31.7	31.7	75.6
	+20 Years	10	24.4	24.4	100.0
	Total	41	100.0	100.0	

The third question of the survey relates to the terms of nanotechnology. Which of the terms (featured words of bibliometric analysis) if used primarily in military technology, contribute to the development of Turkish Defense Industry for you? According to 32.3% of participants **nanostructure,** 26.9% of participants **nanocomposites,** 14% of participants **graphene** and 8.6% of participants **nanoparticles** contribute to the development of Turkish Defense Industry if used primarily in military technology.

The fourth question of the survey relates to the areas to be focused on. Which areas should be focused on for the development of the Turkish Defense Industry for you? According to 26.5% of participants **Material Sciences**, 17.7% of participants Engineering, 12.4% of participants Physics and 10.6% of participants Biochemistry & Molecular Biology areas should be focused on for the development of Turkish Defense Industry.

The fifth question of the survey relates to the transfer method. How can nanotechnology issues focused in the world be imported to the Turkish Defense

Industry? (which transfer methods) According to the nearly half of the participants (46.3%) **university-industry cooperation method** can be used for transfer. According to 29.9% of participants technology transfer method can be used for importing.

"In which military technology field and when will nanotechnology applications be used for you?" This question included seven sub-questions. The answers are given at Table 4.4. According to the survey result; nanotechnology applications will be used in armour technology in predictable time (2017-2020). Other nanotechnology applications will be used in foreseeable time (2020-2025).

Table 4.4 The Combined Answers of Military Related Questions of the Survey

		Predictable	**Foreseeable**	**Probable**
		(2018-2020)	**(2020-2025)**	**(2025-2035)**
Armour Technology		**x**		
Warrior			**x**	
Survival Technologies			**x**	
Weapon Technologies			**x**	
Ammunition Tech.			**x**	
Energy Technologies			**x**	
Command and Control Technologies			**x**	
Others	Security (Biotech.)	x	x	
	Space Systems		**x**	

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The sixth question of the survey relates to predicting the time to use NT in Armour Technology. According to 62.5% of participants NT will be used in Armour Technology in predictable time (2017-2020). The distribution of the answers given to the sixth question is given in the Table 4.5.

Table 4.5 The distribution of the answers of the sixth question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	25	62.5	62.5	62.5
	2020-2025	12	30.0	30.0	92.5
	2025-2035	3	7.5	7.5	100.0
	Total	40	100.0	100.0	

The seventh question of the survey relates to predicting the time to use NT in Warriors. According to 40.5% of participants NT will be used in warriors in foreseeable time (2020-2025). The distribution of the answers given to the seventh question is given in the Table 4.6.

Table 4.6 The Distribution of the Answers of the Seventh Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	10	27.0	27.0	27.0
	2020-2025	15	40.5	40.5	67.6
	2025-2035	12	32.4	32.4	100.0
	Total	37	100.0	100.0	

The eighth question of the survey relates to predicting the time to use NT in Survival Technologies. According to 43.2% of participants NT will be used in Survival Technologies in foreseeable time (2020-2025). The distribution of the answers given to the eighth question is given in the Table 4.7.

Table 4.7 The Distribution of the Answers of the Eighth Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	13	35.1	35.1	35.1
	2020-2025	16	43.2	43.2	78.4
	2025-2035	8	21.6	21.6	100.0
	Total	37	100.0	100.0	

The nineth question of the survey relates to predicting the time to use NT in Weapon Technologies. According to 52.8% of participants NT will be used in Weapon Technologies in foreseeable time (2020-2025). The distribution of the answers given to the nineth question is given in the Table 4.8.

Table 4.8 The Distribution of the Answers of the Nineth Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	11	30.6	30.6	30.6
	2020-2025	19	52.8	52.8	83.3
	2025-2035	6	16.7	16.7	100.0
	Total	36	100.0	100.0	

The tenth question of the survey relates to predicting the time to use NT in Ammunition Technologies. According to 62.2% of participants NT will be used in Ammunition Technologies in foreseeable time (2020-2025). The distribution of the answers given to the tenth question is given in the Table 4.9.

Table 4.9 The Distribution of the Answers Given to the Tenth Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	9	24.3	24.3	24.3
	2020-2025	23	62.2	62.2	86.5
	2025-2035	5	13.5	13.5	100.0
	Total	37	100.0	100.0	

The eleventh question of the survey relates to predicting the time to use NT in Energy Technologies. According to 52.8% of participants NT will be used in Energy Technologies in foreseeable time (2020-2025). The distribution of the answers given to the eleventh question is given in the Table 4.10.

Table 4.10 The Distribution of the Answers Given to the Eleventh Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	8	22.2	22.2	22.2
	2020-2025	19	52.8	52.8	75.0
	2025-2035	9	25.0	25.0	100.0
	Total	36	100.0	100.0	

The twelfth question of the survey relates to predicting the time to use NT in Command and Control Technologies. According to 46% of participants NT will be used in Command and Control Technologies in foreseeable time (2020-2025). The distribution of the answers given to the twelfth question is given in the Table 4.11.

Table 4.11 The Distribution of the Answers Given to the Twelfth Question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2018-2020	6	16.2	16.2	16.2
	2020-2025	17	46.0	46.0	62.2
	2025-2035	14	37.8	37.8	100.0
	Total	37	100.0	100.0	

The value of reliability is an indicator of the same resultant degree in the repeated measures of a measuring tool. The reliability analysis (Cronbach's Alpha) for the whole survey is 0.946 as shown in the "Reliability Statistics" table below. If this value is greater than 0.70, it can be said that the survey is reliable. Reliability Statistics are given at Table 4.12.

Table 4.12 Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items			N of Items
.946	.975			12

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Armour_Technologies	23.97	76.999	.811	.944
Warriors	23.25	71.164	.926	.937
Survival_Technologies	23.44	71.854	.918	.938
Weapon_Technologies	23.42	72.879	.903	.939
Ammunition_Tech.	23.42	74.764	.853	.942
Energy_Technologies	23.25	72.421	.924	.939
C&C_Technologies	23.08	72.593	.890	.939
Branches	22.61	57.273	.916	.943
Experience	21.86	67.266	.925	.935
If it is used primarily in military technology, which ones' contribution to the development of Turkish defense industry will be more?	23.50	78.543	.688	.947
Which of these areas should be focused on for the development of the Turkish Defense Industry?	23.50	78.543	.688	.947
Which method should be used to transfer?	22.75	55.450	.874	.951

The column "Cronbach's Alpha If Item Deleted" on the table shows the new reliability value of the survey after the question is removed.

4.7 Nanotechnology Roadmap

Finally, prepared in the light of the obtained data, analysis and evaluations, Nanotechnology Roadmap for the defense industry is shown at Table 4.13.

This nanotechnology roadmap consists of three parts. The first part is related to the conclusion of interview. Commercialization time of nanotechnological applications (predictable, foreseeable and probable time) has been tried to be determined. According to the roadmap; nanoparticles, graphene, nano composits, carbon nanotube and nano photonics will be commercialized in predictable time (2017-2020), quantum dots, electro spinning and self assembly method in foreseeable time (2021-2025) and drug delivery and 2D materials excluding graphene in probable time (2026-2035). Domestic companies will contribute to the strengthening of both the defense industry and the TAF by using these products in military technologies, which are expected to be commercialized. In this sense, the aim of the studies is to shorten the commercialization time of nano applications as possible.

The second part is related to the results of the survey. Military use of NT are determined according to the military categories. In this sense, NT will be used in armour technologies in predictable time and NT will be used in other military technologies in foreseeable time. defense industry firms can invest in military areas where nanotechnology can be used as a result of the survey.

The third part of the roadmap is related to the execution method. According to this; R&D characteristics are commercialization, demonstration and basic application. Developing strategy for using NT in defense industry is university-industry cooperation method and technology transfer method. Focusing areas and focusing applications have been identified for better using NT in defense industry.

Table 4.13 Nanotechnology Roadmap for Turkish Defense Industry

Technology	Predictable			Foreseeable			Probable				Specific Aim	Related Units
	2018	2019	2020	2021	2023	2025	2026	2029	2032	2035		
Commercialization time of Nanotech. Applications	Nanoparticles										To shorten the commercialization time of nano applications as possible.	Defense Industry Companies, R&D Centers, Technoparks, Other Industrial Companies Research Centers of Universities TÜBİTAK TOBB KOSGEB TTGV
							Drug delivery					
				Quantum dots								
	Graphene											
				Self assembly								
	Nano composites											
	Carbon nanotube											
	Nano photonics											
				Electro spinning								
							2D materials exc.graphene					
Military use of nanotechnology	Armour										To increase military use of nanotechnology at maximum level.	MSB. SSB SaSaD, SSI TÜBİTAK TOBB KOSGEB TTGV Research Centers of Universities Technoparks Defense Industry Companies,
				Warrior								
				Survival								
				Weapon								
				Ammunition								
				Energy								
				Command&Control								
	Security (Biotechnology)											
			Space systems									
Execution method	R&D Characteristics: Commercialization Demonstration Basic application		Developing Strategy: University-industry cooperation Technology Transfer				Focusing Area: Materials Science, Biochemistry&Molecular Biology, Physicss, Engineering				Focusing applications: Nanocomposits, Nanoparticles, Graphene, Nanostructure,	

4.7.1 The Leading Nanotechnological Products & Applications In The World

In this section, featured products and applications related to nanotechnology, which is the result of bibliometric analysis, are mentioned. The activities performed in accordance with the methodology applied in this study follow each other. Firstly, prominent words related to nanotechnology were identified, then the commercialization time of these words were asked to experts, and finally, in which military technologies nanotechnological products and applications could be used is determined according to the engineers answers. The result of the bibliometric analysis formed the framework of the study. Prominent words of bibliometric analysis are nanoparticles, drug delivery, quantum dots, graphene, self-assembly, nanocomposites, carbon nanotube, nanostructure and electrospinning as mentioned before.

4.7.2 The Commercialization Time Of NT Products And Applications

It is stated by experts that the commercialization period of nanotechnological products and applications will take place in the short term. Such nano products and methods can be widely used in civilian and military applications (dual-use). By acting more rapidly than competitors in inventing new products and applications will provide crucial advantages for firms and on a large-scale state economy. As stated in this roadmap, the use and dissemination of products such as nanoparticles, graphene, nano composites, carbon nanotubes and nano photonics in military systems will provide commercial superiority to the firms while providing technological superiority to the military in the short run (2018-2020). The search for ways to use these products in military systems at the R&D centers in each level will open the way for nanotechnology-based growth and empowerment. This situation is shown at Table 4.14.

Table 4.14 Comercialization time of NT products and applications

Predictable (2018-2020)	Foreseeable (2021-2025)	Probable (2026-2035)	Related Units
Nanoparticles Graphene Nano composits Carbon nanotube Nano photonics	Quantum dots Self assembly Electro spinning	Drug delivery Quantum dots Self assembly 2D materials exc.graphene	R&D Centers, Technoparks, Companies, Research Centers, SSB TÜBİTAK TOBB KOSGEB TTGV SaSaD SSI TSKGV R&D Dept.of TAF &SSB

4.7.3 NT Products And Applications In Military Systems And Usage Time

After getting the results of the bibliometric analysis and the interview, it is time to reveal the use of nanotechnology in military systems and to put forth the using time of nanotechnology in military systems. Experts have pointed out the necessity of using nanotechnology in the field of armour technology, security and biotechnology in near future. They expressed requirement of using nanotechnology in Warrior Systems, Survival Technologies, Weapon Technologies, Ammunition Technologies, Energy Technologies, Space Systems and Command&Control Technologies in foreseeable time. The commercialization time, usage areas and the probable usage times of nanotechnological products and applications in military technologies are shown at Table 4.15. Also Table 4.15 included the priority studies to be done by various units.

Tablo 4.15 The Commercialization Time, Usage Areas And The Probable Usage Times Of NT Products And Applications In Military Technologies

Subject /Time	**Predictable (2018-2020)**	**Foreseeable (2021-2025)**	**Probable (2026-2035)**	**Related Units**
Products to be Commercialized	Nanoparticles Graphene Nano composits Carbon nanotube Nano photonics	Quantum dots Self assembly Electro spinning	Drug delivery Quantum dots Self assembly 2D materials (exc.graphene)	
In which military technology can be used?	Armoured Technologies, Security (biotech.)	Warriors, Survival Tech. Weapon Tech. Ammunition Tech. Energy Tech. C&C Tech. Space Systems	In the required systems	MoND MoI&T TAF SSB TÜBİTAK R&D Departments of TAF and SSB TSKGV SaSaD SSI R&D Centers, Technoparks, Companies, Research Centers, TOBB KOSGEB TTGV
What to do?	1. Primarily R&D Centers, Technoparks, Companies, Research Centers and Military Factories should study for the use of the above mentioned nanotechnological products especially in armoured systems. 2. Company's R&D Centers should study on NT in order to find new usage areas. 3. Prominent reserach centers on NT (UNAM, NANOTAM, GUNAM, SUNUM etc.) should do dual-use nanotechnological innovations.	1. Strategic plans, prepared by MoND, TAF and SSB should include the use of commercial / being commercialızed nanotechnological products above-mentioned in military systems. 2. Companies should use products in military systems expected to be commercialized. 3. SHP/OYTEP should include the projects / systems that contain nanotechnological applications.	1. Systems with nanotechnological products should be included in the official strategic plans. 2. The units that make defense planning should give tasks and targets to the firms.. 3. MoND should correctly identify the systems needed by the command forces in the long term. Necessary studies should be done in order to support the needed systems with nanotechnology. 4. SHP/OYTEP plans should include the project / systems that contain nanotechnological applications.	

CHAPTER 5

CONCLUSIONS

The goal of this study is to prepare a nanotechnology road map for the Turkish Defense Industry. The main motivation for creating nanotechnology roadmap is the geographical region in which Turkey is located. It is close to potential conflict regions such as Iraq, Syria, Iran and Middle East. Obviously, it is necessary to have a powerful army to survive in this region. There is a need for a well-organized defense industry that effectively uses advanced technology to have a powerful army. The defense industry can only produce unique products with advanced technology, well-prepared plans, programs and policies. In accordance with the purpose of this study, the Turkish defense industry will be able to produce new systems by using the prepared nanotechnology roadmap that will give superiority to the military.

As discussed in Chapter 1, nanotechnology offers a wide range of solutions to a number of problems in the military field or in other areas. It is called as the "next industrial revolution‟ by researchers. The nanotechnology field has enormously grown in terms of the publications, patents, research centers, researchers etc. since 2000s. Moreover, nanotechnology R&D budget has increased rapidly worldwide. In Turkey, some important studies have been made for NT development. For example; Vision 2023 prepared by TÜBİTAK shows us nanotechnology as one of the strategic technology fields for scientific and technological development of the Turkey.

Nanotechnology is also included in the Development Programs and SSB Documents as Mentioned in Chapter 3. At the moment, nanotechnology studies are carried out both in research centers of universities and in R&D Departments of private companies. There is an increase in the number of research centers that can be regarded as important compared to the past years. There is also a considerable increase in the number of master and PhD programs of universities based on nanotechnology. Similarly, the number of theses is increasing in recent years.

The change and development experienced in nanotechnology, military technology trends, changing structure of the war, military applications of NT and national defense planning strategy of Turkey have been examined in detail at Chapter 2. In this sense, wars may emerge in the future that have no definite boundaries, methods and sides. In such an environment, an army equipped with advanced technology will be needed to win a war.

This thesis aims at determining the factors that influence to have a powerful army and defense industry in the context of nanotechbology. For this purpose, the thesis carries out three different studies which all contribute to the nanotechnology policy in Turkey. The first one covers the bibliometric analysis of nanotechnology publications from WoS. Using nanotechnology publications provides valuable findings about the main characteristics of NT research in the World and in Turkey. Secondly, using data conducted with nano-experts, who are currently studying at Turkish Research Centers that stand out with scientific studies through an interview, the commercialization time of nanotechnological applications is examined. Finally, based on the survey applied to the engineers working at MoND R&D and Technology Department, it is aimed to understand which nanoapplications will affect the military field in the future.

In this section, in the context of the thesis, results of the study are given. The struggle around our country requires that the TAF should be very strong. It is very important for the defense industry to be developed for this reason. The existence of an advanced defense industry will allow the TAF to respond more strongly to threats. Internal Security Operation, Euphrates Shield Operation, Olive Branch Operation and Syrian War have shown us the advantages of having advanced weapons systems. In this sense, a road map has been prepared for the defense industry to identify how and when nanotechnology can be used for further technology development.

Nanotechnology, one of the key pillars of global scientific competition in the 21st century, has a potential to change peoples' way of living and economies of countries. By focusing on nanotechnology in military, it is expected to be seen radical changes in the structure of the wars and the defense industry. It will be needed to reconsider the concepts of the wars by the means of equipments helping soldiers to survive, including precision sensors, effective and light manned/unmanned vehicles, C4ISR systems, smart ammunition, bullet proof clothing that made of nanotechnology.

While changes are taking place very fast, technologies are now completing technological life without completing their economic life. With investigating the progress of nanotechnology through examining scientific publications in the world and in the light of examined trends, integrating technology areas for the defense industry will provide effective use of resources and it will contribute to create economic value for the country.

Nanotechnology is an area that promises great hopes for military applications as well as for the civil applications. Because of its interdisciplinary nature, it has become very prominent in recent years. According to the interview and survey results, it can be said that scientific areas like Material Science, Biochemistry & Molecular Biology, Engineering and Physics are very important for the development of defense industry in the context of military use of nanotechnology. Using nanotechnological applications like nanostructure, nanocomposites, nanoparticles and graphene will conduce mostly to the development of defense industry. Powerful defense industry that uses nanotechnology effectively contribute to economic gains for developing countries. The determination of achieved level of the world in nanotechnology and putting forward the issue to catch up the technology race is very important for the Turkish Defense Industry.

As stated in Vision 2023 prepared in coordination with TÜBİTAK for Turkey (Saritas et al., 2006), nanomaterial science will be crucial for the development of defense system related to national security. Finally, in the countries that have advanced technology, economy, national security and welfare will be in a better position. Nanotechnology is a new opportunity for the countries that could not catch up the innovations in time from the industrial revolution until today. Leading countries in this field get their administrative and structural measures for the effective use of nanotechnology. Creating awareness about nanotechnology in defense industry is important to keep up with this global technology race.

In addition, when looking at the rapid developments and changes in NT, the efforts carried out in order to keep pace with developments, a variety of studies performed in this area and international competition between countries / companies, already show us the importance of nanotechnology. The share of R&D investments in GDP is not yet at the desired level for Turkey. Because the funds allocated to R&D studies and investments in defense sector are very considerable. Studies related to nanotechnology are also being investigated by the developed countries for military purposes. New technologies and products are being developed in the light of the future defense concepts. In order to stand in the rapid changing technology storm, making foresight studies and continuous assessment related to the future with the terms of the system point of view is needed. Conducting foresight studies in accordance with national policies and strategies with considering the dynamic environmental contiditons usually allows the efficient utilization of national resources.

Consequently, the warfare is constantly changing. New war methods and new techniques are taking place. At the same time technology is growing faster in the world. The countries that using developed technology will gain the upper hand in the theater of war. In this context having advanced technological weapons helps to overcome the enemies. In the light of the analysis and evaluations that made, nanotechnology studies focus on applications such as graphene, quantum dots, nanocomposite or fields like biotechnology, energy, material science, pharmaceuticals, chemistry. The important implications of military nanotechnology can be evaluated as armor, fuel, battery and survival materials. Nanotechnology applications are expected to be commercialized especially after 2020. In order to be ready for producing military nanotechnological applications, developing country's defense industries should start to work immediately. These countries have to allocate more resources to nanotechnology R&D and they have to establish nanotechnology research centers for military studies.

Turkey needs to have a strong military and a defense industry that uses nanotechnology to reach its short, medium and long term goals. Determining the level of advanced countries in the field of nanotechnology and revealing what needs to be done in order not to fall behind in this technology race for the Turkish defense industry is very important. In the world where the concept of war changes rapidly, a strong army and well-functioning defense industry are crucial for developing countries.

As stated in Vision-2023 Document, nanomaterial science will hit its mark on the subjects such as the development of new defense systems dealing with national security and production of devices in very small sizes for intelligence issues. As a result, welfare, economy and national security will be in a much stronger position in the countries that have this technology. Leading countries in this area seem to have taken the administrative and structural steps to use nanotechnology firstly. It is seen that they then proceed within a plan by carrying out foresight studies or preparing technology road maps.

In addition, after this study, a scenario-based foresight study can be made by preparing a more comprehensive project including expert panels and workshops in which the opinions of stakeholders on nanotechnology are evaluated, as well as the updating of existing data and the inclusion of patents in nanotechnology.

In this sense, establishing a department, like NNI in the USA, in order to advance a world-class nanotechnology research and development program; to foster the transfer of new technologies into products for commercial and public benefit; to develop and sustain educational resources, a skilled workforce, and supporting infrastructure and tools to advance nanotechnology; and to support development of nanotechnology can be very useful for Turkey.

Similarly, Institute for Soldier Nanotechnology (ISN) was founded in the USA to meet the needs of military systems using nanotechnology. ISN was established within the Massachusetts Institute of Technology (MIT) with a budget of $ 50 million as mentioned at Chapter 3. Due to the need of soldier protection and survivability and Army's demand, The ISN emerged. It was planned as a university center for basic research on nanotechnology. Opening a Nanotechnology Institute for TAF within a university can be very beneficial. It will be a team of university, army and industry partners working together to discover and find solutions for soldier's needs.

Competence Centers are good examples of Germany for nanotechnology activities. The nine competence centers scattered across different regions of the country are very useful for NT activities. The establishment of such competence centers makes NT studies more effective.

Thus, within the scope of nanotechnology trends in the world, establishing awareness about nanotechnology in defense industry firms by preparing Nanotechnology Road Map for Turkish Defense Industry will contribute to TAF to have advanced weapons, systems, platforms and sensors.

Some major implications derived from findings of the research can be summarized as follows:

Despite the growing number of nanotechnology publications, the share of Turkey in total publications worldwide is still low. For this reason, new policies and strategies should be developed to embolden NT research in Turkey.

Public and private sector R&D budgets should be increased as targeted in Vision-2023 Document. Nanotechnology R&D projects should be further supported.

Nanotechnology patent numbers are not at the desired level. Research Centers, researchers from universities and private sector should be encouraged for more patent applications.

For effective information sharing and experience transfer, a common network should be developed firstly among domestic nanotechnology research centers. This network should then be linked to nanotechnology research centers operating abroad.

Although nanotechnology products may be dual-use, opening the Military NT Research Center to work on military systems may be a good starting point.

Establishment of NT Departments, NT Research Centers or laboratories may be a good exercise for further nanotechnology researches within TAF, SSB, MKEK and MoND. These units can be used as a kind of technology platform within TAF and MoND which put together warrior, industry and university. So that more information can be shared between the units.

According to the result of the interview, defense industry firms are expected to invest on nanoparticles, graphene, nano composits, carbon nanotube and nano photonics foreseen to be commercialized in predictable time (2018-2020), invest on quantum dots, electro spinning and self-assembly method foreseen to be commercialized in foreseeable time (2021-2025) and invest on drug delivery and 2D materials exc. graphene foreseen to be commercialized in probable time (2026-2035).

According to the results of the survey, defense industry firms are expected to invest on armor and security (biotechnology) systems related to NT foreseen to be used in the military field in predictable time (2018-2020) and invest on warrior, survival, weapon, ammunition, energy, command&control and space systems related to NT foreseen to be used in the military field in foreseeable time (2021-2025).

It may be very useful to set up various working groups or think tanks to predict the future warfare and take precautions accordingly.

"Defense Industry R&D and Technology Policy" should be prepared at national level. Reachable Goals should be given to the private and public sector.

As a result; Turkish Defense Industry should use university-industry cooperation and technology transfer method for transfering knowledge as a developing strategy. Focusing areas of the defense industry have been identified as the result of the research like that; Materials Science, Biochemistry&Molecular Biology, Physicss and Engineering. In this sense focusing applications should be nano composites, nanoparticles, graphene and nanostructure for the development of defense industry.

In order to use NT in military systems efficiently, a number of policy tools should be conceived and implemented. The targeted time in Vision-2023 Document is approaching. Firstly, the most crucial policy tool which should be promptly started is a specific NT programme like Vision-2023. Similar applications observed in other countries as well; Japan, China, India and South Korea since 2000s. They launched special nanotechnology programs and subsequently have achieved a great success as can be seen in number of patents, publications or R&D budgets.

Once a general nanotechnology plan for the country has been made, it would be very useful to prepare long term policies separately for various sectors and/or converging technologies such as biotechnology, information technology or cognitive technology. These plans should clearly state the role of the private sector and the public sector units. Specific targets should be given to these sectors and the attainment of these objectives should be checked from time to time. According to the feedback received, the plan should be reviewed again.

Finally, a network which is designed to provide access to all the information about nanotechnology applications/projects, publications, patents etc. would be very helpful to increase the collaboration between military units and defense industry firms. MoND or SSB may prepare such a network tool. Moreover, over such a web-based system, defense industry firms can be allowed to make some announcements to find partners from other firms or sub-contractors for their research projects. Such a network might also be very useful in uncovering new defense projects or new military systems.

CHAPTER 6

POLICY RECOMMENDATIONS

In this section, suggestions are presented in order to improve the nanotechnology applications/products in defense industry. This section discusses some directions for further research related to nanotechnology and military. Preparing a nanotechnology roadmap for the Turkish Defense Industry is the objective of this study. This research is limited to the use of NT in defense industry and/or military use of nanotechnology in Turkey. Therefore, many questions have remained out of the scope of this research. Some of these questions are : To which extent the outcomes of this study are appropriate for other industry sectors in Turkey? How much commercialization of NT will affect the areas out of the defense industry? And Which of the science fields out of nanotechnology may contribute more to the construction of future army?

Because of its limitations, this study did not address the private sector nanotechnology firms' specialists. In other words, in this thesis, we did not interview with these specialists. Further research on the private firms' activities would provide another important contribution to the development of the military. Preparing roadmaps in other converging technology areas will contribute to the science and technology policy studies in Turkey.

As a result, the determination of when, how, by whom and what to do is important for the development of the national defense industry and for the strengthening of the army. Main strategies for TAF and Defense Industry Firms prepared in this context are presented at Table 6.1 and Sub-Strategies for TAF and Defense Industry Firms are shown at Table 6.2.

Tablo 6.1 Main Strategies for TAF and Defense Industry Firms

No	Action	Related Unit
1	NT action plans for the defense industry should be prepared.	MoND, SSB R&D Departments
2	The NT R&D centers should be installed at each force command level.	MoND, TAF, SSB Force Commands
3	Military NT Institute/research center should be established	MoND, TAF TSKDV
4	The number of military engineers working in the field of nanotechnology should be increased.	MoND, TAF, SSB Force Commands
5	SHP / OYTEP should include the projects / systems to be produced by using nanotechnology.	TAF, SSB Force Commands
6	The nanotechnology departments should be established where engineers and warriors are working together at force commands level.	MoND, TAF Force Commands
7	The use of nanotechnology in military systems should be worked together with defense industry firms.	MoND, TAF, SSB Force Commands Companies

Tablo 6.1 (cont'd)

No	Action	Related Unit
8	Military personnel should be informed about military materials which is produced bu using NT	MoND, TAF, SSB Force Commands
9	NT awareness of military personnel should be increased.	MoND, TAF SSB
10	The use of nanotechnology should be widened in military systems by giving various projects to technopark companies.	MoND, TAF, SSB Force Commands Technoparks
11	Defense industry firms should make military systems stronger by using more effective materials and production techniques.	Defense Industry Companies
12	Use of nanotechnological products and applications in military systems that are expected to be commercialized should be investigated in detail.	SSB, TSKGV, SaSaD, SSI Defense Industry Companies
13	By providing nanotechnological products expected to be commercialized in short, medium and long term, firms should use these products in the specified military systems determined in this study	SSB, TSKGV, SaSaD, SSI Defense Industry Companies
14	The projects in SHP/OYTEP should be monitored continuously.	Defense Industry Companies

Tablo 6.1 (cont'd)

No	Action	Related Unit
15	Nanotechnology R&D Centers should be opened within the companies	Defense Industry Companies
16	In order to determine the needs of the soldiers correctly, collaboration opportunities should be developed.	MoND, TAF, SSB Force Commands Technoparks Defense Industry Companies
17	Participation in activities such as international fairs, meetings, symposiums related to NT should be encouraged.	MoND, SSB Universities R&D Units Companies

Table 6.2 Sub-Strategies for TAF and Defense Industry Firms

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-1	Nanoparticles should be used in armored technologies in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Innovative Systems, SSB. 2. Department Of Technical And Project Management, TLF. 3. Defense Industry Firms
SUB-2	Nanoparticles should be used in security systems in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-3	Graphene should be used in armored technologies in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3. Defense Industry Firms
SUB-4	Graphene should be used in security systems in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3. Defense Industry Firms
SUB-5	Nano composites should be used in armored technologies in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-6	Nano composites should be used in security systems in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1. Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-7	Carbon nanotube should be used in armored technologies in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-8	Carbon nanotube should be used in security systems in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-9	Nano photonics should be used in armoured technologies in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-10	Nano photonics should be used in security systems in predictable time.	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-11	Quantum dots should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-12	Self-assembly applications should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont’d)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-13	Electro-spinning should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-14	Quantum dots should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-15	Self-assembly applications should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-16	Electro-spinning should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-17	Quantum dots should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-18	Self-assembly applications should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-19	Electro-spinning should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-20	Quantum dots should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-21	Self-assembly applications should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-22	Electro-spinning should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-23	Quantum dots should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-24	Self-assembly applications should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-25	Electro-spinning should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-26	Quantum dots should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-27	Self-assembly applications should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-28	Electro-spinning should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-29	Quantum dots should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-30	Self-assembly applications should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-31	Electro-spinning should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-32	Drug delivery systems should be used in needed military applications in probable time.	Department of R&D & Technology, Department of Material Management, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems, SSB. 2.Dept. Of Technical&Project Manage.,, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-33	Quantum dots should be used in needed military applications in probable time.	Department of R&D & Technology, Department of Material Management, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-34	Self-assembly applications should be used in needed military applications in probable time.	Department of R&D & Technology, Department of Material Management, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-35	2D materials (excluded graphene) should be used in needed military applications in probable time.	Department of R&D & Technology, Department of Material Management, MOND	1.Dept. of R&D & Technology Management, Division for Innovative Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-36	Nano particles should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-37	Graphene should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-38	Nano composites should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-39	Carbon nanotube should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-40	Nano-photonics should be used in warrior systems in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-41	Nano particles should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-42	Graphene should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-43	Nano composites should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-44	Carbon nanotube should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-45	Nano-photonics should be used in survival technologies in foreseeable time.	Department of R&D & Technology, MOND	1.Department of R&D & Technology Management, Division for Innovative Systems Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-46	Nano particles should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-47	Graphene should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-48	Nano composites should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-49	Carbon nanotube should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-50	Nano photonics should be used in weapon technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-51	Nano particles should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-52	Graphene should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-53	Nano composites should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-54	Carbon nanotube should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-55	Nano-photonics should be used in ammunition technologies in foreseeable time.	Department of R&D & Technology Management, Department Of Weapons and Ammunition, SSB	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-56	Nano particles should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-57	Graphene should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-58	Nano composites should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-59	Carbon nanotube should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-60	Nano-photonics should be used in energy technologies in foreseeable time.	Department of R&D & Technology Management, Division for Strategic Systems, Division for Innovative Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-61	Nano particles should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-62	Graphene should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-63	Nano composites should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-64	Carbon nanotube should be used in C&C technologies in foreseeable time.	Department Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-65	Nano-photonics should be used in C&C technologies in foreseeable time.	Dept. Of Communications, Electronic and Information Systems, Division for Cyber Security and IT Systems, SSB.	1.Department of R&D & Technology, MOND. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-66	Nano particles should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-67	Graphene should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-68	Nano composites should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-69	Carbon nanotube should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms
SUB-70	Nano-photonics should be used in space systems in foreseeable time.	Department Of Air Defence and Space, SSB.	1.Department of R&D & Technology, MOND. 2.Defense Industry Firms

Table 6.2 (cont'd)

NO.	SUB-STRATEGY SUBJECT	RESPONSIBLE UNIT	RELATED UNIT
SUB-71	Quantum dots should be used in armoured technologies in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-72	Self-assembly applications should be used in armoured technologies in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-73	Electro-spinning should be used in armoured technologies in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-74	Quantum dots should be used in security systems in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-75	Self-assembly applications should be used in security systems in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms
SUB-76	Electro-spinning should be used in security systems in foreseeable time	Department of Material Management, Department of R&D & Technology, MOND	1.Dept. of R&D & Technology Management, Division for Strategic Systems, SSB. 2.Department Of Technical And Project Management, TLF. 3.Defense Industry Firms

Apart from these, general recommendations on this subject are given below. It will be useful to act in accordiance with the recommendations.

It can be a good starting point to establish the **Nanotechnology Coordination Counsil** for planning, implementation, monitoring and coordination, control, guidance and evaluation of nanotechnology studies countrywide.

For the detection of military nanotechnology needs, **Military Nanotechnology Institute** should be established within the National Defense University.

Nanotechnology studies should be encouraged to increase the number of defense industry companies working in the field of nanotechnology.

The number of qualified research centers should be increased for the advanced NT research in Turkey.

Institutions and ministries such as TTGV, TUBITAK, SSB, MoND and MoI&T can organize competitions nationwide and give various awards for nanotechnology projects that can be used in the military.

“Digital Turkey Roadmap” and “Turkey Biotechnology Strategy Document and Action Plan 2015-2018” was prepared by the MoI&T. Nanotechnology action plans, roadmap and strategy documents should be done similarly.

In order to attract the attention of society to technology, fairs such as technofest and IDEF should be organized regularly.

In conclusion, this thesis has investigated the use of nanotechnology in military systems, structure of the war in the future and nanotechnology advancements in developed countries. It is the first study in Turkey which explores the use of NT in military systems and the role of defense industry companies. Therefore, it is believed that this thesis has made an important contribution to defense sector, military system and science & technology policy research in Turkey. This study also turn on some new perspectives of research on military use of nanotechnology.

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APPENDICES

APPENDIX A: INCLUDED AND EXCLUDED KEYWORD SET OF ARORA ET AL. (2013)

Included Keywords	Excluded Keywords	Publication Year	Data base	Author
TS = (nano*) TS = ((“quantum dot*” OR “quantum well*” OR “quantum wire*”) NOT nano*) TS = ((“self assembl*” OR “self organiz*” OR “directed assembl*”) AND MolEnv- TS = ((“molecul* motor*” OR “molecul* ruler*” OR “molecul* wir*” OR “molecul* devic*” OR “molecular engineering” OR “molecular electronic*” OR “single molecul*” OR fullerene* OR buckyball OR buckminsterfullerene OR C60 OR “C-60” OR methanofullerene OR metallofullerene OR SWCNT OR MWCNT OR “coulomb blockad*” OR bionano* OR “langmuir–blodgett” OR Coulombstaircase* OR “PDMS stamp*” OR graphene OR “dye-sensitized solar cell” OR DSSC OR ferrofluid* OR “core–shell”) NOT nano*) Microscopy and spectroscopy Yes, MolEnv-R TS = ((((TEM or STM or EDX or AFM or HRTEM or SEM or EELS or SERS or MFM) OR “atom* force microscop*” OR “tunnel* microscop*” OR “scanning probe microscop*” OR “transmission electron microscop*” OR “scanning electron microscop*” OR “energy dispersive X-ray” OR “xray photoelectron*” OR “x-ray photoelectron” OR “electron energy loss spectroscop*” OR “enhanced raman-scattering” OR “surface enhanced raman scattering” OR “single molecule microscopy” OR “focused ion beam” OR“ellipsometry” OR “magnetic force microscopy”) AND MolEnv-R) NOT nano*) TS = (((NEMS OR Quasicrystal* OR “quasi-crystal*” OR “quantum size effect” OR “quantum device”) AND MoleEnv-I) NOT nano*) TS = (((biosensor* OR NEMS OR (“sol gel*” OR solgel*) OR dendrimer* OR CNT OR “soft lithograph*” OR “electron beam lithography” OR “e-beam lithography” OR “molecular simul*” OR “molecular machin*” OR “molecular	plankton* nanometer* n*plankton nano-metre m*plankton nano-meter b*plankton nano-metre p*plankton nanosecond* z*plankton nano-second nanoflagel* nanomolar* nanoalga* nano-molar nanoprotist* nanomole(s) nanofauna* nanogram* nano*aryote* nano-gram nanoheterotroph* nanoliter* nanophtalm* nanolitre* nanomeli* nano-liter nanophyto* nano-litre* nanobacteri*nano2 nano3, nanos, nanog nanor, nanoa nanonanognanoananornanosatellite* Nanoa; Nanoacalles; Nanoagraylea; nanoapiculatum; Nanoarchaea; Nanoarchaeota; Nanoarchaeum; Nanoastegotherium; Nanobagrus; Nanobalcis; Nanobaris; Nanobates; Nanobatinae; Nanobius; Nanobryaceae; nanobryoides; Nanobuthus; Nanocalcar; Nanocambridgea; nanocapillare; nanocarpa; nanocarpum; Nanocarpus; Nanocassiope; Nanocavia; nanocephalum; Nanocheirodon; Nanochilina; Nanochilus; Nanochitina; Nanochlaenius; Nanochlorum; Nanochoerus; Nanochromis; Nanochrysopa; Nanochthonius; Nanocixius; Nanocladius; Nanoclarelia; Nanoclavelia; nanoclimacium; Nanoclymenia; Nanocnide; Nanocochlea; Nanocolletes; Nanocondylodesmus; Nanocopia;	2013	WOS, SCI, Micro Patent, INPADOC Patent	Sanjay K. Arora • Alan L. Porter • Jan Youtie • Philip Shapira

imprinting'' OR ''quantum effect*'' OR ''surface energy'' OR ''molecular sieve*'' OR ''mesoporous material*'' OR ''mesoporous silica'' OR ''porous silicon'' OR ''zeta potential'' OR ''epitax*'') AND MolEnv-R) NOT nano*) (monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array* or molecul* or polymer* or (co-polymer*) or copolymer* or mater* or biolog* or supramolecul*) (monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array*), nano, (quantum dot* OR quantum well* OR quantum wire*) NOT nano*, (((SELF ASSEMBL*) or (SELF ORGANIZ*) or (DIRECTED ASSEMBL*)) AND MolEnv-I) NOT nano*, ((molecul* motor*) or (molecul* ruler*) or (molecul* wir*) or (molecul* devic*) or (molecular engineering) or (molecular electronic*) or (single molecul*) or (fullerene*) or (coulomb blockad*) or (bionano*) or (langmuir-blodgett) or (Coulombstaircase*) or (PDMS stamp*)) NOT nano*, ((TEM or STM or EDX or AFM or HRTEM or SEM or EELS) or (atom* force microscop*) or (tunnel* microscop*) or (scanning probe microscop*) or (transmission electron microscop*) or (scanning electron microscop*) or (energy dispersive X-ray) or (Xray photoelectron*) or (electron energy loss spectroscop*)) AND MolEnv-I) NOT nano*, (pebbles OR NEMS OR Quasicrystal* OR (quasi-crystal*)) AND MolEnv-I) NOT nano*, (biosensor* or (sol gel* or solgel*) or dendrimer* or soft lithograph* or molecular simul* or quantum effect* or molecular sieve* or mesoporous material*) AND (MolEnv-R)) NOT nano*, fullerene* or ieee transactions on nano* or journal of nano* or nano* or materials science & engineering C - biomimetic and supramolecular systems (in JOURNAL title field) NOT nano*	Nanocoquimba; Nanocrinus; Nanoctenus; Nanocthispa; Nanocuridae; Nanocuris; Nanocyclopia; Nanocynodon; Nanocythere; Nanodacna; nanodactylus; Nanodamon; Nanodea; nanodealbata; Nanodectes; nanodella; Nanodelphys; nanodendron; nanodes; Nanodiaparsis; Nanodiaptomus; Nanodidelphys; Nanodiella; Nanodiodes; Nanodiplosis; Nanodiscus; nanodisticha; Nanodromia; Nanodynerus; Nanofila; Nanofilidae; Nanogalathea; nanoglobum; Nanoglossa; Nanognathia; Nanognathus; Nanogomphodon; Nanogona; Nanogonalos; Nanogorgon; Nanogramma; Nanograptus; Nanogyra; Nanogyrini; Nanohalus; Nanohammus; Nanohemicera; nanohystrix; nanoides; Nanoini; Nanojapyx; Nanokerala; Nanokermes; Nanola; Nanolachesilla; Nanolania; Nanolauthia; Nanolestes; Nanolichus; Nanolobus; Nanoloricida; Nanolpium; nanolumen; Nanomaja; Nanomantinae; Nanomantini; Nanomantis; Nanomelon; Nanomermis; Nanomerus; Nanomeryx; Nanometa; Nanometidae; Nanometinae; Nanometra; Nanomia; Nanomias; Nanomicrophyes; Nanomilleretta; Nanomimus; Nanomis; nanomitra; Nanomitriella; Nanomitriopsis; Nanomitus; Nanomutilinae; Nanomutilla; Nanomyces; Nanomyina; Nanomyrmacyba; Nanomyrme; Nanomys; Nanomysis; Nanomysmena; Nanonaucoris; Nanonavis; Nanoneis; Nanonemoura; nanonocticolus; Nanonycteris; Nanopachyiulus; Nanopagurus; Nanopareia; Nanoparia; Nanopatula; nanopennatum; Nanoperla;Nanophareus; Nanophemera; Nanophthalmus; Nanophya; Nanophydes; Nanophydinae; Nanophydini; Nanophyes; Nanophyetinae; Nanophyetus; Nanophyidae; Nanophyinae; Nanophyini; nanophylla;Nanophylliini; Nanophyllium; nanophyllum; nanophyllus; Nanophytes; nanophyti; Nanophyton; Nanopilumnus; Nanopitar; Nanoplagia; Nanoplax; Nanoplaxes; Nanoplectrus; Nanoplinthisus; Nanopodella; Nanopodellus; nanopolymorphum; Nanopolystoma; Nanopria; Nanops; Nanopsallus; Nanopsis; Nanopsocetae; Nanopsocus; Nanopterodectes; Nanopterum; Nanoptilium; Nanopus;nanopyxis; Nanoqia; nanoqsunquak; Nanorafonus; Nanorana; Nanoraphidia; Nanorchestes; Nanorchestidae; Nanorhamphus;Nanorhathymus; Nanorhopaea;			

	Nanorrhacus; Nanorrhynchus;Nanorthidae; Nanorthis; Nanos; nanosalicium; Nanosauridae; Nanosaurus; Nanoschema; Nanoschetus;Nanoscydmus; Nanoscypha; Nanosella; Nanosellini; nanoserranus; Nanosesarma; nanosetus; Nanosilene; Nanosiren; Nanosius; Nanosmia; Nanosmilus; nanosomus; nanospadix; nanospathulatum; Nanospira; Nanospondylus; nanospora; Nanosteatoda; nanostellata; Nanostictis; Nanostoma;Nanostomus; Nanostrangalia; Nanostrea; Nanostreptus; Nanosura; Nanosylvanella; Nanotagalus; Nanotanaupodus; nanotaphus; Nanotermitodius; Nanothamnus; nanothecioidea; Nanothecium;Nanothinophilus; Nanothrips; Nanothyris; Nanotitan; Nanotitanops; Nanotopsis; Nanotragulus; Nanotragus; Nanotrema; Nanotrephes; Nanotrigona; Nanotriton; Nanotrombium; Nanotyrannus;Nanovirida; Nanovirus; Nanowana; Nanowestratia; Nanoxylocopa.			

APPENDIX B: STRUCTURED INTERVIEW FORM

"A NANOTECHNOLOGY ROAD MAP FOR THE TURKISH DEFENSE INDUSTRY"
INTERVIEW FORM

Dear Participant,

The aim of this study is to create "A Nanotechnology Roadmap for the Turkish Defense Industry". In this context, by using the Web of Science database, the most cited nanotechnology related 50,000 articles published in the last decade have been analyzed with bibliometric analysis methods. Your views about the findings of bibliometric analysis are important for the roadmap to be formed. I would like to thank you for your valuable contributions, interest and valuable time which you have given to this study.

1. What is your branch?

2. How many years have you been doing this job?

3. As a result of the bibliometric analysis; frequency-based featured key words of the first thousand articles from the 50,000 most cited publications on nanotechnology published in the last decade are like this: nanoparticles, nanostructure, self-assembly, drug delivery, graphene, carbon nanotube, nano composites, electrospinning, quantum dots. Which of the terms (featured words of bibliometric analsis) if used primarily in military technology, contribute to the development of Turkish Defense Industry more from your point of view?

4. Looking at the areas of nanotechnology publications in the last decade, according to the result of bibliometric analysis; Chemistry, Materials Sciences, Physics, Science&Technology and other subjects, Biochemistry&Molecular Biology, Engineer, Polymer Sciences, Electrochemistry, Pharmacology and Cell Biology have been among the top ten fields of research in nanotechnology. Which areas should be focused on for the development of the Turkish Defense Industry for you?

5 What do you think about the commercialization time of nanotechnology's sub-areas? When will the commercialization of nanotechnology sub-areas take place according to you?

	Predictable	Foreseeable	Probable
	2018-2020	2020-2025	2025-2035
Nanoparticles			
Drug delivery			
Quantum dots			
Graphene			
Self-assembly			
Nanocomposites			
Carbon nanotube			
Others			

6. How can nanotechnology issues focused in the world be imported to the Turkish Defense Industry (which transfer methods)? (Technology transfer, University industry cooperation, Technical Cooperation Agreements, Foreign capital investments, License agreements, Reverse engineering etc.)

APPENDIX C: SURVEY FORM

"A NANOTECHNOLOGY ROAD MAP FOR THE TURKISH DEFENSE INDUSTRY"

Dear Participant,

The aim of this study is to create "A Nanotechnology Roadmap for the Turkish Defense Industry". In this context, by using the Web of Science database, the most cited nanotechnology related 50,000 articles published in the last decade have been analyzed with bibliometric analysis methods. Your views about the findings of bibliometric analysis are important for the roadmap to be formed. The study is carried out under the supervision of Assoc.Prof.Dr. Serhat BURMAOGLU in the Department of Technology Management of Defense Sciences Institute of the Turkish Military Academy. Your assessments will only be used for scientific purposes.

Interviews were held with the METU Center For Solar Energy Research and Applications (GUNAM) staff and Bilkent University National Nanotechnology Research Center (UNAM) staff about the subject. Experts of the subject gave the following answers:

1. Which of the frequency-based featured keywords of the first thousand most cited publications related to nanotechnology contribute more to the development of the Turkish defense industry, if they are used primarily in military technology fields? Experts answered this question mostly as nanocomposites, nanoparticles and graphene.

2. Which areas should be focused on for the development of the Turkish Defense Industry? Experts mostly told that Materials Sciences and Biochemistry&Molecular Biology should be focused on.

3. When will the commercialization of nanotechnology sub-areas take place? Experts expressed the commercialization time like this: nanoparticles in 2017-2020, drug delivery in 2025 and later, quantum dots in 2020 and later, graphene in 2017-

2020, self-assembly in 2025 and later, nanocomposits in 2017-2020 and carbon nanotube in 2017-2020. Besides, they stated that nanophotonics will be commercialized in 2017-2020, electrospinning (nanofiber) in 2020-2025 and 2D non-graphene materials in 2025.

4. How can nanotechnology issues focused in the world be imported to the Turkish Defense Industry (which transfer methods)? Experts replied as university-industry cooperation method. In addition, some of the experts also stated that investment in basic science and basic researches is important for gaining advanced technology.

When evaluating the results of the research, no application will be made to display the company/institution/organization or individual information. Answering realistically is very important in terms of consistency and reliability of the study. I would like to thank you for your valuable contributions, interest and valuable time which you have given to this study.

Ayhan AYDOĞDU
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Department of Technology Management,

e-mail: aydogdu60@hotmail.com
Cell Phone: 533 2454144

* What is your branch?…………….

* How many years have you been doing this job?

a. 1-3 b. 4-9 c. 10-14

ç. 15-20 d. More than 20

1. As a result of the bibliometric analysis, frequency-based featured key words of the first thousand articles of the 50,000 most cited publications related to

nanotechnology published in the last decade are shown in the table below. According to you, which of these words contribute more to the development of the Turkish defense industry, if they are used primarily in military technology fields?

nanoparticles	nanostructure	self-assembly	drug delivery	graphene	carbon nanotube	nano composites	electrospinning	quan tum dots
a	b	c	ç	d	e	f	g	ğ

2. Looking at the areas of nanotechnology publications in the last decade, according to the result of bibliometric analysis; Chemistry, Materials Sciences, Physics, Science&Technology and other subjects, Biochemistry&Molecular Biology, Engineer, Polymer Sciences, Electrochemistry, Pharmacology and Cell Biology have been among the top ten fields of research in nanotechnology. According to you, which areas should be focused on for the development of the Turkish Defense Industry?

Chemistry	Materials Sciences	Physics	S&T and other subjects	Biochemistry&Molecular Biology	Engineer	Polymer Sciences	Electrochemistry	Pharmacology	Cell Biology
a	b	c	ç	d	e	f	g	ğ	h

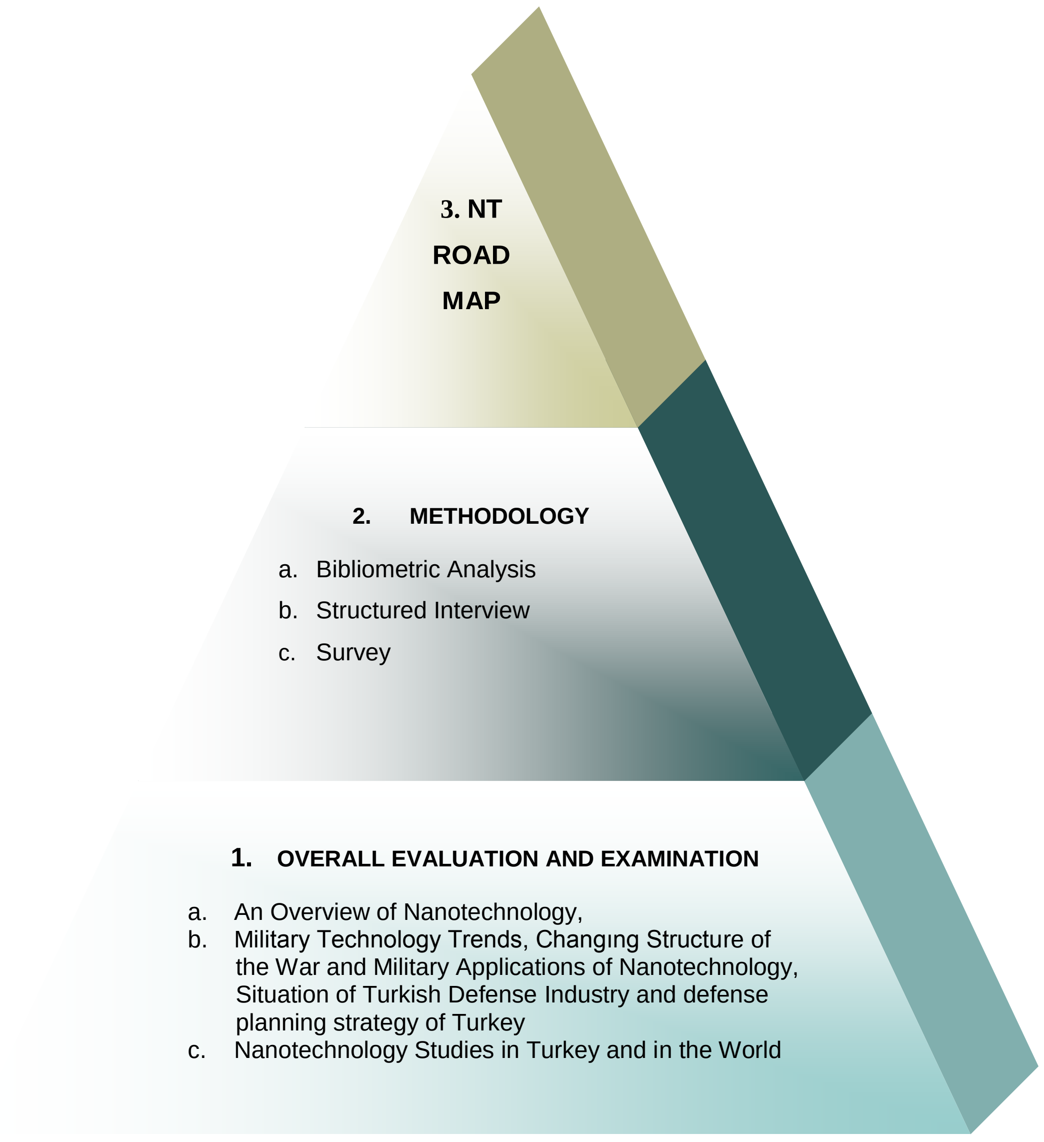
3. Which nanotechnology applications will be used in the field of military technology and when?

	Predictable	Foreseeable	Probable
	(2018-2020)	(2020-2025)	(2025-2035)
Armoured Technologies			
Warriors			
Survival Technologies			
Weapon Technologies			
Ammunition Technologies			
Energy Technologies			
Command and Control Technologies			
Others			

4. How can nanotechnology issues focused in the world be imported to the Turkish Defense Industry (which transfer methods)? (University industry cooperation, Technical Cooperation Agreements, Foreign capital investments, License agreements, Reverse engineering etc.)

a.	Technology transfer	b.	Foreign capital investments
c.	License agreements	ç.	Technical Cooperation Agreements
d.	Reverse engineering	e.	University industry cooperation
f.	Other		

APPENDIX D: MODEL APPLIED IN THE THESIS



APPENDIX E: CURRICULUM VITAE

PERSONAL INFORMATION:

Surname, Name: AYDOĞDU, Ayhan
Nationality: Turkish
Date and Place of Birth: 15th September 1976, Amasya
E-mail: aydogdu60@hotmail.com

EDUCATION:

Degree	Institution	Year of Graduation
MS	KHO SAVBEN Technology Management	2004
BS	KHO Systems Engineering	1999

ACADEMIC WORK EXPERIENCE

Project Officer at MoND Technical Services Department 2009-2015

Defense Industry Communication and Coordination Branch
(Briefing and demonstration activities of domestic and foreign companies related to their military technological products)

PROFESSIONAL WORK EXPERIENCE

Platoon Commander	2000-2004
Company Commander	2004-2009

Project Officer at MoND	2009-2015
Headquarters Officer	2015-2016
Social Facility Officer	2016-2018
Batallion Commander	2018-

PUBLICATIONS

Aydoğdu, A. 2004. “The Comparison of the new supply system with the existing one in Turkish Army”. MS Thesis. KHO Defense Science Institıute, Ankara.

Aydogdu, A., Burmaoglu, S., Saritas, Ö., and Cakir, S. 2017. "A Nanotechnology Roadmapping Study For the Turkish Defense Industry", Foresight, Vol. 19 Issue: 4, pp.354-375, https://doi.org/10.1108/FS-06-2017-0020.

INTERESTS

Military systems, robotics, technology and innovation management, technology transfer, technology development, science and technology policy, technology road maps, R&D studies in the context of technology.

APPENDIX F: TURKISH SUMMARY / TÜRKÇE ÖZET

Nanoteknoloji geleceğin sanayi devrimi olarak ta adlandırılan bir teknolojiyi temsil etmekte ve gelecekte hayata dair birçok ürünün/hizmetin bu teknoloji yoluyla değiştirileceği öngörülmektedir. Ancak açıkça belirtmek gerekirse nanoteknoloji alanındaki bu gelişmeler onu tanımlayabilme ve düzenleyici tedbirler almanın ötesinde daha süratli bir değişim göstermektedir. Dolayısıyla ulusal düzeyde strateji ortaya koymak ve ulusal kaynakların aktarılması için AR-GE öncelikleri saptayabilmek ulusal ve uluslar arası düzeyde ciddi uzgörü çalışmaları yapılmasını gerekli kılmaktadır. Meissner (2012) ulusal uzgörü çalışmalarının sonuç ve etkilerini incelediği makalesinde kısa ve orta vadede bu tip çalışmaların örneklemindeki ülkeler için önemli katkılar sağladığını belirtmektedir. Dolayısıyla 2023 için kendisine hedefler belirleyen ülkemiz için farklı konu alanlarında yürütülecek uzgörü çalışmalarının sağlayacağı olumlu katkının önemli olacağı da Meissner (2012)'in bulgularından hareketle söylenebilir.

Bu nedenle yürütülen çalışmanın amacı Dünya'da nanoteknoloji alanındaki ilerlemelerin bilimsel yayınlar üzerinden incelenmesi ve bu incelenen trendler ışığında savunma sanayi alanında teknoloji alanlarının nasıl bütünleştirilebileceği üzerinde teknoloji yol haritası oluşturmaktır. Çalışmanın veriye dayalı ve uzman etkileşimli bir model olarak kurgulanmış olması bugüne kadar Türkiye'deki diğer politika geliştirme süreçlerinden farklılığıdır. Savunma alanında yapılan yatırımlar ve yürütülen AR-GE çalışmaları düşünüldüğünde ise konunun önemi aşikardır.

Bu tezle ilgili problem sahası aslında nanoteknolojideki hızlı gelişmeler ve bu gelişmelere ayak uydurabilmek için yürütülen çabalar olarak ifade edilebilir. Nanoteknoloji konusunda küresel eğilimlere ve son dönemde yapılmış önemli çalışmalara yer verilen literatür araştırmasında görülebileceği gibi bu alanda yapılan çalışmaların çok çeşitli ve hatta insanın hayallerini zorlayacak tarzda olduğu söylenebilir. Bu çalışmalar askeri açıdan da gelişmiş ülkeler tarafından araştırılmakta, incelenmekte ve geleceğin savunma konspetleri ışığında yeni ürünler, teknolojiler geliştirilmektedir. Bu kapsamda iki temel soru karşımıza çıkmaktadır:

(i) Dünya'da nanoteknoloji alanında gelişmeler hangi yönde ilerlemektedir ve bu ilerlemelerin savunma alanında uygulama alanları hangi malzeme alanlarında olabilir?

(ii) Türkiye'nin savunma sanayi stratejisi incelendiğinde Türk Savunma Sanayisi için nanoteknoloji yol haritası nasıl oluşturulabilir?

Bu tez çalışması kapsamında Web of Science veri tabanından en çok atıf alan nanoteknoloji ile ilgili makaleler bibliyometrik analize tabi tutulmuştur. En çok atıf alan ilk 50.000 yayın Web of Science (WOS) veri tabanından indirilerek VantagePoint yazılımı ile ayrıştırıldığında 130 araştırma alanı, 119 ülke, 1048 üniversite ve 1906 yazardan oluşan bir küme elde edilmiştir. Başlangıçta Dünya ve Türkiye arasındaki Gap Analizi icra edileceğinden politika geliştirme çalışmalarına ışık tutabilmesi açısından en çok atıf alan çalışmaların anahtar kelimelerine odaklanılmış ve bu anahtar kelimelerin hangi konularda yoğunlaştığı anlaşılmaya çalışılmıştır. Son 10 yılda en çok atıf alan ilk bin yayın içerisinde yazarların kullandıkları anahtar kelimeler temel bileşenler analizi ile kümelenmiş ve Aduna Kümeleme Algoritması ile haritalandırılmıştır. Haritalandırmada 17 ana kümenin oluştuğu gözlenmiştir. Bunların bazıları nanoteknolojik özellikleri ihtiva etmekte, bazıları ise doğrudan ürünlere işaret etmektedir. Polimerler, nanokompozit, grafen ve karbon nanotüp gibi ürünler son on yılın en çok atıf alan yayınlarında öne çıkmaktadır. Ayrıca ilaç taşıma/ilaç salınımı (drug delivery), manyetik özellikler ve kendi kendine birleşme (self-assembly) gibi özelliklerin de araştırma konusu içerisinde olduğu gözlenen bulgular arasındadır.

Burmaoğlu, (2016) tarafından yapılan çalışmada "Türkiye Adresli Yazarlar Tarafından Kullanılan Anahtar Kelimelere İlişkin Haritalandırma"da Dünya literatüründe yüksek oranda bulunan Grafen kavramının oluşturulan haritada bulunmadığı dikkat çekici bir veri olarak belirtilmektedir. Ayrıca Dünya ölçeğinde en çok atıf alan yayınlar kullanılarak oluşturulan haritalarda, nanoteknolojide kullanılan araçların (AFM, XRD gibi) bir küme olarak çıkmadığı ancak Türkiye için oluşturulan haritada bir küme olarak geliştiğinin görüldüğü belirtilmektedir.

Aynı çalışmada, karşılaştırma yapılabilmesi için hangi terimlerin öne çıktığının da değerlendirilmesinin önemli olduğu belirtilmektedir. Bu kapsamda Kleinberg'in ani ortaya çıkma algoritmasından yararlanıldığı ifade edilmektedir. Böylece Kleinberg'in ani ortaya çıkma algoritması kullanılarak hangi konuların benzerlik taşıdığından hareketle niteliksel bir değerlendirmenin de yürütülmesi ve alanın anlaşılması açısından daha gerçekçi fikir elde edileceğinin düşünüldüğü belirtilmiştir. Dünya verisi üzerinden Citespace (Chen, 2006) yazılımı kullanılarak yürütülen analizde ani ortaya çıkan anahtar kelimeler olarak Graphene kavramının ve Sheet kavramının ağırlıklı olduğu gözlenmektedir. Bu kavramlardan özellikle nanoteknolojinin uygulanmasında yararlanıldığı söylenebilir. Bu analizde elde edilen veriler içerisinde bir diğer önemli konu ise yayın yılı ortalaması, ani ortaya çıkma başlangıç ve bitiş yılları olarak gösterilebilir. Bu değişkenler incelendiğinde son on yılın en çok atıf alan çalışmaları üzerinden çalışma yürütülmüş olsa bile son 3-5 yıllık süre içerisinde ani ortaya çıkan kelimelerin enerji alanında ağırlıklı çalışmaları barındırdığı görülmektedir. Özellikle var olan batarya veya fotovoltaik hücrelerin malzeme niteliklerinin daha da geliştirilmesi çalışmalarının bu alanda yer aldığı görülmektedir.

Graphene'in ağırlıklı bir çalışma alanı olması da önemsenmesi gereken bir durum olarak söylenebilir. Karşılaştırma yapılabilmesi maksadıyla Türkiye verisi üzerinden çalışma yürütüldüğünde ise Türkiye verisinde ani ortaya çıkan anahtar kelimeler ile Dünya'da ani ortaya çıkan anahtar kelimeler arasında ortak olan bir kelimeye rastlanılmamıştır. Dünya'da özellikle enerji sistemleri bağlamında ani ortaya çıkan terimlerin yoğunlaşması, bu alanda yapılacak yönlendirmelerin Türkiye için de önemli olabileceği öngörülebilir. Biyoteknoloji, enerji ve ilaç gibi Türkiye'nin de aslında dışa bağımlılığın yüksek olduğu alanlarda yeterli uygulamanın yapılmıyor olması dikkat çekicidir. Diğer yandan Dünya'da enerji alanında yoğunlaşan çalışmaların konuları bağlamında Türkiye'de benzer bir yapı göstermiyor olması veya kritik yoğunluğa veya frekansa ulaşacak miktarların yakalanamamış olması Türkiye gibi enerji bağımlılığı yüksek bir ülke için önemli bir boşluk olarak değerlendirilebilir.

Yapılan analiz ve değerlendirmeler ışığında, dünyada nanoteknoloji çalışmalarının grafen, grafit, quantum dots, nano-kompozit, nano-sheet gibi malzemeler ve biyoteknoloji, enerji, malzeme bilimi, kimya ve ilaç gibi uygulama alanlarına yoğunlaştığı söylenebilmektedir. Bu durumun önemli yansıması askeri teknolojiler bağlamında özellikle zırh, yakıt, pil ve hayatı idame malzemeleri bağlamında değerlendirilebilir.

Anılan teknolojik gelişmelere yardımcı nitelikteki teknoloji alanları ise malzeme bilimi, bilgisayar ve enformatik bilimi, biyoloji ve mühendislik bilimleridir. Örneğin biyopolimerler, biyoloji ve malzeme bilimlerinin kesişimi olarak oldukça güçlü, hafif, esnek ve fark edilmesi daha zor insansız araç gövdeleri tasarlamak için yeni fırsatlar sunmaktadır. Malzeme biliminde, nanoparçacıklar özellikle karbon nanotüpler (en çok atıf alan ilk bin yazarın anahtar kelimelerinde öne çıkanlar arasında yer almaktadırlar), insansız sistemlerin haberleşme altyapısında kullanılabilecek çok yüksek frekanslarda mekanik cihaz yapımında kullanılabilmektedir.

Ayrıca nanoparçacıkların kullanımı ve elektriksel uyarımlı polimerlerin kullanımı ile kamuflaj özellikli insansız araçların üretimi söz konusu olabilecektir. Bizmut nanoparçacıkları sayesinde elde edilecek yüksek verimli, katı enerji dönüşüm cihazları eskiye göre insansız muharebe araçlarına ağırlık ve boyut açısından önemli avantaj sağlayacaktır. Algılama, kontrol ve tepki yeteneklerini birleştiren ve değişen çevre koşullarına uyum sağlayan akıllı materyaller, malzeme ve bilgisayar mühendisliklerinin bünyesinde gelişmekte olan manyetik nanoparçacıkların kullanıldığı manyetik depolama cihazları insansız araçların bilişsel kapasitesini artıracaktır (Teknoloji Bülteni, 2016).

Bibliyometrik analiz sonucunda ortaya çıkan sonuçlarla ilgili Bilkent Üniversitesi Ulusal Nanoteknoloji Araştırma Merkezi (UNAM), Orta Doğu Teknik Üniversitesi Güneş Enerjisi Araştırma ve Uygulama Merkezi (GÜNAM) ve Sabancı Üniversitesi SUNUM çalışanları ile görüşme yapılmıştır.

Frekans bazında öne çıkan anahtar kelimeler ile askeri teknolojilerin ilişkilendirilebileceği konular MSB'de görev yapan mühendislere bir anketle sorulmuştur. Görüşme ve anket sonucunda ulaşılan sonuçlardan yöntem bölümünde bahsedilmektedir.

Geleceğin muharebe ortamında teknolojinin çok yoğun kullanılacağı gerçeğinden hareketle ihtiyaç duyulan silah, sistem, araç, teçhizat ve malzemenin üretilmesinde nanoteknolojiden ve nanoteknolojinin alt dallarından istifade edilmesiyle daha güçlü silah sistemlerine ve muharebe gücüne sahip olunabileceği değerlendirilmektedir.

Ancak hayal etmenin gerçekleştirmenin ilk adımı olacağı düşüncesiyle Dünya'nın nerede olduğunu kestirebilmek için teknoloji madenciliği yöntemlerinden bibliyometrik çalışmalar yürütmenin bu aşamada katkı sağlayacağı düşünülmektedir. Norton (2008) bibliyometrik çalışmaları metin ve bilgilerin ölçülmesi bilimi olarak tanımlamaktadır. Bibliyometrik yöntemler yoluyla büyük miktardaki verilerin edinimi, toplanması, organizasyonu ve analizi ile geçmişte ortaya çıkan ve gelecekte gözlenecek eğilimlerin tanımlanması mümkündür (Daim ve Suntharasaj, 2009). Bu tez çalışmasında tasarlanan yaklaşım ile Web of Science yayın veri tabanından yararlanılarak nanoteknoloji ile ilgili olarak literatürde önerilen anahtar kelimeler ve ifadeler kullanılarak bunlara yönelik bilimsel ve teknolojik gelişme alanları tanımlanmış olup, bu konularda Dünya'da ve Türkiye'deki yetkinleşme düzeyleri ortaya çıkarılmıştır. Yayınların analizi ile gelecekte bugünden yapılacak Ar-Ge çalışmalarına ilişkin stratejilere yönelik ipuçları belirlenebilmiştir.

Konuya genel olarak bakılırsa; Nanoteknolojinin; ölçeği olan "nanometre" kavramı ile tanımlandığı ve bir metrenin milyarda biri ile (10^{-9}) nitelendirildiği söylenebilir (Bowman ve Hodge, 2006). Temel olarak nanoteknoloji molekül ve atom bileşimlerinin kontrol edilebilirliği olarak ta adlandırılmakta ve 100 nm ile 1 nm arasındaki aralıkta bulunan ürün geliştirmeleri kapsadığı ifade edilmektedir (Wood ve diğerleri, 2003). Moleküler düzeyde çalışma yapılabilmesi doğal olarak bilim adamlarının çok farklı özelliklerde yapılar ortaya koyabilmelerinde ve yeni araçlar yapmalarında esneklik sağlamaktadır (Forrest, 1989). Lele'ye (2009) göre nanoteknolojiyi yapısal ve moleküler olarak ikiye ayırmak mümkündür. Yapısal nanoteknoloji var olan ürünlerin nanoteknoloji ile geliştirilmesi anlamında kullanılırken moleküler nanoteknoloji ise daha radikal süreçleri içeren yeni maddelerin tasarımı alanına işaret etmektedir. Bu sınıflandırma Lele (2009) tarafından araştırma perspektifleri ile de nitelendirilebileceği ortaya çıkarılmış ve yapısal nanoteknoloji için yukarıdan aşağıya (top-down) yaklaşımın, moleküler nanoteknoloji için ise aşağıdan yukarıya (bottom-up) yaklaşımın karşılık olabileceğini belirtmiştir.

Nanoteknoloji'nin tarihsel geçmişi kısaca özetlendiğinde ise bu konunun 1959 Fizik Nobel Ödülü sahibi Richard P. Feynman'ın "Aşağıda daha çok oda bulunmaktadır- There's plenty of room at the bottom" ifadesini kullandığı bir konuşma ile başladığı söylenebilir (Feynman, 2002). Feynman'ın düşünceleri tek bir atom düzeyinde işlem yapmaya imkân sağlayacak sistemler üzerinde odaklanmıştır. Hatta Feynman'ın bu vizyonu ile kendi kendini yapabilen nanobotlar (yani nano robotlar veya nanobotlar) yapılabileceği öngörülmüş ve bu süreç moleküler üretim olarak tanımlanmıştır. Bu vizyon doğal olarak öngörülemeyen tehditleri ve fırsatları da içinde barındırmaktadır (Drexler, 2004). Feynman'ın konuşmasından yaklaşık 20 yıl sonra Zürih'te IBM'de çalışan bir grup araştırmacı Tarama Tünel (Scanning Tunnelling) Mikroskobunu (Binnig ve Rohrer, 1982) geliştirmek suretiyle tek bir atomun görülebildiği ve işlenebildiği bir cihaz üretmiş oldular. Bu gelişmeyi takip eden birkaç yıl içinde ise Atomik Kuvvet (Atomic Force) Mikroskobu (Binnig ve diğerleri, 1986) geliştirilmiştir. Bu cihazlar çok önemli bir boşluğu doldurma çabası olarak ta değerlendirilebilir. Zira atom düzeyinde çalışma yaparken görmek ve manipüle etmek önemli bir husus olarak düşünüldüğünde mikroskop geliştirmenin nanoteknoloji alanında bir devrim niteliği taşıdığı öne sürülebilir. Bir diğer kilometre taşı ise elektronik ve malzeme mühendisliğinde çok büyük potansiyeli bulunan Fulleren'lerin keşfidir (Kroto et al., 1985).

Keşiflerin başlaması bir diğer malzeme olan graphene teknolojisini de beraberinde getirmiştir. Lv ve diğerleri (2011) graphene teknolojisinin yükselen bir yıldız olduğunu ve birçok uygulamada kullanılabileceğini yaptıkları bibliyometrik çalışma ile ortaya koymuşlardır. Graphene bir atom kalınlığında bulunan düz yapraksı malzemeyi nitelendirmektedir. Birçok yaprağın bir araya getirilmesi sonucunda ise graphite olarak tanımlanan malzemeye ulaşılmaktadır. 1-10 nm ölçüsündeki graphite'in uzun silindirik yapıya dönüştürülmesi ile günümüzde adından teknoloji alanında çok sık bahsedilen Carbon Nanotube malzemesine ulaşılmaktadır. Carbon nanotube'ler çelikten 100 kat daha sağlam bir malzemedir ve güçlü kompozitler, sensorlar, hidrojen depolama birimleri (Tegart, 2004), robotlar için suni deri (Oulette, 2003) gibi ürünlerin yapımında kullanılabileceği öngörülmektedir.

Nanoteknoloji konusunda kısa bir bilgi verdikten sonra bu konuda yapılan uzgörü çalışmalarına bakıldığında Lv ve diğerlerinin (2011) graphene üzerinde bibliyometrik bir çalışma yürüttükleri görülmektedir. Araştırmacılar yaptıkları yayın analizinde "graphen* or single layer graphit*" anahtar kelimesini konu başlığında tarayarak 1991-2010 yılları arasında toplam 8727 araştırma çalışmasına ulaşmışlardır. Sonuçta graphene alanında yapılan araştırmalar içerisinde hangi konulara odaklanıldığı ve hangi araştırmacılar ve araştırma merkezlerince bu konular üzerinde çalışıldığı hususları ortaya konmuştur. Tabii bu araştırma Graphene odaklı bir çalışma olduğu için nanoteknoloji alanının sadece özel bir alanını ihtiva etmektedir.

Bir diğer çalışma ise Tayvan'ın 2020'de nanoteknoloji sanayisini konu alan uzgörü çalışmasıdır (Su vd.leri, 2010). Bu çalışmada Delfi tabanlı uzgörü/ öngörü çalışması yürütülmüş ve nano malzeme, nano elektronik ve nano biyotıp gibi üç ana nanoteknoloji alanı ile ilgili 25 uzmandan alınan bilgiler nanoteknoloji sanayisi için hedef olarak ortaya konmuştur.

Hollanda'da nanoteknolojinin yönetimi konusunda yapılan çalışmada ise van Est ve diğerleri (2012) konuya biraz daha sosyal perspektiften bakarak devlet-bilim-toplum ilişkilerinin yeniden çerçevesinin çizilmesi konusunu gündeme taşımışlardır. Bu çalışma sonucunda nanoteknoloji konusunun aslında sadece mühendislik alanını ilgilendiren bir konu olmadığı ve bu konunun sosyal ve yönetişim boyutlarıyla birlikte ele alınması gerektiği vurgulanmıştır.

Genel olarak nanoteknoloji ile ilgili bilgilerden sonra gelecekte muharebelerin yapısına ilişkin öngörü ve nanoteknolojinin askeri uygulamalarını incelemek faydalı olacaktır. Son elli 50 yılda yaşanan savaşlardaki asker kayıpları geleceğin orduları için çözülmesi gereken önemli bir sorun olarak ortaya çıkmıştır. Hayatını kaybeden ve yaralanan askerler savaşın sonucuna tesir eden bir etken olarak görülmektedir. Muharebe sahasında ölen ve yaralanan asker problemi çözülmesi gereken önemli bir sorun olarak karşımızda durmaktadır. Ayrıca asker kayıpları diğer muharebe eden askerlerin psikolojisini, moral ve motivasyonunu çok olumsuz olarak etkilemektedir. Muharebe ortamında tehlikeli bölgelerde, zor arazi ve iklim koşulları altında istenen görevleri yerine getirebilecek sistemlere de ihtiyaç duyulmaktadır. Ayrıca muharebe sahasında personel, istihbarat, harekat ve lojistik alanında askerlerin yerini alması beklenen ileri teknoloji ürünü sistem/platformların üretilmesi ihtiyacı artık daha çok hissedilmektedir. Bu ihtiyaçlar sonucunda firma/kurum/kuruluşlar ile üniversiteler bu alanda yoğun olarak çalışmaya başlamıştır. Bu çalışmalar kapsamında son yıllarda çeşitli maksatlarla muharebe sahasında kullanılabilecek ve bahsedilen zafiyetleri ortadan kaldırabilecek robotlar üretilmeye başlanmıştır.

Dünya üzerinde hali hazırda ABD'den Boston Dynamics firması, Almanya'dan Festo firması ile ABD'den Carnegie Mellon Üniversitesi askeri maksatlı kullanılması planlanan robot üretiminde öncü durumda bulunmaktadır. Adı geçen firmalardan Google'ın satın aldığı Boston Dynamics firması saatte 25 km. hızla dört nala koşabilen ve zorlu arazi koşullarında dengesini kaybetmeyen Wildcat'i (Vahşi Kedi), saatte 45 km. hızla koşabilen Cheetah'ı (Çita) ve lojistik alanda rahatlıkla kullanılabilecek Bigdog'u (Büyük Köpek) üretmiştir. Almanya'dan Festo firması iki ayak üzerinde hareket edebilen BionicKangaroo'yu üretmiştir. Carnegie Mellon Üniversitesi'nde ise bir yılan gibi hareket edebilen robot icat edilmiş durumdadır. Söz konusu robotlar geleceğin muharebe ortamındaki ihtiyaçlar düşünülerek veya öngörülerek üretilmiştir.

Nanoteknoloji ile ilgili bahsedilen genel hususlara ilave olarak konunun askeri boyutu incelendiğinde de çok önemli hususlara ulaşılabilmektedir. Askeri birliklerin koruma, angajman, tespit, harekat, iletişim ve bilgi toplama gibi karşılıklı ilişkili pek çok çekirdek yetenek seti ve karşılıklı ilişkili muharebe stratejileri üzerinde nanoteknoloji önemli etkilere sahiptir (Caygill et al, 2012). Kharat et al.(2006)'a göre ordular nanomateryal, nanobot ve nanoteknolojinin kitle imha silahlarının üretiminde kullanılması ile tek bir muharabede bile düşmanı yenecek büyük bir güce sahip olacaklardır. Ayrıca Kharat et al.(2006) nanoteknolojinin savunma alanında uygulamalarını dokuz kategoride analiz etmiştir: (i) Silahlanma sistemi (ii) Nanorobotlar (iii) Sensör ve iletim sistemi (iv) Uzay asansörleri (v) İstihbarat teçhizat sistemi (vi) Mikroelektromekanik sistemler (MEMS) (vii) Nano yapılı platformlar (viii) Aerodinamik ve itki sistemleri (ix) Patlayıcılar.

İlave olarak yazarlar, gelecekte savunma alanında nanoteknoloji kullanımını altı kategoride değerlendirmektedir: (i) Mikrosensörler (ii) Nanobilgisayarlar (iii) Akıllı üniformalar (iv) Papatya kesici (v) Süper termitler (vi) Mini atom bombaları.

Lele (2009) ise nanoteknoloji ve nanoteknolojinin askeri uygulamalarını elektronik/bilgisayar/sensörler, bio-savunma, denizcilik uygulamaları, uzay ve diğer savunma uygulamaları, konvansiyonel silahlar/mühimmat ve uzay hava tahmini alanlarında incelemiştir.

Altmann ve Gubrud (2004) bazı askeri alanda öngörüde bulunanların beklentilerine uygun olarak muharebe ortamında savaşanların küçük güdümlü füzeler atan silahlara sahip olacağını, uçan mini robotlar ile keşif ve nöbetçiler için mikro sensör ağları ve her ortamda su toplayabilen taşıyıcı cihazların kullanılacağını aktarmaktadır. Bilgi ve talimatlarla donatılmış bahse konu sistemler taktik komuta merkezi ile korunaklı olarak ağ üzerinden irtibat halinde bulunacaktır. Altı metrelik duvarın aşılmasına yardımcı olan, aynı zamanda kurşun geçirmeyen, vücut sıcaklığını düzenleyen ve gerekli sinyalleri takip eden kıyafet giyen savaşanların dayanıklılığı artırılmış olacaktır. Bu özelliklere bio-kontrol de eklenince savaşçılar bir hafta süresince görev başında ayakta kalabilecek ve uykusuzluk problemi gibi sorun yaşamayacaklardır. Sonuç olarak bu önseziden hareketle kimya, tıp, malzeme bilimi, elektronik, bilgisayar bilimi gibi diğer pek çok bilim dalı bu süper kahramanların yaratılmasına katkıda bulunacaktır.

Ürün bazında nano uygulamaları incelendiğinde ise kabaca Tablo 1'de verildiği şekliyle sınıflandırılabileceği söylenebilir:

Tablo : 1 Ürün Bazında Nano Uygulamaları

Savaşçılar	İlaç taşıma/ilaç salınımı (drug delivery), Kimya-biosensörleri, Askerlerin bedenlerini ve hareket yeteneklerini güçlendirecek implantlar, Görünmezlik özelliği kazandırılmış kamuflajlar (Cai et al., 2007), Ultra-güçlü hafif vücut zırhı (Miaudet et al.,2005), Uzun süre dayanıklı lityum piller, Arama ve kurtarma için künyeler (war tags) (Tiwari, 2012), Kendi kendini yapan (self-assembly) nanobotlar (Drexler, 2004).
Araçlar:	Otonom savaşan araçlar, Milimetre boyutunda keşif araçları, Biomimetrik- güvenilir motor ve daha güçlü zırh için nano kaplama, Karbon nanotüpler kullanılarak yapılan çarpmaya dayanıklı araçlar, Bukelemun stili kamuflaj (Michalet et al., 2005),
Silahlar:	Hafif silah, Daha güçlü ve hafif mühimmat, Yüksek enerji yoğunluklu patlayıcılar, Biyolojik silahlar gibi nanopartiküllerin taşıdığı zararlı maddeler,
Sensörler:	Daha güçlü biyolojik ve kimyasal sensörler, Küçük boyutta ve uzun süre görevini yapan sensörler, Taşınabilir biyolojik muharebe tespit cihazları için biosensörlerde kullanılan organik boyaların yerine geçen kuantum noktalar,
Lojistik:	Güvenli etiketleme için nano RFID levhalar (Verma, 2012), Enerji için hidrojen depolama sistemleri, Düşük maliyetli güneş pili ve bataryalar (Petersen ve Egan, 2002), Su temizleyici Argonit nanomateryal filtreler, Nano su temizleyici (Tiwari, 2012), Nano yiyecek.

Konunun diğer bir boyutu olan gelecekte nanoteknolojideki değişimler ve muharebeye etkileri detaylı olarak incelenmiştir. Altmann'a (2008) göre NT ve Yakınsayan Teknolojilerin potansiyel askeri uygulamaları önemli gelişmeleri içermektedir. NT Silahlı Kuvvetler tarafından özellikle bütün aktiviteler için kullanılabilir. Küçük fakat güçlü bilgisayarlar, muharebe alanı kıyafetleri ve araçlar gibi.

Muharebe Yönetimi ve Lojistik için daha büyük bilgisayar sistemleri kullanılabilir. Küçük ve ucuz sensör sistemleri bol miktarda üretilebilir. Yönlendirme sistemi monte edilmiş küçük mühimmatlar ve küçük füzeler üretilebilir. Nanolif kompozitler metalsiz küçük silahların ve mühimmatın yapılmasına imkan vermektedir. Benzeri malzemeler araçların ve hava taşıtlarının daha hafif ve daha atik olmasına, ısı direnci daha fazla olan malzemeler ise daha etkin motorların üretilmesine katkı sunacaktır.

Böylece muharebe sahasında keşif ve iletişim için kullanılacak otonom araçların üretilmesi mümkün olacaktır. Bazı otonom sistemler çok küçük boyutlarda (önce santimetre. sonra milimetre ve daha küçük boyutlarda) olabilecektir. Nanoteknoloji sinir hücresi iletişimi, bio-uyum, küçük bilgisayar ve güç kaynağı imkanı vermesiyle askerlerin bedenlerinde yapılacak protezlerde de kullanılabilir. Böyle dahili sistemler izleme, iletişim, genişletilmiş duyular veya ilaç salımı gibi kullanılabilir. Zaten bugün genetik mühendisliği ve bioteknoloji yeni hedef olarak belirlenmiş kimyasal ve biyolojik savaş ajanları için seçenekler sunmaktadır.

Birçok ülke ordusu NT'ye dayalı silahlanmayı hedeflemektedir. Silahlar değişik yolla kullanılabilir. Örneğin büyük çapta akciğerlere zarar verilebilir. Dizel makinelerden, santrallerden ve atık yakma fırınlarından çıkan çok küçük parçacıklar insanın akciğerlerine önemli oranda zarar verebilmektedir. Ayrıca askeri maksatlarla kullanılan en tehlikeli nano uygulaması nano-bombadır. Bir topluluğa, bir şehre veya bir ülkeye zarar verebilecek kendini çoğaltan öldürücü virüsler içermektedir. Tüm dünyada ordular artık kitle imha silahı üretebilecekleri nanomalzeme, nanobot ve nanoteknolojiyi öğrenip kullanma yoluna gitmektedir. Çok güçlü ordular bir savaşa girmeden yok olabilir. Askerler ne zaman nanozehir aldıklarını hiçbir zaman bilemeyebilir. Askeri uygulamalarda kullanılan nano malzemeler; nanorobotlar, patlayıcı ve itici gazlar, MEMS/NEMS, akıllı giysi sistemleri, akıllı malzemeler, aerodinamik ve itme gücü, silahlanma elektroniği ile sensörler ve güç çeviricileridir. Gelecekte nanoteknoloji kullanımı mikrosensör, nanobilgisayar, akıllı giysi, papatya kesici, mini atom bombası ve süper termit alanlarında katlanarak artacaktır (Kharat vd., 2006).

Ülkeler tarafından metalürji, patlayıcılar, içten yanmalılar, havacılık, elektronik ve nükleer enerji gibi her bir ana teknoloji dalına sadece barışçıl amaçlarla değil savaşa hazırlık maksadıyla da önem verilmektedir. Nanoteknoloji disiplinlerarası bir bilim olarak özel, kamu ve diğer kuruluşların önem verdiği bir alan haline gelmiştir.

2006 yılında dünya çapında nanoteknoloji ARGE'sine ayrılan para 12.4 milyar dolar iken 2014 yılında bu rakamın 2.4 trilyon dolar olacağı tahmin edilmiştir. 30'dan fazla ülke nanoteknoloji ARGE'sini kurarak çalışmaya başlamış durumdadır (Whitman, 2007).

Nanoteknolojik silahların bakteri benzeri eşleyiciler olabileceği, düşman sınırları içinde kalan topraktan beslenecekleri ve nihayetinde toprağı toza çevirecekleri ya da silahı geliştirenler hangi yıkıcı etkiyi istiyorsa onu yerine getirecekleri gibi bir düşünce mevcuttur. Bugün akıllı bombalar ve füzeler mevcutken, nanoteknoloji sayesinde akıllı kurşunlar üretilebilir. Nanobilgisayarlar, mekanik yeteneklerin üzerine Yapay Zeka özelliğini eklerse, düşman hatlarına sızmak için katlanarak fare boyuna inen, nesne ya da silah kullanmak için tekrar açılıp insan boyuna çıkan ve saatte yüzlerce kilometre hızla uçan robot askerler üretilebilir. Faz sıralı optik deriler sayesinde fiilen görünmez olabilirler. Hareketleri, insan gözünün izleyemeyeceği bir hıza ulaşabilir (Hall, 2013).

Savaşa hazırlanmak için ulusların sadece yaygın bir nano imalat altyapısına ihtiyacı olacaktır. Bu imalat sistemi, gereksinim doğduğu zaman, bu tarz robotlar ve onlara eş silahlar ve araçlar üretilebilir. Bıçak kemiğe dayanınca, hakiki ordu bir saat içinde üretilebilir. İri bir faz-sıralı optik dokusu, istenilen hedefe ışık odaklayabilir. Eğer binaların çatıları bu dokuyla kaplanırsa, güneş ışığı toplayıcısı, radar, optik kamera, spot ışığı ve yeterince eğim verilirse sokak lambası vazifesi görülebilir. Gerekli olursa ve birçok binanınki eşgüdümlü olarak kullanılırsa, lazer benzeri bir uçak savar işlevleri de olabilir (Hall, 2013).

Yirminci yüzyılda, insanoğlunun başına gelecek felaketlerin sebepleri arasında en göze çarpanı savaştır. Savaşın ölümcüllüğüne teknolojinin bariz katkısı olmuştur. Nanoteknolojinin devreye girmesiyle tüm ülke sinek boyutunda insansız uçaklarla doldurulabilir. Bu durumda suçluların ve/veya terörist grupların saklanması daha zor olacaktır. Günümüzde insansız uçaklar (İHA/İKU) havadan yere fırlatılan füzelerle donatılmıştır. Binaları ve ağaçları vurmak için kullanılabilir. İnsansız nanouçaklar, çeşitli türlerde iğneler taşıyabilir ve insanlara öldürücü, takat kesici, ya da acıdan kıvrandırıcı dozlarda kimyasal veya biyolojik etkenler zerk edebilirler (Hall, 2013).

Wang ve diğerleri (2012) gelecekte ülkeler arasındaki savaşın klasik muharebeler gibi olmasından ziyade asıl olarak bilim ve teknoloji savaşı şeklinde olacağını belirtmektedir. Bundan dolayı yeni savaş şeklinde Nanoteknolojinin yeri çok önemli olacaktır. Nano silahlar ve nano silah sistemleri ultra-minyatürleşme, istihbarat ve yüksek performans gibi konularda önemli avantajlara sahiptir. Nanoteknolojik silah sistemleri, operasyonel komuta ve muharebe modelleri gibi alanlarda bir dizi önemli değişikliklere sebep olacaktır.

Wang ve diğerleri (2012) gelecekte nanoteknoljinin askeri eğilimleri kesinlikle etkileyeceğini belirtmektedir. Özellikle muharebenin yapısının devrimsel değişimi, bilgiye yeni bir erişim şekli (uydular, keşif uçakları, yüksek teknolojili silahların kullanılması), insan/makine kombinasyonunun yeni çağrışımları ve operasyonel komuta platformunun korunması ve görünmez olması gibi konularla karşılaşılacaktır. Gelecekte muharebe sahasında, dev silah sistemleri ve minyatür silah sistemleri aynı anda faaliyette olacaktır. Birlikte çok önemli işler başaracaktır. Hatta karıncaların filleri yediği, küçük sistemlerin etkin olduğu ve mikronun devi yendiği sahneleri görmek mümkün olacaktır. Görülebileceği üzere Nanoteknoloji uygulamaları savunma alanında da geniş bir yelpazede incelenebilecek potansiyel taşımaktadır.

Teknolojinin sürekli evrilerek gelişmesi (Bassalla, 1988) geçmişte yüz yıllık süreçler için öngörü çalışmalarını yeterli olarak görmekte iken bugün daha sık aralıklarla uyumlu politika ve strateji çalışmalarının yapılmasına ihtiyaç duymaktadır. Zira süratli değişen teknoloji fırtınasında ayakta durabilmek için sistem bakış açısı ile dinamik çevresel şartları göz önüne alarak geleceğe ilişkin sürekli değerlendirmeler yapmak ve uzgörü çalışmaları ile uyumlu (adaptive) politika ve strateji araştırmaları yürütmek ulusal kaynakların etkin, etkili ve verimli kullanılması için önemlidir.

Bu kapsamda teknolojinin geldiği nokta itibariyle özellikle nanoteknoloji gibi özel bir alanın sanayi devriminde Fordist uygulamaların geçmişte yarattığı etkiden daha büyük bir etki yaratacağı araştırmacılar tarafından öngörülmektedir. Ülkemizde de konunun önemi TÜBİTAK (Türkiye Bilimsel ve Teknolojik Araştırma Kurumu) ve Bilim ve Teknoloji Yüksek Kurulu tarafından fark edilerek 2004 yılında bu konu yayınlanan Strateji Belgesinde yerini almıştır. Nanoteknoloji; TÜBİTAK Ulusal Bilim ve Teknoloji Politikaları 2003-2023 Strateji Belgesinde stratejik teknoloji alanları içerisinde değerlendirilmiş ve ülkelerin refah seviyesi, ekonomisi ve ulusal güvenliği bağlamında; (i) Nanofotonik, Nanoelektronik, Nanomanyetizma, (ii) Nanomalzeme, (iii) Nanokarakterizasyon, (iv) Nanofabrikasyon, (v) Nano Ölçekte Kuantum Bilgi İşleme, (vi) Nanobiyoteknoloji başlıkları altında incelenmesi gerektiği vurgulanmıştır.

Nanoteknoloji konusunun derinlemesine araştırılmasının ülkemizin ve savunma sanayimizin nanoteknoloji stratejisine yeni bir bakış açısı kazandırabileceği ve bilgi kapasitesi, işbirliği ve gelecek teknolojileri bağlamında politikanın değişik bir yorumunu ortaya çıkarabileceği düşünülmektedir. Çünkü teknoloji madenciliği uygulamaları çok yüksek miktardaki veriyi analiz ederek bunların içerisindeki görülemeyen trendleri ve gelecekte değişimin öncüsü olabilecek zayıf sinyalleri ortaya çıkarmakta ve bu trendler doğrultusunda alternatif araştırma konuları ortaya konulabilmektedir. Bu alternatif araştırma konuları doğrultusunda geliştirilecek stratejiler ile ülkemizin ve savunma sanayimizin nanoteknoloji alanında gideceği farklı yönelimlere yenilikçi yaklaşımlar ile hazırlıklı olması sağlanabilecektir.

Çalışma alanı ile ilgili teorik çalışmalar yazın taramasıyla gerçekleştirilmiştir. Nanoteknoloji konusunda dünyada ve Türkiye'de mevcut durumun tespiti için ulusal ve uluslar arası çalışmalar, kamu kurum ve kuruluşlarının yayınları, kanunlar, yönetmelikler ve genelgeler gibi mevzuat taraması yapılmıştır. Bu çalışmada teknoloji madenciliği yöntemlerinden bibliyometrik analiz yöntemi ile nanoteknolojideki gelişmeler incelenmiştir. Ayrıca görüşme ve anket yoluyla değişik uzmanlardan veriler elde edilmiştir.

Nanoteknolojinin Dünya'daki gelişimini ve öne çıkan konularını son on yılın en çok atıf alan 50.000 makalesi Web of Science veri tabanından indirilerek yayın trendleri konu, anahtar kelime, yazar, ülke bağlamında incelenmiştir. Anahtar kelime seti olarak Arora vd. (2013)'nin Georgia Tech Üniversitesinde mevcut son güncellenen hali kullanılmıştır.

Bibliyometrik analiz sonucunda ortaya çıkan sonuçlarla ilgili Bilkent Üniversitesi Ulusal Nanoteknoloji Araştırma Merkezi (UNAM), Sabancı Üniversitesi Nanoteknoloji Araştırma Merkezi (SUNUM) ve Orta Doğu Teknik Üniversitesi Güneş Enerjisi Araştırma ve Uygulama Merkezi (GÜNAM) çalışanları ile nitel araştırma yöntemlerinden yapılandırılmış görüşme (Structured Interview) (standartlaştırılmış açık uçlu görüşme) formatında görüşme yapılmıştır. Tüm katılımcılara dikkatlice hazırlanmış ve bir sıraya konmuş aynı sorular yöneltilmiştir. Açık uçlu soru tipi kullanılmıştır. Frekans bazında öne çıkan bu anahtar kelimelerin Türkiye için ticarileşme süresinin ortaya konmasına yönelik olarak veri toplanmıştır.

Uzmanlara göre; Anahtar kelimelerden nano composites, nanoparticles ve graphene askeri teknoloji alanlarında öncelikle kullanılırsa Türk savunma sanayinin gelişimine daha fazla katkı sağlar, Türk Savunma Sanayinin geliştirilmesi için Malzeme Bilimi ve Biyokimya&Moleküler Biyoloji alanlarına odaklanılmalıdır.

Dünyada odaklanılan nanoteknoloji konuları Türk savunma sektörüne üniversite-sanayi işbirliği yöntemi ile ithal edilmelidir. Ayrıca temel bilimlere yatırım yapılması ve temel araştırmalara önem verilmesi gerekliliği de vurgulanmıştır.

Nanoteknoloji alt alanlarına ilişkin; nanoparticles 2017-2020 yıllarında, drug delivery 2025 ve sonrasında, quantum dots 2020 ve sonrasında, graphen 2017-2020 yıllarında, self-assembly 2025 ve sonrasında, nanocomposits 2017-2020 yıllarında ve carbon nanotube 2017-2020 yıllarında ticarileşecektir. Ayrıca nanofotonik 2017-2020 yıllarında, electrospinning (nanofiber) 2020-2025 yıllarında ve grafen dışı iki boyutlu malzemeler 2025 sonrasında ticarileşeceği belirtilmiştir.

Frekans bazında öne çıkan anahtar kelimeler ile askeri teknolojilerin ilişkilendirilebileceği konular MSB'de görev yapan mühendislere bir anketle sorulmuştur. Anket sonucunda; nano composite, nano structure, nanoparticles ve grafen Türk Savunma Sanayine en çok katkı sağlayacak ürünler olarak, Malzeme Bilimi odaklanılması gereken alan olarak, teknoloji transferinde üniversite – sanayi işbirliği yöntem olarak belirtilmiştir.

Nanoteknoloji uygulamaları zırh teknolojisinde 2017-2020 yıllarında, savaşçıda 2020-2025 yıllarında, hayatı idame teknolojilerinde 2020-2025 yıllarında, silah teknolojilerinde 2020-2025 yıllarında, mühimmat teknolojilerinde 2020-2025 yıllarında, enerji teknolojilerinde 2020-2025 yıllarında ve komuta-kontrol teknolojilerinde 2020-2025 yıllarında kullanılmaya başlanacaktır.

Sonuçta bibliyometrik analiz, anket ve görüşme sonucu elde edilen karşılaştırma verileri ışığında Türkiye'nin trendleri ile Dünya trendleri arasındaki boşluk (Gap) analiz edilerek alternatif araştırma stratejisi konusunda önerilerde bulunulmuştur.

Bu tezde kullanılan bibliyometrik analiz yönteminde "kelimesel tarama stratejileri" ve "bibliyometrik denklemler" kullanılmıştır. Bu denklemler yayınlara ilişkin rakamsal değerlendirmelerin tutarlı olup olmadığının test edilmesine ve büyüme oranlarının bir trend oluşturup oluşturmadığının anlaşılmasına yardımcı olmaktadır.

Bibliyometrik analiz matematik ve istatistik kullanılarak tarihsel verilerin gizli kalmış desenlerini tespit etmeleri için büyük ölçekli verinin analiz edilmesi, düzenlenmesi ve keşfedilmesidir (Daim ve diğerleri, 2006; Norton, 2001).

Birçok analiz aracı bibliyometrik alanında kullanılmaktadır. Bunlar; basit doküman sayma, kelime frekans analizi, atıf analizi, kelime-kelime analizi, kümeleme analizi ve işbirliği analizidir. Analiz için kullanılan bazı yazılımlar ise Thomson Data Analyzer, VantagePoint ve CiteSpace olarak gösterilebilir. On yıllardır bilim ve teknoloji çalışmalarına katkı sağlayan (van Raan, 2005) bibliyometrik yöntemler araştırmacılara yazar, anahtar kelime, cümlecik (phrase), organizasyon, ülke, işbirliği, atıflar ve diğerleri gibi bilgileri sınıflandırarak gizli desenleri bulmalarında yardımcı olmaktadır.

Yapılacak analiz ve değerlendirmeler sonucunda Türk Savunma Sanayiine yönelik olarak Nanoteknoloji Yol Haritası oluşturulmuştur. Teknoloji yol haritası karmaşık sistemlerin gelişim evriminin haritalandırılmasını sağlayan yapılandırılmış bir yaklaşımdır (Phaal ve diğerleri, 2011) ve öne çıkan teknolojilerin gelecekteki gelişmelerine ilişkin olarak ta açık ve etkili bir planlama aracı olarak gösterilebilir (Robinson ve Propp, 2008). Ancak geleneksel teknoloji yol haritası modelleri bazı sınırlılıklara da sahiptir. Örneğin; çalıştay süreçleri katılan uzmanların içgüdüsel bilgisine dayanmaktadır ki bu bilgi bazen sübjektif ve yanlı olabilmektedir. Buna karşılık yayın, patent, literatür ve ticari veri gibi objektif veriyi kullanan bazı yeni uyarlanmış kantitatif analizler teknolojik inovasyonun var olan yönünün analiz edilmesinde yardımcı olmaktadır. Bu analizlerin veriye dayalı olması yanlılığın ve sübjektivitenin de azaltılmasına yardımcı olabilmektedir. Bahsedilen yöntemlerden en çok kullanılanı bibliyometrik analizler olarak gösterilebilir.

Bibliyometrik analiz büyük miktardaki tarihsel veriyi analiz etmeye, düzenlemeye ve keşfetmeye yardımcı olmaktadır. Böylece araştırmacılar bibliyometrik analiz ile gizli desenleri tanımlayabilir ve karar süreçlerine analiz bulgularını yansıtabilirler. Bu yöntem öne çıkan araştırma konularının ve yeni teknolojilerin öngörülmesinde yaygın olarak kullanılmaktadır (Shibata ve diğerleri, 2008; Kajikawa ve Diğerleri, 2008).

Teknoloji yol haritasi sureçlerinde kullanilan yontem ve teknikler de çeşitlilik göstermektedir. Kullanilan yöntem ve tekniklerden bir kısmı; beyin firtinasi and anket uygulamasi (Kim vd., 2009). Delphi sorgulamasi (TÜBİTAK. 2003), SWOT anaiizi (Lee vd.. 2007; Lee vd., 2009). bibliyografik analiz (Kim vd.. 2009; Lee vd.. 2009: Daim ve Oliver. 2008). patent analizi (Kim vd.. 2009; Lee vd.. 2009) ve Analitik Hiyerarşi Sureci (AHP) (Kim vd., 2009)'dir. Bu tez çalışmasında bahsedilen yöntemlerden anket uygulanması ve bibliyografik analiz yapılması planlanmaktadır.

Teknoloji yol haritası inovasyon, strateji ve politika belirlemede firma ve sektörel düzeylerde yaygın olarak uygulanan bir yöntemdir (Robinson ve Propp, 2008). Teknoloji Yol Haritası ayrıca değişimin yoğun olduğu çevresel bir ortamda faydalı bir araç olarak ta gösterilebilir. Gerdsri konuyla ilgili olarak Teknoloji Geliştirme Zarfı (Technology Development Envelope) konseptini önermiş ve kurumların teknoloji yol haritasının optimal yönünün bulunmasında öne çıkan teknoloji yol haritasını daha dinamik, esnek ve uygulanabilir hale getirmiştir (Gerdsri, 2007).

Robinson and Propp (2008) çoklu yol haritalama (multi-path mapping) metodunu geliştirmiş ve bu metodla öne çıkan bilim ve teknoloji alanlarını hizaladığını öne sürmüştür.

Buraya kadar bahsedilen yol haritası oluşturulması faaliyeti, uzun vadeli kritik kararların alınmasına imkan veren teknoloji uzgörüsünün veya teknoloji öngörüsünün (foresight) bir sonucudur. Teknoloji öngörüsü ülke için arzu edilebilir -ama erişilebilir- uzun vâdeli bir gelecek inşasında, teknolojinin oynayacağı rolün ortaya konmasını ve ülkenin geleceğiyle ilgili olarak öngörülen vizyonun gerçekleşmesini mümkün kılmak için bilim ve teknoloji bağlamında, bugünden alınması gereken kritik/stratejik kararların belirlenmesini konu alır (Göker, 2004).

Martin (1995) teknoloji uzgörüsünü uzun dönemli olarak bilim, teknoloji, ekonomi ve topluma sistematik olarak bakma çabası şeklinde tanımlamakta ve en yüksek ekonomik ve sosyal faydaları türetebilecek öne çıkan jenerik teknolojilerin ve stratejik araştırma alanlarının tanımlanmasını amaçladığını ifade etmektedir.

Uzgörü yapılmasında, teknoloji değerlendirmesi, trend analizi, stratejik planlama, önceliklerin belirlenmesi, hedefe yönelik ve işlevsel bilim ve teknoloji bütçelerinin hazırlanması, alan taramaları, Ar-Ge istatistikleri, patent göstergeleri gibi iyi bilinen ve birbirlerini besleyerek sinerjik etkiler oluşturan çok sayıda araç kullanılmaktadır. Bu yönüyle uzgörü çalışmaları, çalışmanın aktörlerine uzun dönem için sistematik düşünmenin ve kendi alanlarına daha geniş bir perspektiften bakarak, alanlarına özgü kısıtlamaları aşmanın yollarını, daha da önemlisi bir arada çalışabilmeyi öğretmiştir. Bu anlamda uzgörü çalışmaları, genellikle bu tür bir kültüre sahip olmayan gelişmekte olan ülkeler için özel bir önem taşımaktadır (TÜBİTAK, 2001).

Uzgörü sürecinin çıktıları bir dizi politika, ürün, program, süreç, birçok diğer sosyo-ekonomik faaliyet ve işbirliği ağları olarak gösterilebilir. Dünyadaki teknoloji öngörüsü çalışmalarında sıklıkla kullanılan yöntemler paneller, delfi sorgulaması ve senaryo yöntemidir; bunların iki veya daha çoğunun birlikte kullanıldığı örnekler de mevcuttur (TÜBİTAK, web). Uzgörü çalışmalarından sonra ise strateji belgesi ve yol haritası oluşturulması faaliyeti gerçekleştirilmektedir (Çelik, 2004).

Teknoloji uzgörüsü, teknoloji gelişim trendinin anlaşılması için uygulanan bir yöntem olarak ifade edilebilir (Wonglimpiyarat, 2007). Uzgörü kullanımı kamu politika yapma sürecine yardımcı olacak bilgi desteğini sağlayabilir. Endüstrileşmenin teşvik edilmesinde birçok ülke uzgörüyü endüstriyel rekabetçiliğe, refaha ve yaşam kalitesine önemli etkisi bulunan bilimsel ve teknolojik gelişmeleri değerlendirmek ve belirlemek için kullanmışlardır (Martin ve Irvine, 1989; Constanzo, 2004).

Teknoloji uzgörüsü teknolojinin tahmin edilebileceğine vurgu yapar ve böylece gelecekte arzulanan çıktılar için planlama yapılmasını önerir. Ancak bilim ve teknoloji yeteneklerinin artırılması için ele alınacak AR-GE yatırımlarının yapılmasında bazı sınırlılıklar bulunmaktadır. Bir başka deyişle, ulusal düzeyde kaynakların yeterince tahsis edilmemesi ile uzgörü çalışması tarafından yönlendirilen teknoloji geliştirmenin etkisi sanayi yapılandırması çıktılarında görülemeyebilir. Politika yapıcılar yeterince uzman olmamaları, öncelikleri yanlış tespit edebilmeleri ve teknolojileri doğru seçememeleri gibi nedenlerle teknolojik yetenekler, sanayi ihtiyaçları, işgücü ve diğer ulusal inovasyon sistemleri bileşenlerine katkı sağlayamayabilirler. Bu nedenlerle iyi organize edilmiş bir uzgörü faaliyeti gereklidir (Wonglimpiyarat, 2007).

Wonglimpiyarat (2007)'a göre uzgörü süreci dört aşamadan oluşmaktadır. Bu aşamalar sırasıyla uzgörü öncesi (pre-foresight), Uzgörü, Uzgörü sonrası (post-Foresight), uygulama ve değerlendirmedir. Uzgörü öncesi aşamada bilim ve teknoloji önceliklerinin tespitinin yapılması önerilmektedir. Uzgörü aşamasında Delfi, Beyin Fırtınası ve Senaryo Yazma yöntemleri ile süreç yürütülmektedir. Uzgörü sonrası aşamada sonuçlar yaygınlaştırılmakta ve belirlenen politikalar uygulanmaktadır. Ayrıca bu aşamada kamu ve ilgili örgütlere önerilerde bulunulabilmektedir. Son aşama olan uygulama ve değerlendirme aşamasında ise bilim ve teknoloji stratejisinin Bilim, Sanayi ve Teknoloji Bakanlığı ile ilgili kurumlarca uyumlandırılıp uyumlandırılmadığı değerlendirilmektedir.

Bu tez çalışmasında uygulanan metodoloji şu şekildedir:. Birinci öncelikle konuyla ilgili genel değerlendirme ve analiz yapılmıştır. Bu kapsamda nanoteknoloji konusunun detaylı incelemesi yapılmış olup daha sonra geleceğin muharebe sahası ve ihtiyaç duyulan savaşçıların özellikleri aktarılmıştır. Türk savunma sanayinin değerlendirilmesi, Türkiye'nin bu alandaki bilim ve teknoloji politikaları da incelenmiştir. İkinci olarak bibliyometrik analiz, görüşme ve anket sonuçları değerlendirilmiştir. Son olarak elde edilen veriler ışığında Türk Savunma Sanayi için NT Yol Haritası oluşturulmuştur.

Yapılan tüm analiz, değerlendirme ve tahliller sonucunda oluşturulan Nanoteknoloji Yol Haritası Tablo 2'de verilmiştir.

Tablo 2 : Türk Savunma Sanayi İçin Nanoteknoloji Yol Haritası

Technology	Predictable	Foreseeable	Probable	Specific Aim
	2018 2019 2020	2021 2023 2025	2026 2029 2032 2035	
Commercialization time of Nanotech. Applications	Nanoparticles			To shorten the commercialization time of nano applications as possible.
			Drug delivery	
			Quantum dots	
	Graphene			
			Self assembly	
	Nano composits			
	Carbon nanotube			
	Nano photonics			
		Electro spinning		
			2D materials exc.graphene	
Military use of nanotechnology	Armour			To increase military use of nanotechnology at maximum level.
		Warrior		
		Survival		
		Weapon		
		Ammunition		
		Energy		
		Command&Control		
	Security (Biotechnology)			
		Space systems		
Execution method	R&D Characteristics: Commercialization Demonstration Basic application	Developing Strategy: University-industry cooperation Technology Transfer	Focusing Area: Materials Science, Biochemistry&Molecular Biology, Physicss, Engineering	Focusing applications: Nanocomposits, Nanoparticles, Graphene, Nanostructure,

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TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English) : Türk Savunma Sanayi İçin Nanoteknoloji Yol Haritası / A Nanotechnology Roadmap Fort he Turkish Defense Industry

TEZİN TÜRÜ / DEGREE**:** **Yüksek Lisans** / Master [ ] **Doktora** / PhD [x]

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