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US Policies and Impacts on Stem Cells Advancements under NNI

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Contents

1. Abstract

Nanotechnology is an enabling technology that has an impact on electronics, computing, data storage, communications, materials and manufacturing, energy, environment, transportation, health and medicine, national security and space exploration. This paper talks about efforts across the United States for reaping the benefits of Nano Technology by commercialization through participation of multinational corporations and government funding and policy making. It is important to understand that nanotechnology is not any one technology or a one-sector technology. Its reach is extremely broad and hence it becomes important to understand the governing and regulatory bodies that form policies for Nano technology. These governing bodies are bureaucratic and hierarchical organization set up by the US government to develop Science and Technology Policy in different areas of Nano technology, to which the nationwide research and commercialization efforts are to be focused. Generally these policies tend to favors the Nation interest to generate revenue by commercialization of new technology and /or find solutions to current societal problem leveraging the innovations in Nano science and Technology.

Ways to foster innovations in a new technology is a highly relevant and intricate question in the arena of policymaking. Various studies have shown that technology-push and demand-pull policies induce innovation. However, there another phenomenon that affect the science and technology policy making and finding solutions to societal problems. Technology push-pull are basically market driven strategy approach to create significant country-level innovation spillovers, which could drive national policymakers to engage in domestic market creation for e.g. creating smaller and faster I.C chips and memory drives. This could also be in align with Government's vision to emerge as world's super power in global innovation race and attract investors resulting in growth in economy. Policies to solve societal problems could be internal or global and the main mission is to find a sustainable solution to societal problem for e.g. finding cure for cancer using stem cell research.

In this paper we evaluate nanotechnology research topics that align with stem cell research and create a roadmap for technology research for next 40 years. We discuss nanotechnology, nanotechnology drivers, federal governing agencies of USA that defines policies and market pull for nanotechnologies. We also have attempted to analyses one societal problem that might be answered by nanotechnology technology. We have chosen *Stem cell based health improvement* as our research topic to evaluate and design roadmap. The roadmap we have created is designed to embed policy and market implications that effects the technology selection. Also we have tried to align vision, mission and goals of NNI and its collaborating agency NIH to bridge the gap in interests that 2 NNI and NIH. We try to conclude that a good scientific and technology policy is required to provide a nurturing ambience, which acts as an incubator to nurture innovations in Nano technology.

2. Introduction to nanotechnology

Nanotechnology operates at the first level of organization of atoms and molecules for both living and non-living matters. This is where the properties and functions of all systems are defined. Such fundamental control promises a broad and revolutionary technology platform for industry, biomedicine, environmental engineering, safety and security, food, water resources, energy conversion, and countless other areas. The first definition of nanotechnology to achieve some degree of international acceptance was developed after consultation with experts in over 20 countries in 1987-1898 [19]. However, despite its importance, there is no globally recognized definition. Any nanotechnology definition would include three elements: - The size range of the material structures under consideration -- the intermediate length scale between a single atom or molecule, and about 100 molecular diameters or about 100 nm. This condition alone is not sufficient because all natural and manmade systems have a structure at the nanoscale; The ability to measure and transform at the nanoscale; without it we do not have new understanding and a new technology; such ability has been reached only partially so far, but a significant progress was achieved in the last five years.- Exploiting properties and functions specific for nanoscale as compared to the macro or micro scales; this is a key motivation for researching nanoscale.

According to National Science Foundation and NNI, nanotechnology is the ability to understand, control, and manipulate matter at the level of individual atoms and molecules, as well as at the “supramolecular” level involving clusters of molecules (in the range of about 0.1 to 100 nm), in order to create materials, devices, and systems with fundamentally new properties and functions because of their small structure. The definition implies using the same principles and tools to establish a unifying platform for science and engineering at the nanoscale, and using the atomic and molecular interactions to develop efficient manufacturing methods [19]

3. Drivers of Innovation in Nano Technology

There are at least three reasons for the current interest in nanotechnology. First, the research is helping us fill a major gap in our ***fundamental knowledge of matter***. At the small end of the scale -- single atoms and molecules -- we already know quite a bit by using tools developed by conventional physics and chemistry. And at the large end, likewise, conventional chemistry, biology, and engineering have taught us about the bulk behavior of materials and systems. Until now, however, we have known much less about the intermediate nanoscale, which is the natural threshold where all living and man-made systems work. The basic properties and functions of material structures and systems are defined here and, even more importantly, can be changed as a function of the organization of matter via 'weak' molecular interactions (such as hydrogen bonds, electrostatic dipole, van der Waals forces, various surface forces, electro-fluidic forces, etc.). The intellectual drive toward smaller dimensions was accelerated by the discovery of size-dependent novel properties and phenomena. Only since 1981 have we been able to measure the size of a cluster of atoms on a surface (IBM, Zurich), and begun to provide better models for chemistry and biology self organization and self-assembly. Ten years later, in 1991, we were able to move atoms on surfaces (IBM, Almaden). And after ten more years, in 2002, we assembled molecules by physically positioning the component atoms. Yet, we cannot visualize or model with proper spatial and temporal accuracy a chosen domain of engineering or biological relevance at the nanoscale. We are still at the beginning of this road [21]

A second reason for the interest in nanotechnology is that nanoscale phenomena hold the promise for ***fundamentally new applications*.** Possible examples include chemical manufacturing using designed molecular assemblies, processing of information using photons or electron spin, detection of chemicals or bio agents using only a few molecules, detection and treatment of chronic illnesses by sub-cellular interventions, regenerating tissue and nerves, enhancing learning and other cognitive processes by understanding the “society” of neurons, and cleaning contaminated soils with designed nanoparticles. Using input from industry and academic experts in the United States, Asia Pacific countries and Europe between 1997 and 1999, we have projected that $1 trillion in products incorporating nanotechnology and about 2 million jobs worldwide will be affected by nanotechnology by 2015 [21]. Extrapolating from information technology, where for every worker another 2.5 jobs are created in related areas, nanotechnology has the potential to create 7 million jobs overall by 2015 in the global market. Indeed, the first generation of nanostructured metals, polymers, and ceramics have already entered the commercial marketplace.

Finally, a third reason for the interest is the ***beginning of industrial prototyping and commercialization*** and that governments around the world are pushing to develop nanotechnology as rapidly as possible. Coherent, sustained R&D programs in the field have been announced by Japan (April 2001), Korea (July 2001), EC (March 2002), Germany (May 2002), China (2002) and Taiwan (September 2002). However, the first and largest such program was the U.S. National Nanotechnology Initiative, announced in January 2000 [18]

4. The Governing agency: Nano Technology Initiative (NNI)

The National Nanotechnology Initiative (NNI) is a long-term research and development (R&D) program that began in fiscal year 2001, and today coordinates 25 departments and independent agencies, including the National Science Foundation, the Department of Defense, the Department of Energy, the National Institutes of Health, the National Institute of Standards and Technology, and the National Aeronautical and Space Administration. PCAST Report states that, the total R&D investment in fiscal years 2001-2005 was over $4 billion, increasing from the annual budget of $270 million in 2000 to $1.2 billion. An important outcome is the formation of an interdisciplinary nanotechnology community with about 50,000 contributors. A flexible R&D infrastructure with over 60 large centers, networks, and user facilities has been established since 2000, as well as an expanding industrial base of more than 1,500 companies with nanotechnology products with a value exceeding $40 billion at an annual rate of growth estimated at about 25%. With such a growth and complexity, participation of a coalition of academic, industry, business, civil organizations, government and NGOs to nanotechnology development becomes essential as an alternative to the centralized approach. The role of government continues in basic research but its emphasis is changing while private sector becomes increasingly dominant in funding nanotechnology applications.

The NNI plan proposed in 1999 has led to a synergistic, accelerated, and interdisciplinary development of the field, and has motivated academic and industry communities at the national and global levels. A key factor that has contributed to establishing NNI in year 2000 was the preparation work for identifying the core nanotechnology concepts and challenges. Secondly, the orchestrated effort to assemble fragmented disciplinary contributions and application-domain contributions has led to broad support from various stakeholders. Thirdly, the long-term view in planning and setting priorities was essential in the transformative governance of nanotechnology. Nanotechnology holds the promise to increase the efficiency in traditional industries and bring radically new applications through emerging technologies.

Key factors that have contributed to establishing NNI around the year 2000 and the rapid growth of nanotechnology are:

- The preparatory work for identifying core nanotechnology concepts encompassing all disciplines, including the definition of nanotechnology and what are key research directions
- The orchestrated effort to assemble fragmented disciplinary contributions and application-domain contributions and get broad and bottom-up support from various contributing communities and other stakeholders; and
- Preparing the initiative as a science project. This included the long-term view (2000-2020) in planning and setting priorities on three time scale (5years, 1 year, 1 month) and three levels (national, agency, and R&D program). The initial R&D focus in the first strategic plan (2001-2005) has been on fundamental research and “horizontal” multidisciplinary R&D with relevance to multiple application areas. A transition to “vertical” industrial development from the basic concepts is a focus for the second plan (2006-2010). The R&D projects have been aligned with societal needs and aspirations from the beginning, with a proactive role in the political and international context. The governing approach was data-driven and transformative [22]

5. Nano Technology – A multi-disciplinary subject

There is a longitudinal process of convergence and divergence in major areas of science and engineering [23]. The convergence at the nanoscale reached its strength in about year 2000, and one may estimate a divergence of the Nano system architectures in the next decades. Current convergence at the nanoscale is happening because the use of the same elements of analysis (that is, atoms and molecules) and of same principles and tools, as well as the ability to make cause-and-effect connections from simple components to higher-level architectures. In Nano Technology world, the phenomena/processes cannot be separated, and there is no need for discipline specific averaging methods. In 2000, convergence had been reached at the Nano-world (Figure 1) because typical phenomena in material nanostructures could be measured and understood with a new set of tools, and nanostructures have been identified at the foundation of biological systems, Nano manufacturing, and communications [18]

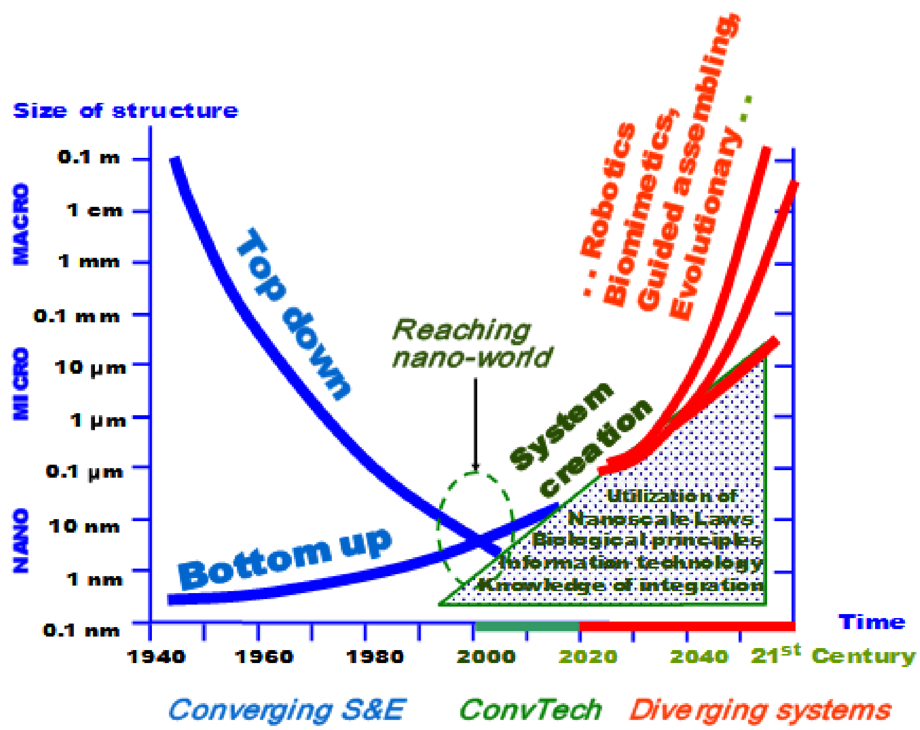

Figure 1 – Multi disciplinary convergent –divergent nature of nanotechnology [18]

6. Influencing Governing Agencies of NNI

The promise of nanotechnology, however, will not be realized by simply supporting research. A specific governing approach is necessary for emerging technologies and in particular for nanotechnology by considering its fundamental and broad implications. Optimizing societal interactions, R&D policies and risk governance for nanotechnology development can enhance economic competitiveness and democratization. These governing bodies develop policies regulate Nano Technology progress in United States and provide guidance to research in Government laboratories, Industries and tie up Universities.

NNI cannot function alone as we know that Nano Technology is multi-dimensional and may not lean on one particular type of science and technology field. In order to NNI has to consult with various other agencies to translate its vision and mission. There is an intricate network of agencies which can be vehicles to drive the NNI policy to the end resources. The NNI R&D program has a total investment of about $1.2 billion in fiscal year 2005 (Table 1). About 65 percent of funds were dedicated to academic R&D institutions, 25 percent to government laboratories and 10 percent to industry of which 7% for SBIR/STTR awards. The first five years (fiscal years 2001-2005) of NNI have led to significant science and engineering advances, have increased the confidence that nanotechnology development is one of the key technologies at the beginning of the 21 st century, and has raised the challenges of responsible development including environmental, health and safety. Major achievements of NNI in the first five years are through its governing agencies are as listed l below:

Federal Department or Agency	FY 2000 Actual ($M)	FY 2001 Actual ($M)	FY 2002 Actual ($M)	FY 2003 Actual ($M)	FY 2004 Actual ($M)	FY 2005 Actual ($M)	FY 2006 Actual ($M)	FY 2007 Estimate ($M)	FY 2008 Request ($M)
National Science Foundation (NSF)	97	150	204	221	256	335	360	373	390
Department of Defense (DOD) (without Congressionally-directed)	70	125	224	322	291	252	324	317	375
Department of Energy (DOE)	58	88	89	134	202	208	231	293	331
National Institutes of Health (NIH)	32	40	59	78	106	165	192	170	203
National Institute of Standards and technology (NIST)	8	33	77	64	77	79	78	89	97
National Aeronautics and Space Administration (NASA)	5	22	35	36	47	45	50	25	24
National Institute for Occupational Safety and Health (NIOSH)	-	-	-	-	-	3	4	5	5
Environmental Protection Agency (EPA)	-	5	6	5	5	7	5	9	10
Homeland Security (TSA)	-	-	2	1	1	1	2	2	1
Department of Agriculture (USDA: CSREES)	-	1.5	0	1	2	3	4	4	3
Department of Agriculture (USDA: Forest Service)							2	3	5
Department of Justice (DOJ)	-	1.4	1	1	2	2	1	1	1
Department of Transportation (DOT: FHVA)							1	1	1
TOTAL without Congr.-directed (% of FY 2000 budget)	**270** (100%)	**464** (172%)	**697** (258%)	**862** (319%)	**989** (366%)	**1,100** (407%)	**1,241** (%)	**1,292** (%)	**1,445** (%)
Congressionally-directed	-	25 (DOD)	40 (DOD)	80 (DOD)	103 (DOD)	~100 (DOD)	100 (DOD) 10 (NASA)	100 (DOD)	
TOTAL with Congr.-directed (% of FY 2000 budget)	**270** (100%)	**489** (181%)	**737** (273%)	**942** (349%)	**1092** (404%)	**1,200** (444%)	**1,351** (481%)	**1,392** (515%)	**1,445** (535%)

Table 1 – Governing agencies of NNI and their Spend [18]

7. Market Drivers –Demand (Push-Pull)

In our paper we are focusing on biological benefits of Nano technology through Stem Cell Research to address societal problems and find cures that would benefit humanity and at the same time could generate revenue, provide jobs and create new avenues through commercialization. Through our literature review we came to know that NNI uses Nano –Bio – Info- Cogno organizational network to deploy its strategies for scientific and technological developments in Biological Science area. N-B-I-C is nothing but governing agencies responsible for research and advancement in different fields of science, under which Nanotechnology is an integral subset.

Science and engineering are the primary drivers of global technological competition. Unifying science based on the unifying features of nature at the nanoscale provides a new foundation for knowledge, innovation, and integration of technology. Revolutionary and synergistic advances at the interfaces between previously separated fields of science, engineering and areas of relevance are poised to create N-B-I-C transforming tools, products and services

The transforming effect of NBIC convergence on society is expected to be large, not only because of the high rate of change in each domain and their synergism with global effect on science and engineering, but also because we are reaching qualitative thresholds in the advancement of each of the four domains. **ITR and NNI provide the technological "push" with broad science and engineering platforms. Realizing the human potential, "the pull", would include the biotechnology and cognitive technologies.** Several topical, agency-specific programs have been initiated in the field of biotechnology, such as NIH Roadmaps (including genome), NSF's Bio complexity, and USDA's roadmap. There was no national initiative on biotechnology and no large scale programs on cognition, except for the core research programs in Social, Behavioral and Economical Sciences and centers for science or learning at NSF. There was a need to balance this situation, and a partial response was, in 2003, the Human and Social Dynamics NSF priority area has been launched. [25]

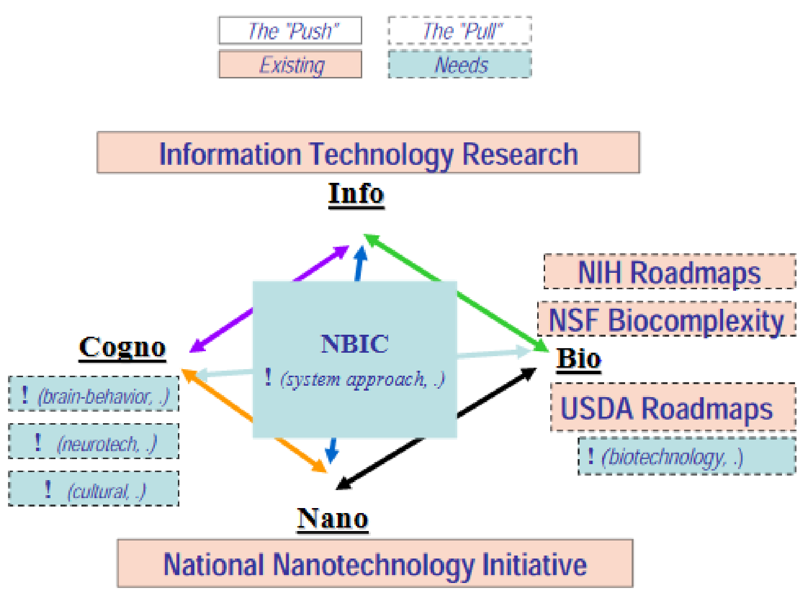

Figure 2 – Market Divers – Demand (Push-Pull) [18]

8. Societal Issues and Key enabling technologies

Nanotechnology can be used to solve many societal problems. Some of the key enabling technologies can be used in advance manufacturing systems in order to resolve problems pertaining to climatic actions, resource efficiency, and improved health, Safety, clean and efficient energy, food security, sustainable agriculture, marine and maritime research and the bio- economy Health, demographic change and wellbeing Inclusive, innovative and secure societies Smart, green and integrated transport [15].
In this paper we propose the technology road mapping of improved healthcare by promoting stem cells research which is a cross disciplinary research area.

In the US, Nanotechnology is governed by NNI and Stem cells research is governed by NHI. However, the study of stem cells is an applied research field which cannot progress without the support of both NIH and NNI. The complexity of stem cell road mapping is high due to involvement of multiple agencies participating policy making.

Some of the societal problems stem cell research can provide answers are [14]

1. Replace neurons damaged by spinal cord injury, stroke, Alzheimer's disease, Parkinson's disease or other neurological problems
2. Produce insulin that could treat people with diabetes and heart muscle cells that could repair damage after a heart attack
3. Can replace virtually any tissue or organ that is injured or diseased
4. The cells could be used to study disease, identify new drugs, or screen drugs for toxic side effects

9. Stem cell

Stem cells and nanotechnology are two different fields of science with potential to grow rapidly. So far the two fields intercross and gradually form a new emerging field, that is, nanotechnology in stem cells or stem cell nanotechnology, which refers to the application of nanotechnology in stem cells research and development [2,3].

Biology dictionary defines stem cells as an unspecialized cell characterized by the ability to self-renew by mitosis(cell division) while in undifferentiated state, and the capacity to give rise to various differentiated cell types by cell differentiation. Stem cells are distinguished from other cell types by two important characteristics: 1) They are unspecialized cells capable of continually renewing themselves through cell division and 2) they have the potential to develop into many different cell types of the body. Given their regenerative potential, stem cells offer new opportunities for treating diseases [1]. There are 3 main types of stem cells. They are

1. Adult stem cell – An unspecialized cell found among specialized cells in a tissue or organ. Adult stem cells can renew themselves and they are multipotent, meaning they have the potential to develop into a limited number of cells in the body (some or all of the specialized cell types of the tissue or organ from which they were derived) [1].
2. Embryonic stem cell – An unspecialized cell type derived from early-stage embryos. Embryonic stem cells can renew themselves and they are pluripotent, meaning they have the potential to develop into any cell type of the body [1].
3. Induced pluripotent stem cell (iPSC) – An unspecialized, embryonic stem cell-like cell that has been derived from an adult cell through epigenetic reprogramming. (Epigenetics relates to cellular changes caused by external or environmental factors that switch genes on and off and affect how cells read genes instead of being caused by changes in the DNA sequence.) Thus, just like embryonic stem cells, iPSCs can also renew themselves and they are also pluripotent [1].

However, several obstacles must be overcome before their therapeutic application can be realized. These include the development of advanced techniques to understand and control functions of micro environmental signals and novel methods to track and guide transplanted stem cells [4-5].

Nanotechnology brings new chance to stem cells research and development. Nanotechnology is the term used to cover the design, construction, and utilization of functional structures with at least one characteristic dimension measured in nanometers [6, 7]

10. Advancement in stem Nanotechnology

In recent years, the application of nanotechnology in stem cell research and development have made great progress. For example,

1. Magnetic nanoparticles (MNPs) have been successfully used to isolate and sort stem cells [8].
2. Quantum dots have been used for molecular imaging and tracing of stem cells [9].
3. Application of 3D Nanostructures in Stem Cell Tissue Engineering [13].
4. Application of Nanotechnology in Stem Cell Therapy [13].
5. Nanomaterials such as carbon nanotubes (CNTs) [10], fluorescent CNTs [11] and fluorescent MNPs [12], etc. have been used to deliver gene or drugs into stem cells, unique nanostructures were designed for controllable regulation of proliferation and differentiation of stem cells, and all these advances speed up the development of stem cells toward the application in regenerative medicine [13].

11. Technology Roadmap for cross disciplinary research (NNI and NIH)

Figure 3 Technology Roadmap for cross disciplinary research (NNI and NIH)

Figure 3 shows the road map for stem cell research tributed by nanotechnology research. In our roadmap we have evaluated current nanotechnology research topics and the current stem cells research topics which are governed by NNI and NIH respectively. The goal of our roadmap was to come up with set of research areas in NT and stem cells which mutually benefit in each other and improve health care over the period of next 40 years. We evaluated the vision mission and goals on both NNI and NIH. We have also evaluated the policy aspect and market drivers. With this roadmap we are able to tie the vision, the mission, and the goals of governing institutes.

i. NNI and NIH Vision and Mission

The vision of the NNI is a future in which the ability to understand and control matter at the nanoscale leads to a revolution in technology and industry that benefits society. The NNI expedites the discovery, development, and deployment of nanoscale science, engineering, and technology to serve the public good through a program of coordinated research and development aligned with the missions of the participating agencies [16]. Whereas NIH's mission is to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability.

ii. NNI and NIH goals

National Nanotechnology initiative goals are to advance a world-class nanotechnology research and development program, Foster the transfer of new technologies into products for commercial and public benefit, Develop and sustain educational resources, a skilled workforce, and a dynamic infrastructure and toolset to advance nanotechnology and support responsible development of nanotechnology [16]. Whereas the goals of National institute of health are to foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for ultimately protecting and improving health, to develop, maintain, and renew scientific human and physical resources that will ensure the Nation's capability to prevent disease, to expand the knowledge base in medical and associated sciences in order to enhance the Nation's economic well-being and ensure a continued high return on the public investment in research and to exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science [17].

12. Nano technology research assessment: Perspective on stem cells

Research indicates that the Nanotechnology research priorities include researching on the magnetic Nano particle, 3D Nano Structures Molecular imaging and tracing, Nano materials, Nano surfaces, Nano membranes Nano optics photonics, Nano sensors, actuators, Nano electronics and components, Nano fabrication, Nanos copy, imaging, inspection, Nano mechanics & physics, Nano fluidics / reactors, Bio-Nanotechnology, Nano medicine and Nano drug delivery.

NIH research priority assessment for health care research includes study on Stem cell research, 4D Necleome, Global health, Epigenomics, Metabolomics, Regulatory science, Single cell analysis. Figure 3 shows the integrated interdisciplinary roadmap spread for next 40 years.

13. Technology roadmap for cross disciplinary research

This section in the figure 3 provides technology research selection. As we have discussed that nanotechnology and stem cells are cross discipline researches, we have mapped the current available technologies with futuristic goals in order to benefit healthcare.

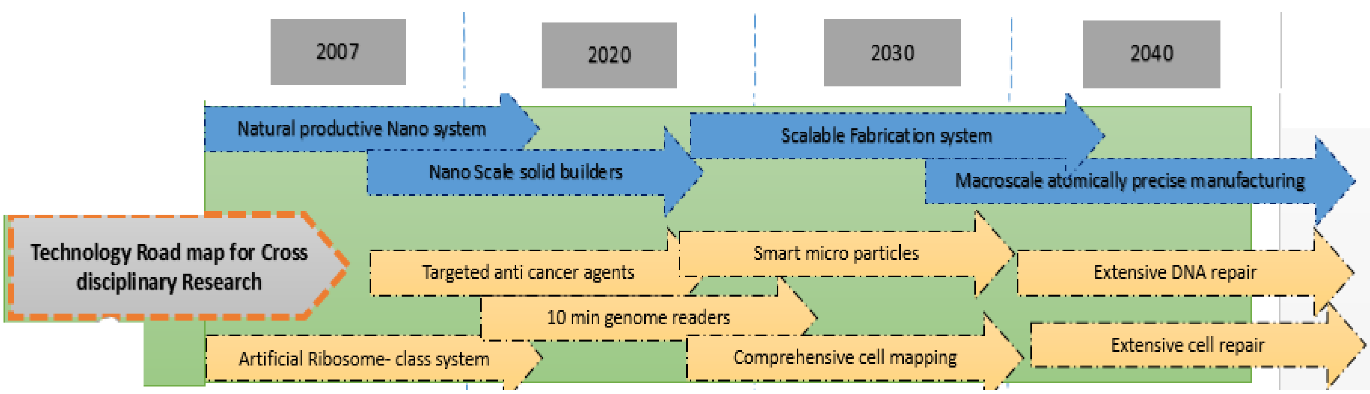

Figure 4 Tech Road Map for cross disciplinary approach

14. The Outcome

The outcome of this road map is the

iii. Cure for Neurons damaged stroke, Alzheimer's disease, Parkinson's disease or other neurological problems
iv. heart muscle cells that could repair damage after a heart attack
v. Replace virtually any tissue or organ that is injured or diseased

vi. Identify new drugs, or screen drugs for toxic side effects

15. Observations

In This study we observed the policy implication and market driver that effects the research.

i. Market drivers

It is evident that nanotechnology is a constant growing field and the acceptance for newer and smaller products are widely accepted by consumers. Hence nanotechnology continues to benefit greater market pull. Due to commercialization opportunities, US government and private sectors are willing to invest in the basic and applied research related to nanotechnology and so we also observe greater technology push. On the other hand, stem cell research has always been a controversial topic. Public have shown mixed reaction on embryonic based stem cell research. We can also say that stem cells research is still in the nascent stages which might take longer years to get to the stage of acceptance. This moral barrier in public proves the lower market pull and nascence in research shows lower technology push.

ii. Policy implication

Nanotechnology relishes open policy. Due to greater market pull and greater technology push and easier commercialization, the Federal, the state and the private sectors continue to fund nanotechnology researches.

On the other hand the US has close policies on stem cell research. Some of the controversy around stem cell research are that stem Cells located within the embryo and the process of removing them destroys the embryo which in turn kills life. However today, the stem cell research is limited to adult stem cells obtained from tissues such as bone marrow or umbilical cord blood. Other scientists believe that adult stem cells should not be the sole target of research because of important scientific and technical limitations. Appendix 1 shows the snippet of historical events that has banned various funding source for stem cell research. There is no federal funding available for stem cell research. However there are a few states and private organization and participating and funding the research. In other words, policies in USA supports nanotechnology research much more than stem cell research. This brings to the discussion point, 'Will advancement of nanotechnology enables progress in stem cell research?'

16. Further discussion

Considering stem cell research as an ethical subject, policy making becomes a moral issue. One cannot argue for or against the existing policy. Policymaking in such subject operates under great deal of uncertainty. Looking at a bigger picture, one can argue that United States might want to consider having open policies around basic and applied stem cell research to improve human lives. Many other countries around the world are staying ahead of stem cell research game by provide infrastructure and funding. Can US government consider nanotechnology advancement as a practical path to overcome embryonic stem cell barriers?

17. Conclusion

The promise of nanotechnology, however, will not be realized by simply supporting research. Just as nanotechnology is changing how we think about unity of matter at the nanoscale and manufacturing, it's also changing how we think about the management of the research enterprise. This switch can be seen as the specialization of scientific disciplines has migrated to more unifying concepts for scientific research and system integration in engineering and technology. Most of the major U.S. science and technology programs in the 20 th century – such as space exploration, energy and environmental programs – have been "pulled" primarily by external factors. The economy, natural resources, national security and international agreements and justifications have initiated top-down R&D funding decisions.

In contrast, nanotechnology development was initially "pushed" by fundamental knowledge (Nano science and Nano engineering) and the long-term promise of its transformative power. For this reason, nanotechnology has to be treated differently. For Nano, research policies have been motivated by long-term vision rather than short-term economic and political decisions. Transforming and responsible development has guided many NNI decisions. Investments must have return, the benefit-to-risk ratio must be justifiable, and societal concerns must be addressed.

Therefore, US Government need to develop anticipatory, deliberate and proactive measures and policies in order to accelerate the benefits of nanotechnology and its applications. Adaptive and corrective approaches in government organizations are to be established in the complex societal system with the goal of improved long-term risk governance. User- and civic-group involvement is essential for taking better advantage of the technology and developing a complete picture of its societal implications.

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19. Appendix

Federal policies so far

- **1950** — Bone marrow transplants to treat leukemia
- **1974** — Congressional involvement
- **1996** — Dickey-Wicker Amendment was passed to bans federal funding
- **2001** — NHI interprets the amendment and releases the guidelines for the research of the stem cells
- **2005** — Congress passes the stem cell research enhancement — Private sector or research conducted with state funding. More than 60 stem cell lines are still available for funding.
- **2007** — congress passes the stem cell research enhancement (revised) — Till vetoed by President Bush
- **2009** — President Barack Obama issues an executive order, titled "Removing Barriers to Responsible Scientific Research Involving Human Stem Cells — Law suit
- **2011** — Court favors research
- **2014** — Advance in SC — FDA approve clinical trails
- **2016** — President Obama signs law for of regenerative therapies