Integrated Methodology for Finding Emerging Technologies Using Publications, Patents and Roadmaps

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Outline

1. Motivation

2. Objective

3. Proposed Approach

4. Illustrative Case

5. Conclusion

Motivation

- Developing a strong manufacturing base in the U.S. is a national imperative.

- Since the past decade, this important component of the U.S. economy is struggling! [1]

AMERICA'S WANING INDUSTRIAL BASE

In periods of economic growth, U.S. companies boost manufacturing capacity. But that didn't happen the last time around.
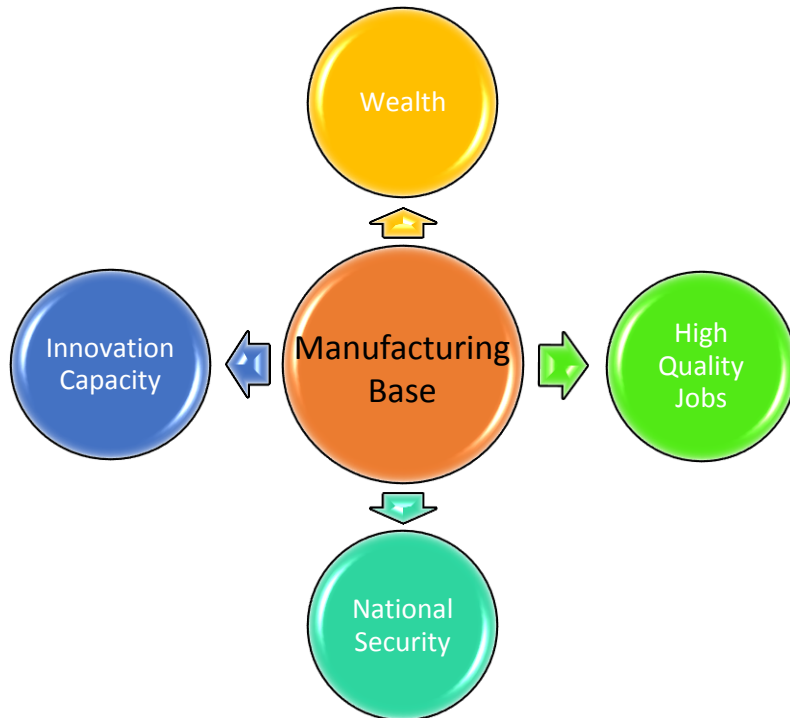
1994-1999
- 44%
- 26%

2001-2007
- 5%
- 17%

● GROWTH IN MANUFACTURING CAPACITY
● ECONOMIC GROWTH

Data: Federal Reserve Bank
Analysis by *BusinessWeek's* James C. Cooper

Countermeasure –

- In June 2011, the White House launched the Advanced Manufacturing Partnership (AMP) with the goals of:
  - Strengthening U.S. Manufacturing competitiveness
  - Creating high-paying jobs

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Objective

President's Council of Advisors on Science and Technology (PCAST) 2012 report [2] recommends:
"Identify a 'starter list' of cross-cutting technologies that are vital to Advanced Manufacturing"
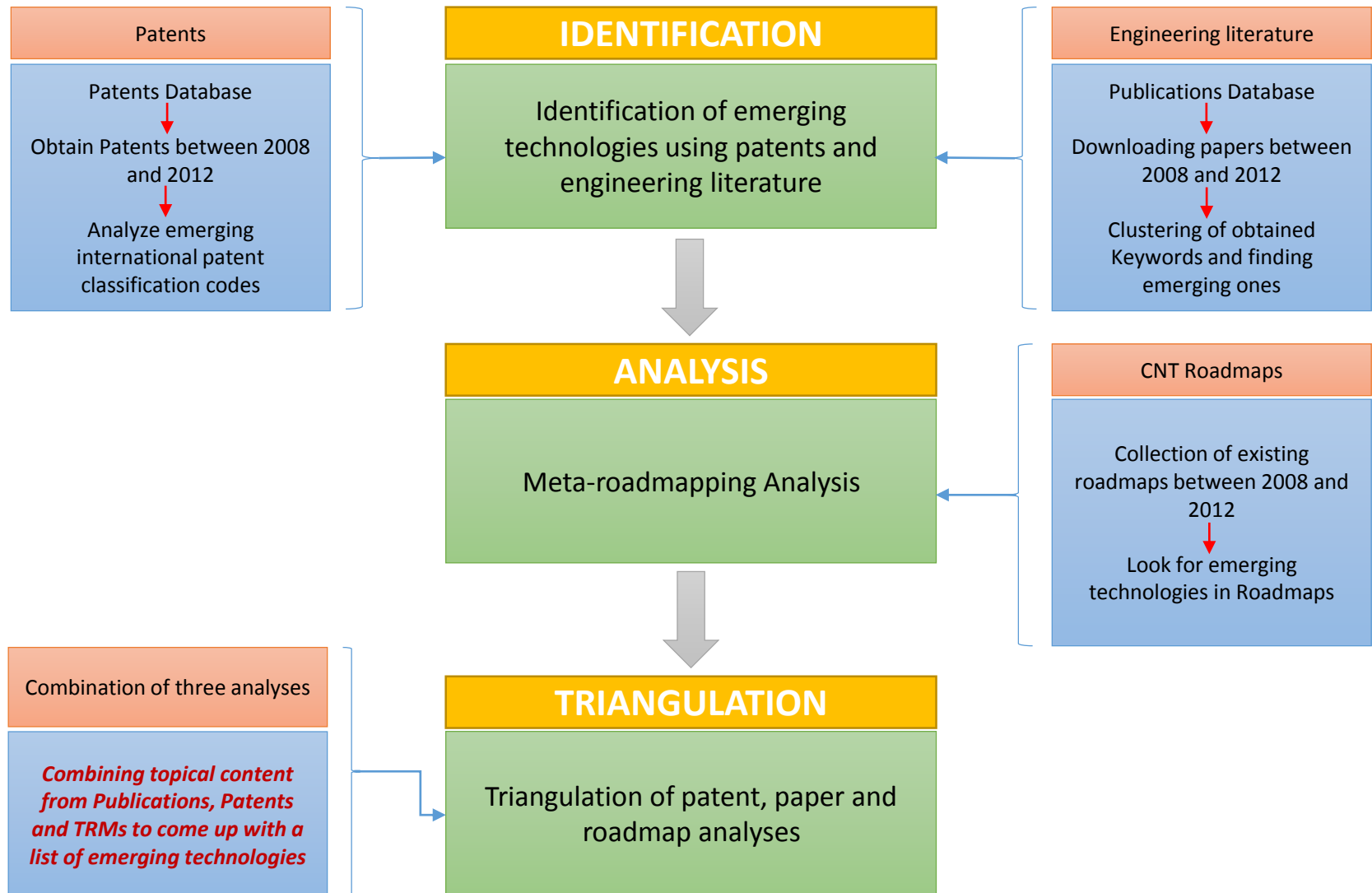
PCAST 2012 [2] report also reveals the need for *"a systematic and credible methodology to identify priority technologies for investment in Advanced Manufacturing R&D"*

Objective of the ongoing study:
- Develop an approach to identify a list of technologies
  - That are "emerging"
  - That are ripe for "production scale up"
  - That have "transformative potential"

In this work, we present a list of technologies that are "emerging" and have large volume applications.
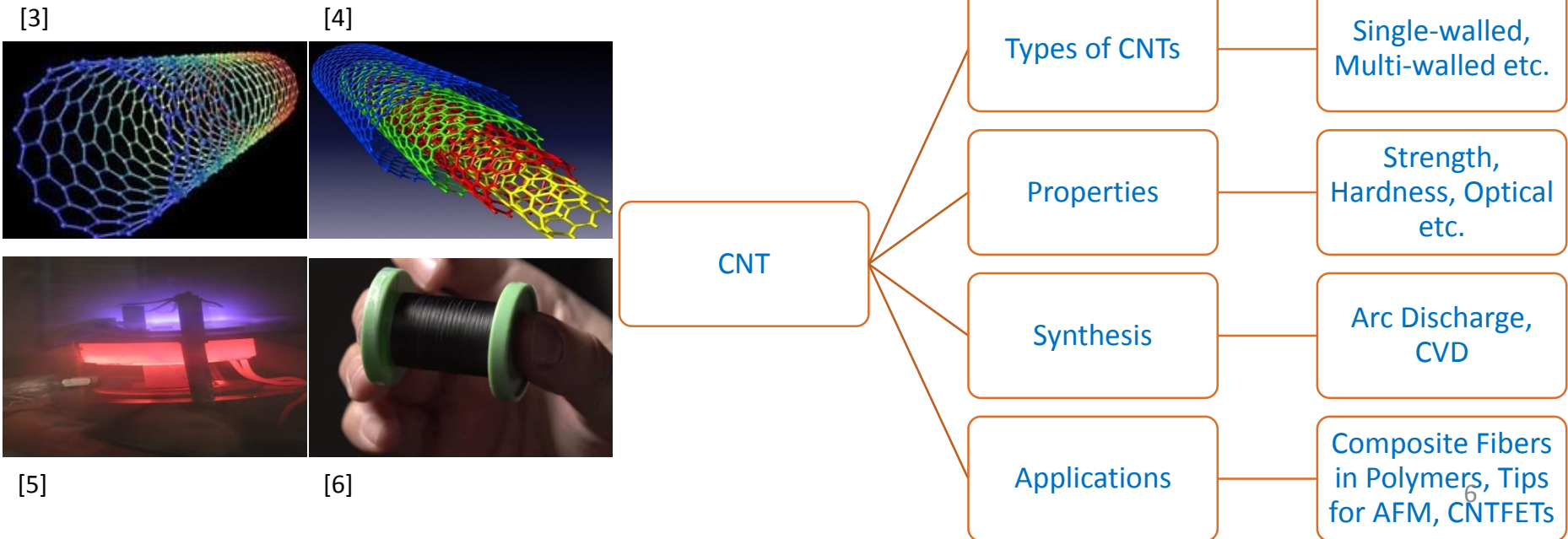
Proposed Approach

Patents	IDENTIFICATION	Engineering literature
Patents Database Obtain Patents between 2008 and 2012 Analyze emerging international patent classification codes	Identification of emerging technologies using patents and engineering literature	Publications Database Downloading papers between 2008 and 2012 Clustering of obtained Keywords and finding emerging ones

ANALYSIS	CNT Roadmaps
Meta-roadmapping Analysis	Collection of existing roadmaps between 2008 and 2012 Look for emerging technologies in Roadmaps

Combination of three analyses	TRIANGULATION
Combining topical content from Publications, Patents and TRMs to come up with a list of emerging technologies	Triangulation of patent, paper and roadmap analyses

Illustrative Case

- As we mentioned in motivation, the need is to find emerging technologies for the broad domain of advanced manufacturing (AM).
- But, in order to show the functioning of our proposed approach, we just consider Carbon Nanotubes (CNTs) as a illustrative case.
- We hope that the proposed approach can be extended to broader domains (like AM) using "Big Data" analytical techniques.

Carbon Nanotubes: Allotropes of carbon with a cylindrical nanostructure

[3]
[4]
[5]
[6]

CNT
- Types of CNTs — Single-walled, Multi-walled etc.
- Properties — Strength, Hardness, Optical etc.
- Synthesis — Arc Discharge, CVD
- Applications — Composite Fibers in Polymers, Tips for AFM, CNTFETs

Illustrative Case

Step 1 Identification Phase: Publications Analysis

VantagePoint (Text Mining Tool; NLP) [7]

1) Consider a time range: **2008 to 2012**

2) Search for **CNT research papers** in a database such as **Compendex**

3) **25,928 publications**! (4000 in a single search; 500 in a single download)

4) Download detailed records (Title, Abstract, Class Codes etc.)

1) Title and its phrases

2) Keywords (controlled, main heading, uncontrolled)

3) Compendex Class Codes

4) Publication Year

5) Phrases from Abstract

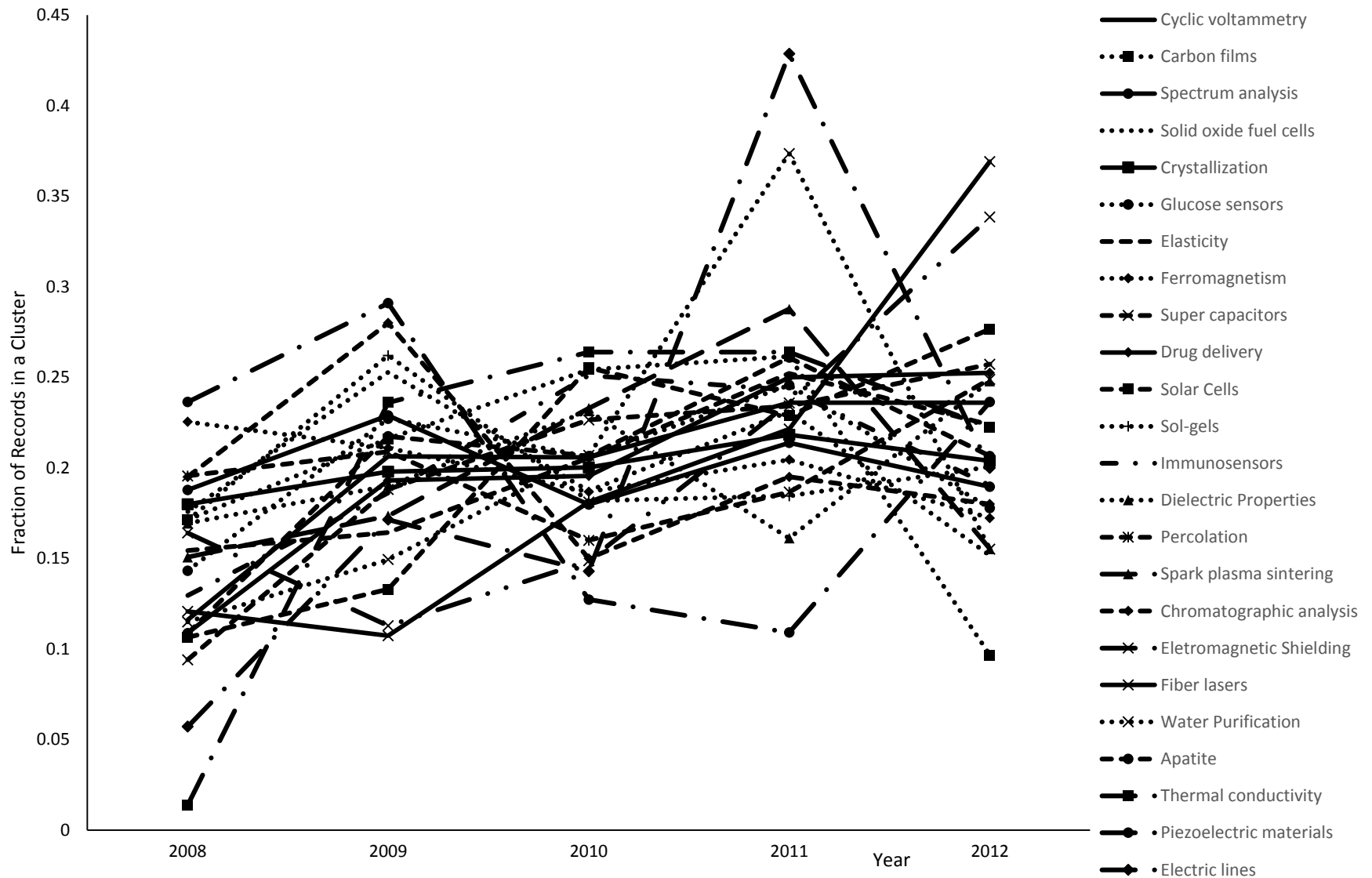6) Author, Affiliation, Number of references, Journal etc.

1) Consider **Keywords (Controlled)**

2) Perform **Clustering of Keywords** using **ClusterSuite** [8] in **Vantage Point**

1) Analyze the clusters

2) Find out the **emerging** ones

Emerging Clusters

Source: 25,928 publication records excerpted from Compendex, EI Village, 2008-2012 (accessed April 2014) [9]

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Emerging Clusters

- We classify Clusters in three categories: CNT Manufacturing/Processing, CNT Characterization, CNT Application.
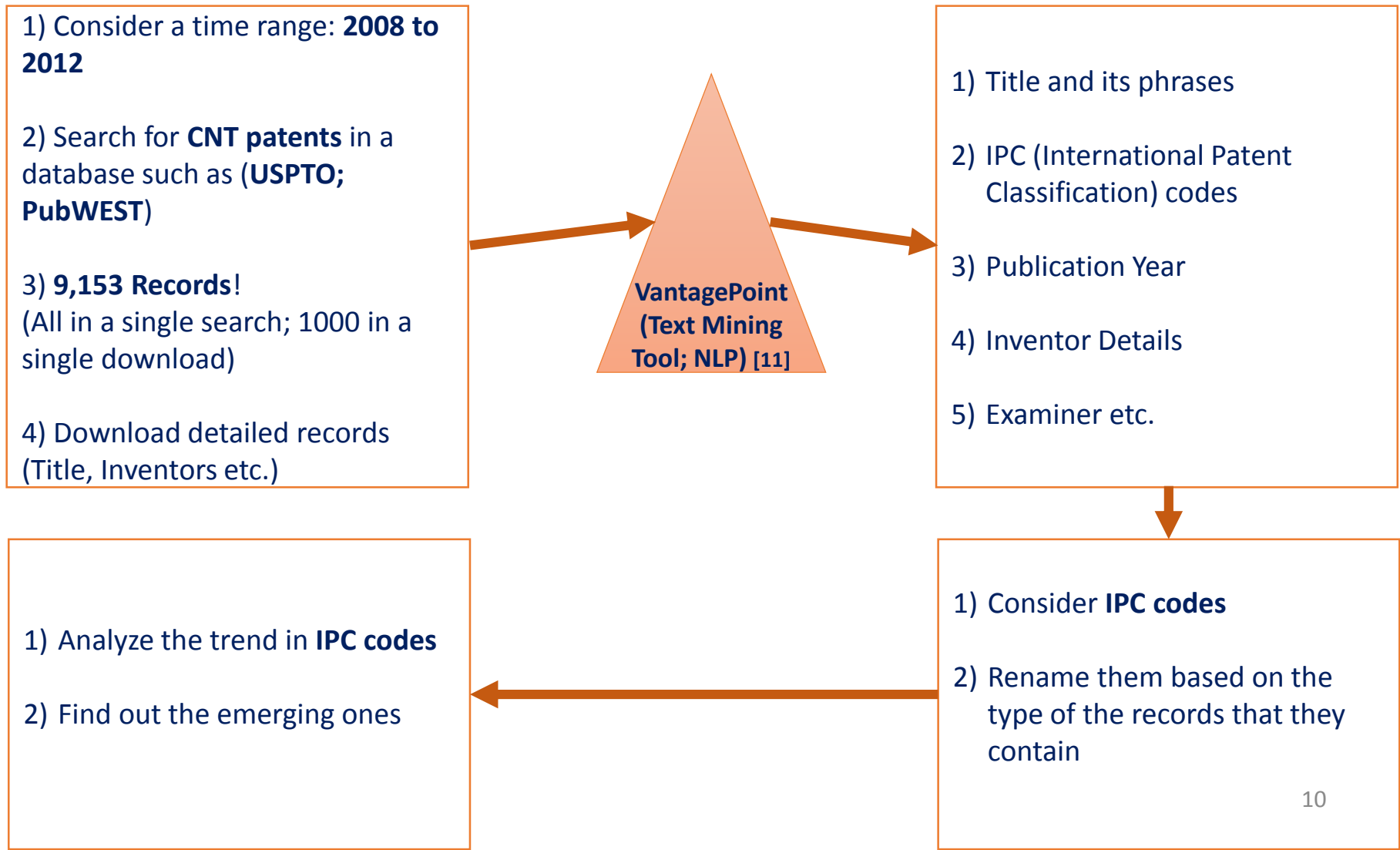- This gives us a clear picture about the focus areas of theoretical research during 2008-2012.

CNT		
Fabrication/Processing	**Characterization**	**Applications**
Spark Plasma Sintering	Electrochemical Properties (Cyclic Voltammetry)	Films (Transparent and Plastics Electronics, Damping Applications)
Chromatography	Optical Properties (Spectroscopy)	Solid Oxide Fuel Cells
	Elasticity (Equations of motion, Continuum Mechanics)	Crystallization (Polymer)
	Ferromagnetism	Glucose Sensors
	Dielectric Properties	Supercapacitors (Power Source and Electronic Products)
	Electrical Percolation	Drug Delivery
	Thermal Conductivity	Solar Cells (Photovoltaics)
		Electrochemical Devices (Composite: CNT + Sol Gel)
		Immuno-sensors
		Electromagnetic Shielding
		Fibre Lasers
		Water Purification
		Apatite
		Piezoelectric Materials
		Electric Lines

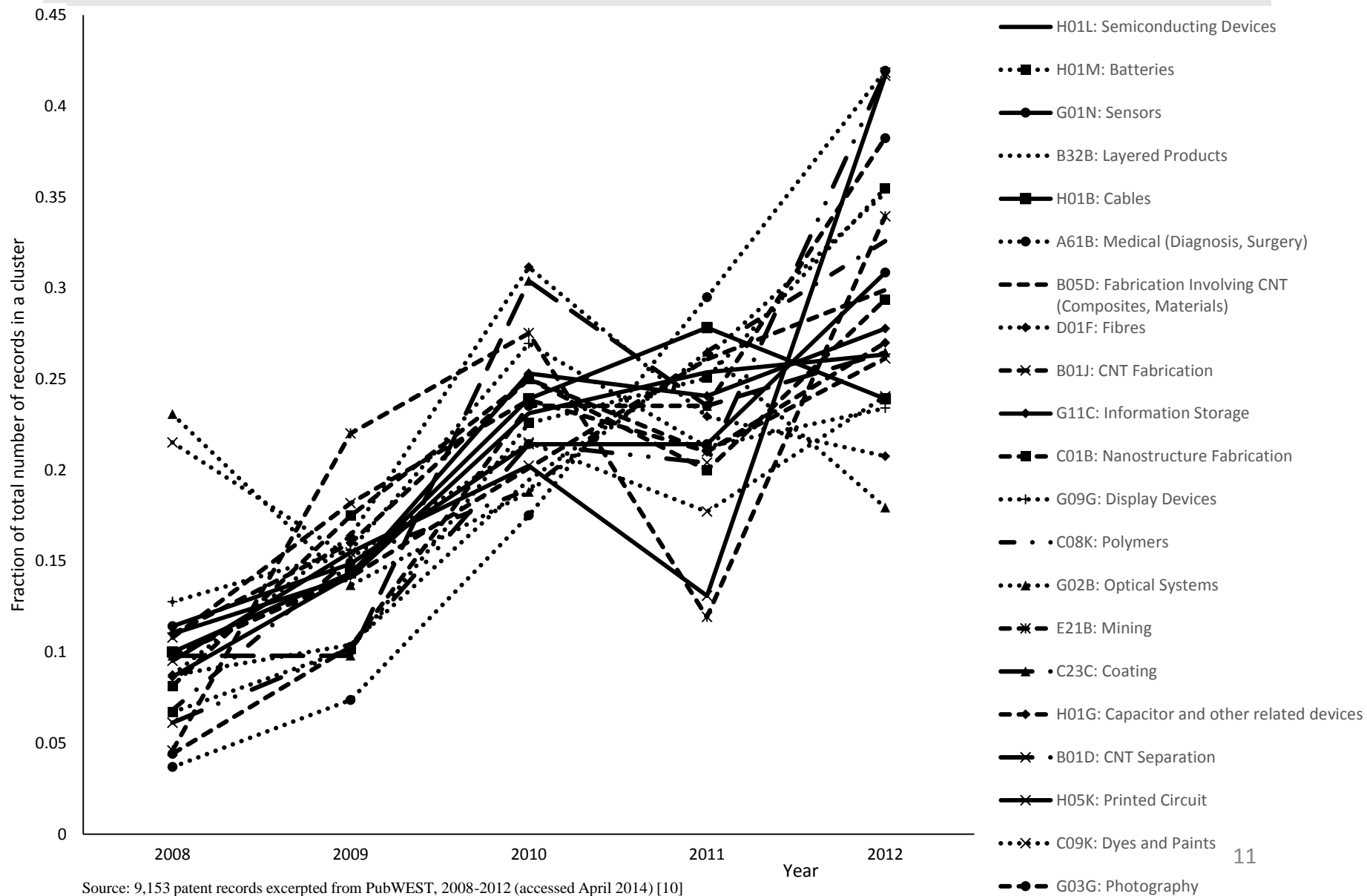**The content of this category just implies that researchers have put in efforts to improve these CNT properties**

On the other hand, this clearly depicts application areas

Illustrative Case

Step 1 Identification Phase: Patents Analysis

1) Consider a time range: **2008 to 2012**

2) Search for **CNT patents** in a database such as (**USPTO; PubWEST**)

3) **9,153 Records**!
(All in a single search; 1000 in a single download)

4) Download detailed records (Title, Inventors etc.)

VantagePoint (Text Mining Tool; NLP) [11]

1) Title and its phrases

2) IPC (International Patent Classification) codes

3) Publication Year

4) Inventor Details

5) Examiner etc.

1) Consider **IPC codes**

2) Rename them based on the type of the records that they contain

1) Analyze the trend in **IPC codes**

2) Find out the emerging ones

Emerging IPC codes

Fraction of total number of records in a cluster

Year

- H01L: Semiconducting Devices
- H01M: Batteries
- G01N: Sensors
- B32B: Layered Products
- H01B: Cables
- A61B: Medical (Diagnosis, Surgery)
- B05D: Fabrication Involving CNT (Composites, Materials)
- D01F: Fibres
- B01J: CNT Fabrication
- G11C: Information Storage
- C01B: Nanostructure Fabrication
- G09G: Display Devices
- C08K: Polymers
- G02B: Optical Systems
- E21B: Mining
- C23C: Coating
- H01G: Capacitor and other related devices
- B01D: CNT Separation
- H05K: Printed Circuit
- C09K: Dyes and Paints
- G03G: Photography

Source: 9,153 patent records excerpted from PubWEST, 2008-2012 (accessed April 2014) [10]

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Emerging IPC codes

- Here, we could classify IPC codes in only two categories: CNT Manufacturing/Processing, CNT Application.
- We can clearly see the innovation areas wherein CNTs are finding tremendous application during 2008-2012.
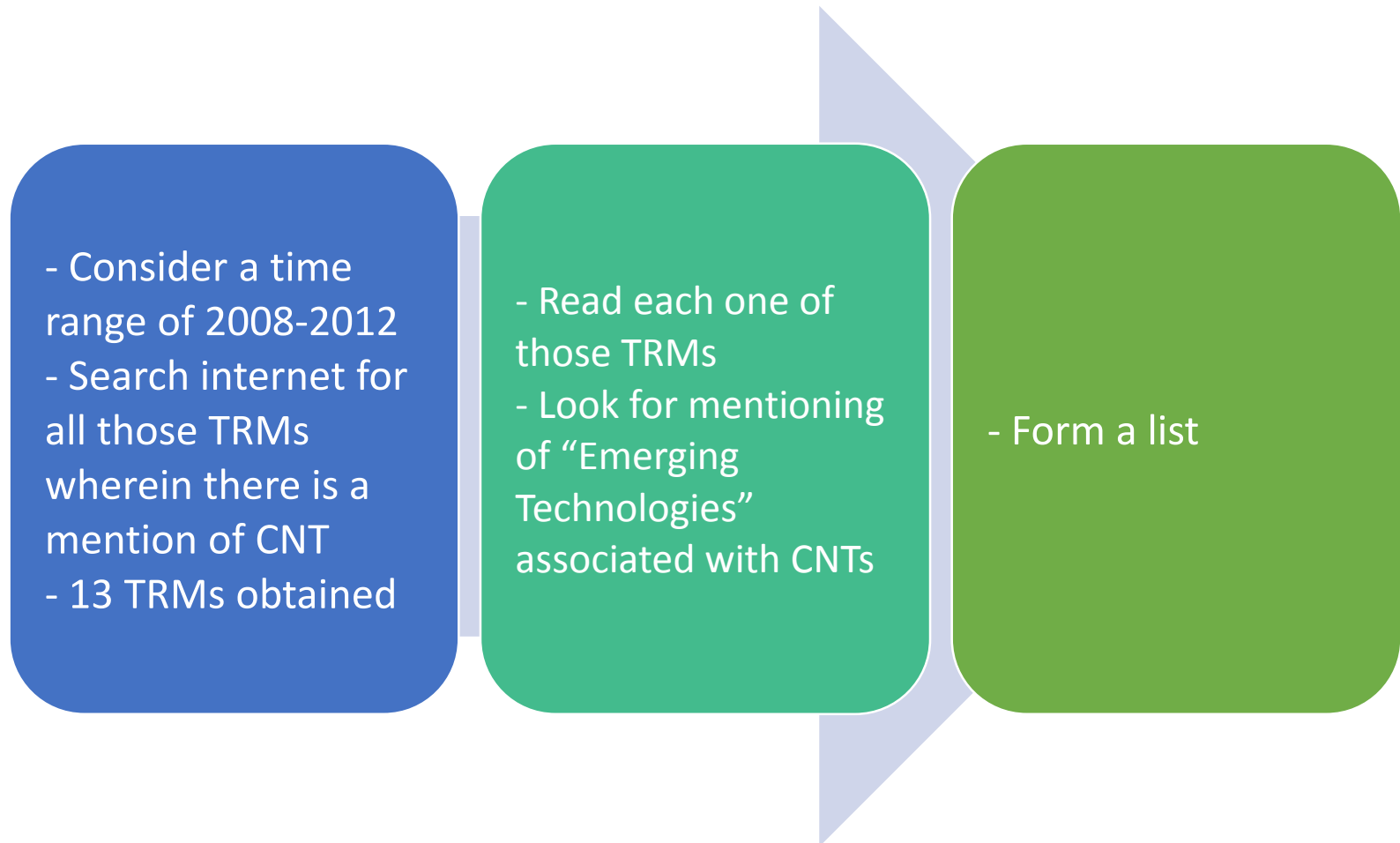
CNT	
Fabrication/Processing	**Applications**
B05D: Fabrication Involving CNT (Composites, Materials)	H01L: Semiconducting Devices
B01J: CNT Fabrication	H01M: Batteries
C01B: Nanostructure Fabrication	G01N: Sensors
B01D: CNT Separation	B32B: Layered Products
	H01B: Cables
	A61B: Medical (Diagnosis, Surgery)
	D01F: Fibres
	G11C: Information Storage
	G09G: Display Devices
	C08K: Polymers
	G02B: Optical Systems
	E21B: Mining
	C23C: Coating
	H01G: Capacitor and other related devices
	H05K: Printed Circuit

The content of this category doesn't give us any helpful information.

On the other hand, this clearly depicts application fields

Illustrative Case

Step 2 Analysis Phase: Technology Roadmaps Analysis

- Consider a time range of 2008-2012
- Search internet for all those TRMs wherein there is a mention of CNT
- 13 TRMs obtained

- Read each one of those TRMs
- Look for mentioning of "Emerging Technologies" associated with CNTs

- Form a list

Roadmaps considered for Analysis

1. Growth of Nanotubes for Electronics
2. International Technology Roadmap for Semiconductors, 2008
3. International Technology Roadmap for Semiconductors, 2009
4. International Technology Roadmap for Semiconductors, 2010
5. International Technology Roadmap for Semiconductors, 2011
6. Carbon Nanotubes and Graphene for Electronics Applications 2010-2020
7. NASA Nanotechnology Roadmap
8. Technology Roadmap For The Canadian Textile Industry
9. Nanoelectronics Technology Roadmap for Malaysia
10. National MEMS Technology Roadmap
11. Naval Power Systems: Technology Development Roadmap
12. A Roadmap for Graphene
13. Productive Nanosystems: A Technology Roadmap

These are the roadmaps found online and they mention about CNT and related fields. So we consider them for our purpose.

Illustrative Case

Technologies from Technology Roadmaps (TRMs)

- TRM identify emerging technologies and their development.
- We **read** the TRMs and find out the key technologies related to CNTs.
- These technologies are forecasted to be gaining importance over the next 5-15 years

CNT	Key Technologies Obtained from TRMs
Application	Semiconductors, Transistors, Super/Ultra-Capacitors, Actuators, Electromagnetic Shields, Charge Transport, Transparent Electrodes, Spectrometer, Nanosprings, Molecular Bearings, Batteries, Coatings, Memory, Emission Display
Fabrication	Chemical Vapor Deposition
Property of Interest	Electrical/Thermal Conductivity, Ultra/Low density, Reliability, Low Power, Light weight, Damage Tolerance
Field of Interest	Electronics, Automotive, Sporting Goods, Photonics

This set of technologies is useful in two ways:
1. It helps in validating our results obtained from Publications and Patents Analyses (to a certain extent).
2. If we miss any important technology in the previous steps, we may expect them to appear in this list.

Illustrative Case

Step 3 Triangulation

[11]

- This is the most important step. Having found the "emerging" technologies in the two previous steps, now we pick those ones that have the potential for large volume applications to fulfil our objective.
- Based on the CNT expertise of our research group, we make an attempt to triangulate the aforementioned results of Step 1 (*Emerging Theoretical Research & Innovation areas*) and Step 2 (*To-be-Emerging Areas*). It appears that -

>Fuel cells,
>Batteries,
>Medical Devices,
>Sensors,
>Optical Devices,
>Display Devices,
>Films,
>Electric Cables,
>Super-capacitors
>and Composites

are the major emerging technology areas wherein CNTs will have large volume applications.

Summary

- List of emerging technologies – Setting up the foundation for spotting transformative and cross-cutting technologies

- Useful for policy makers, strategists, technologists

- Amalgamation of patents, publications and roadmaps analyses – (*Quantitative + Qualitative*)

- Additional Last Step – Experts' Opinion

- Can the triangulation step be more robust?

[12]

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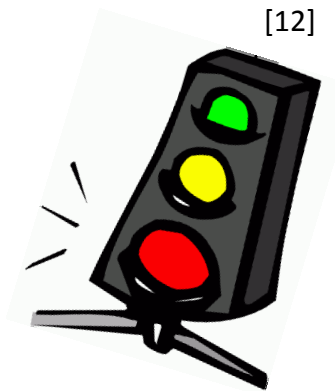
References

1. America's Waning Industrial Base http://www.scdigest.com/assets/newsviews/09-09-18-2.php?cid=2751&ctype=content

2. PCAST (2012). Capturing Domestic Competitive Advantage in Advanced Manufacturing: AMP Steering Committee Report. Washington DC: President's Council of Advisors on Science and Technology.

3. SWCNT http://www.azonano.com/article.aspx?ArticleID=3029

4. MWCNT http://www.turbosquid.com/3d-models/multiwalled-carbon-nanotube-3ds/363229

5. CNT http://en.wikipedia.org/wiki/Carbon_nanotube#Chemical_vapor_deposition_.28CVD.29

6. CNT Spool of Wire http://news.discovery.com/tech/robotics/carbon-nanotubes-spun-spools-wires-130111.htm

7. VantagePoint, https://www.thevantagepoint.com/ (accessed May, 2014).

8. O'Brien, J.J., Carley, S., & Porter, A.L. (2013). ClusterSuite [computer software]. Atlanta, GA.

9. http://www.engineeringvillage.com/

10. https://library.gatech.edu/

11. Keywords http://www.siliconcloud.com/Portals/55887/images/google%20keywords.jpg

12. Traffic Signal http://www.clipartbest.com/clipart-niXarM5iB

Thank You!

Questions??