SCIENCE, TECHNOLOGY AND INNOVATION : SOME RANDOM THOUGHTS

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Outline

- **The Scientific Enterprise :The Foundations of Modern Society**
- **The Evolution of Technology : The Journey from Concept to Market**
- **The Enigma of Innovation**
- **Innovation Challenges in an Emerging Economy**

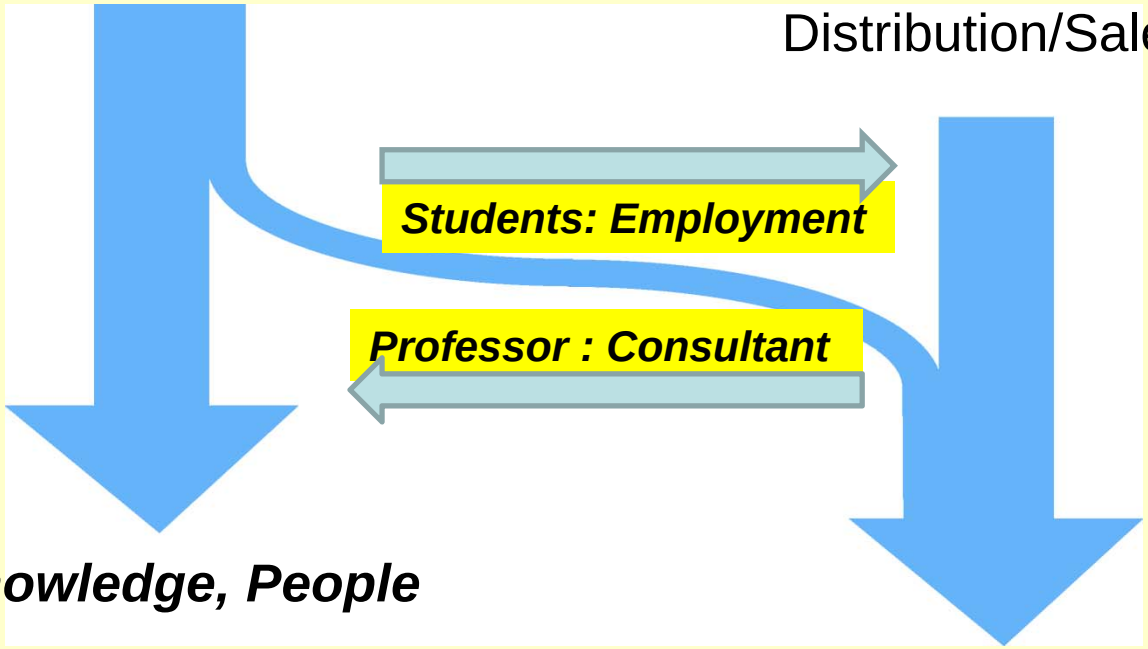
THE SCIENTIFIC ENTERPRISE

Money

University ← **Government** → Laws, Regulation → **Industry**

("Liebig" Model:
Professor/Student/Problem/Thesis)

(Development, Manufacturing,
Distribution/Sales)



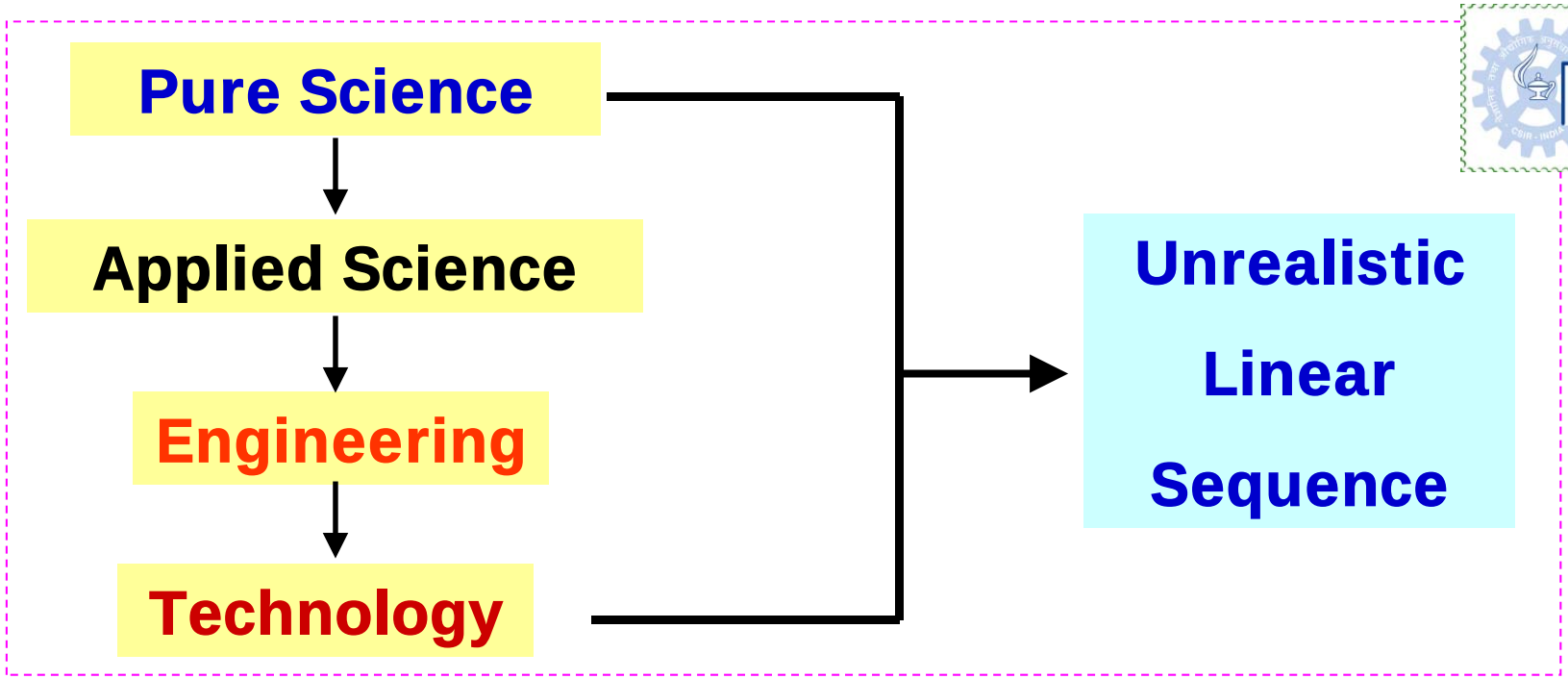
Knowledge, People

Products/Solutions

LIEBIG'S MODEL

Professors + Money → **University + Students** → **Knowledge + Scientists + Engineers** → **Industry** → **Money** → **Industry + Government** → **Professors + Money**

1803-1873



Science by itself provides no panacea for individual, social and economic ills. It can be effective in national welfare only as a member of a team. But without scientific progress, no amount of achievement in other directions can insure our health, prosperity and security

Vannevar Bush "Science: The Endless Frontier" (1946)

SCIENCE & ENGINEERING

“Often considered distinct, engineering and science are frequently difficult to distinguish”

Henry Petroski **,** ***American Scientist, 2008, Vol 96, 368***

“The scientist seeks to understand what is : the engineer seeks to create what never was”

Theodore von Karman

THE NON LINEAR PROCESS : SEAMLESS INTEGRATION OF SCIENCE, TECHNOLOGY AND INNOVATION

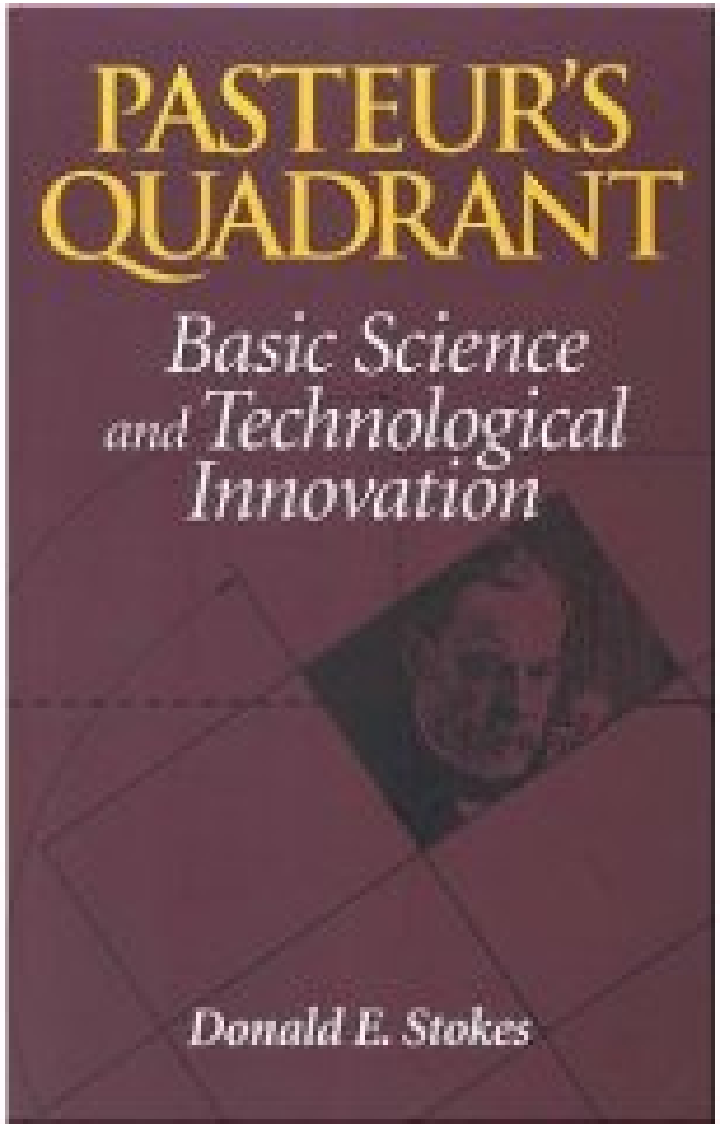
- **Research : ideas, concepts, principles, techniques, theories (*Discover)***

- **Translation : proof of concept, connecting solutions with needs, validation *(Develop)***

- **Defining the customer and his needs (met or unmet) and cost –performance targets, prototype or pilot plant development, customer acceptance, business plan, investment and economics *(Demonstrate)***

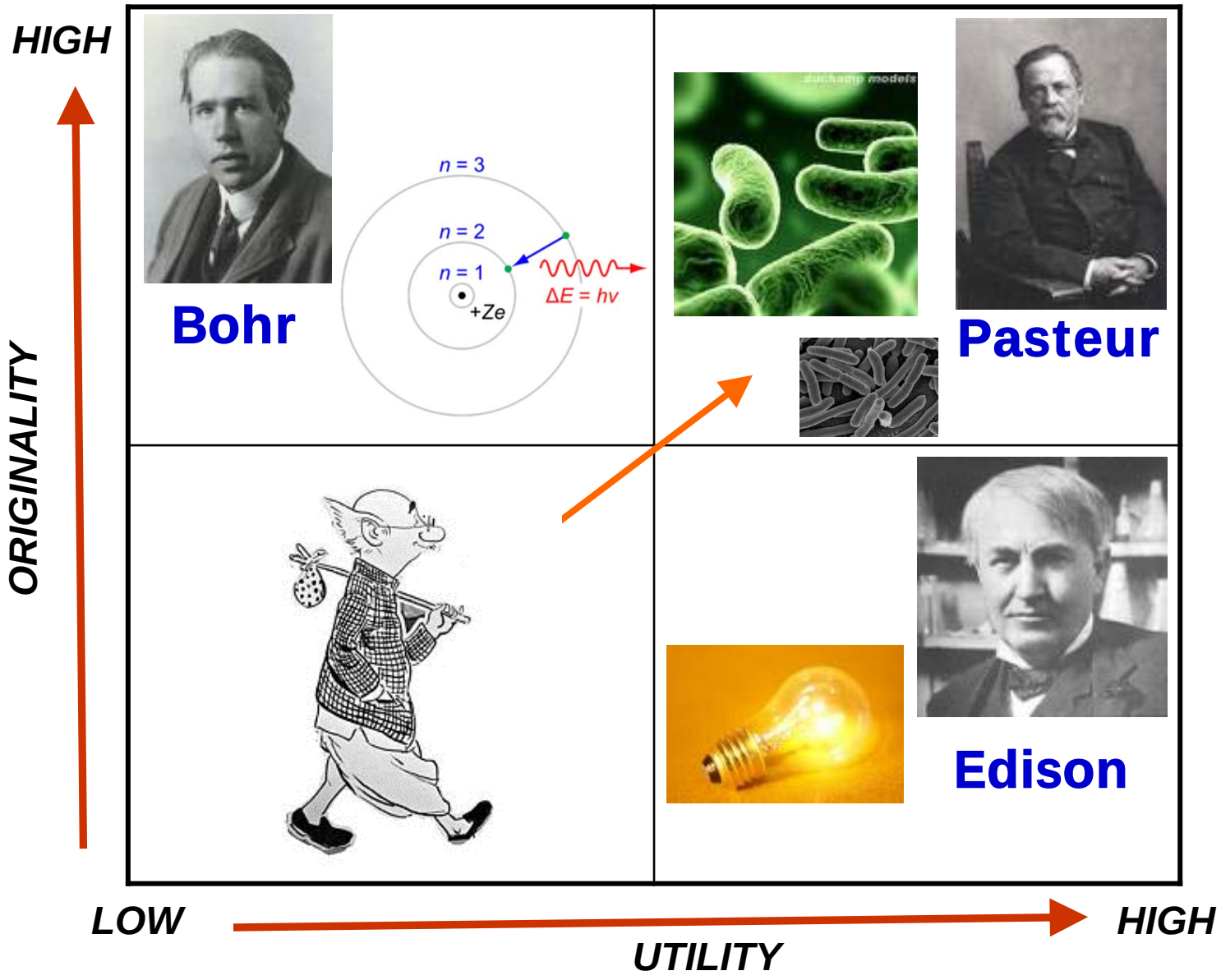
- **Marketable Product *(Deploy)***

Success in the laboratory does not always translate into success in the market place

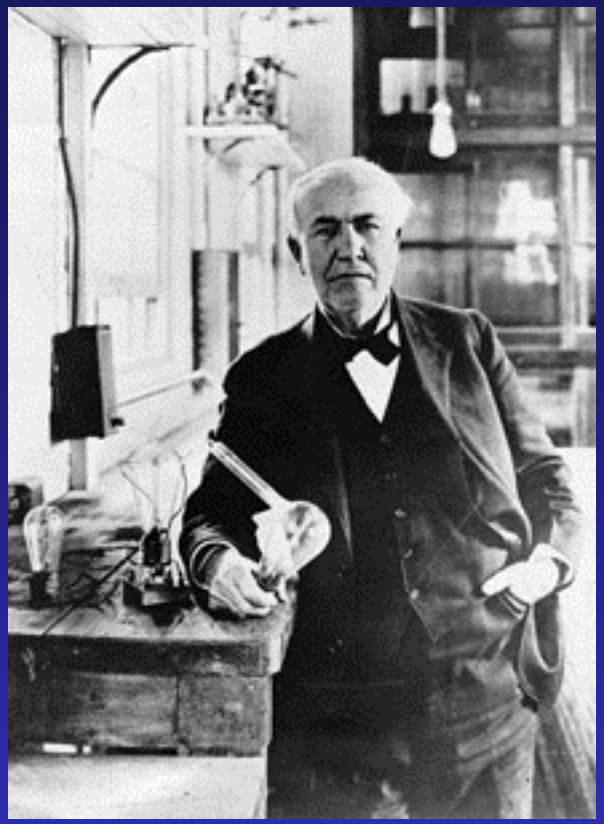

PASTEUR'S
QUADRANT
Basic Science
and Technological
Innovation
Donald E. Stokes

1997

Pasteur's Quadrant



EDISON AND MENLO PARK : THE BIRTH OF INVENTION FACTORY



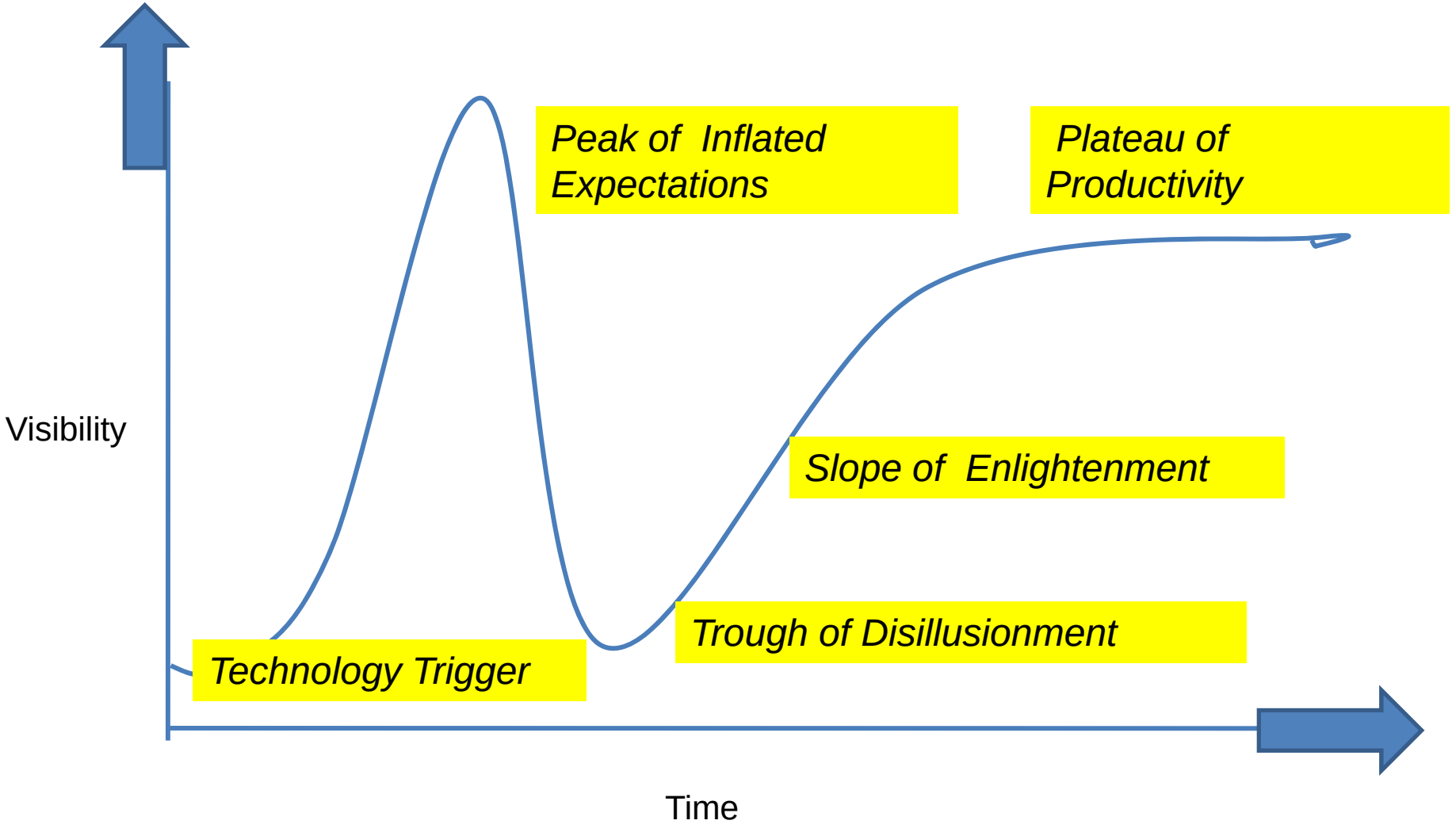
Thomas Alva Edison (1847-1931)

Menlo Park, NJ Laboratory

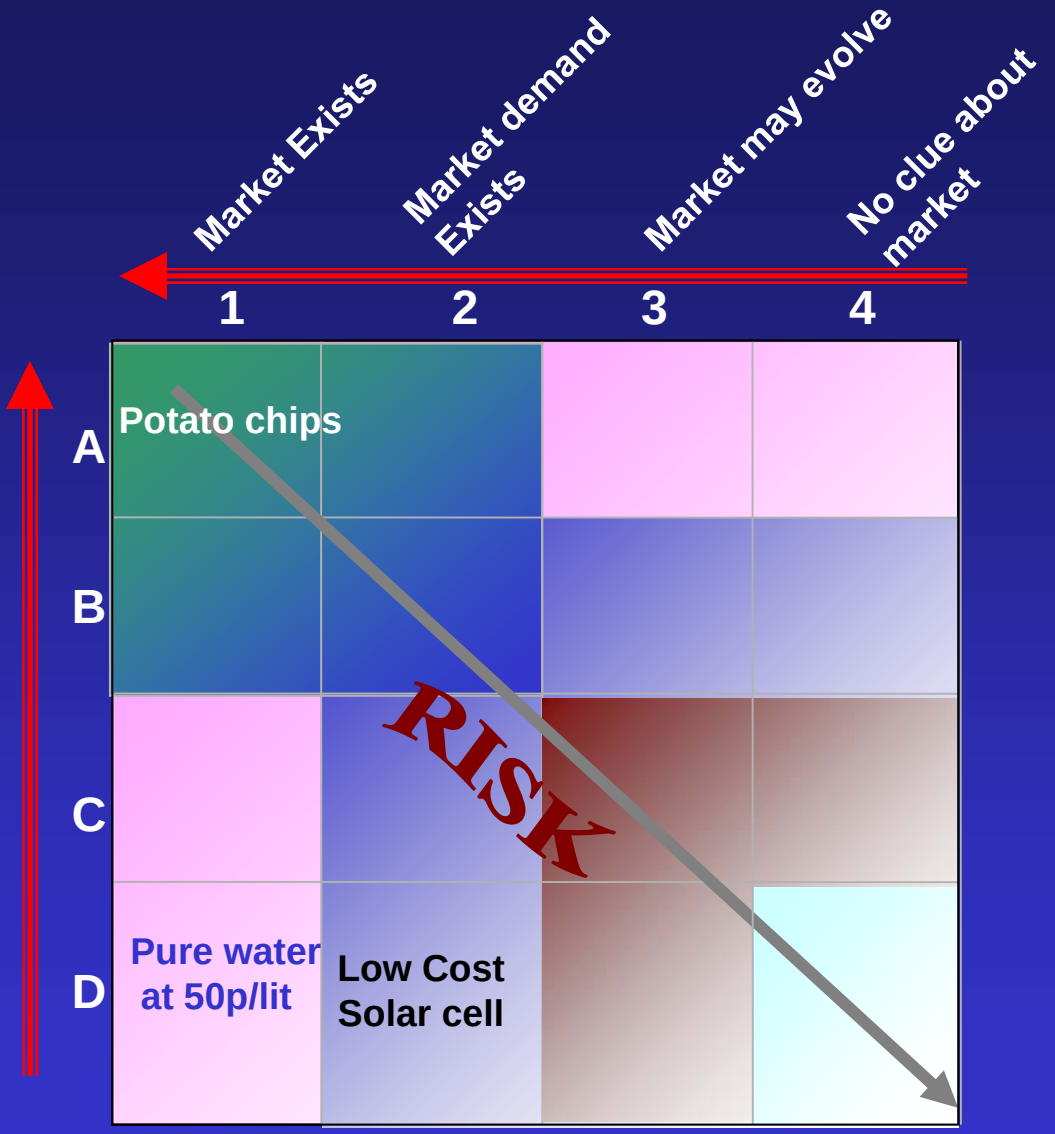
- **Most prolific inventor in the history**
- **Edison holds the record for the largest number of patents granted to an individual inventor, 1093**
- **Inventor of phonograph, incandescent bulb, motion picture camera, alkaline battery and many others**
- **First to organize and manage research , a forerunner to the later day corporate research laboratories of companies**
- **Assembled a cross functional global team of coworkers, from Germany(glass blowing), Switzerland (watch making),mathematicians, chemists , carpenters and machinists**
- **In 1900 Menlo Park employed over hundred people who were inventing for a salary and living**

Evolution of Technologies : The Hype Cycle

(http://en.wikipedia.org/wiki/Hype_cycle)



PRE COMPETITIVE POSITIONING OF KNOWLEDGE AND TECHNOLOGY BASE



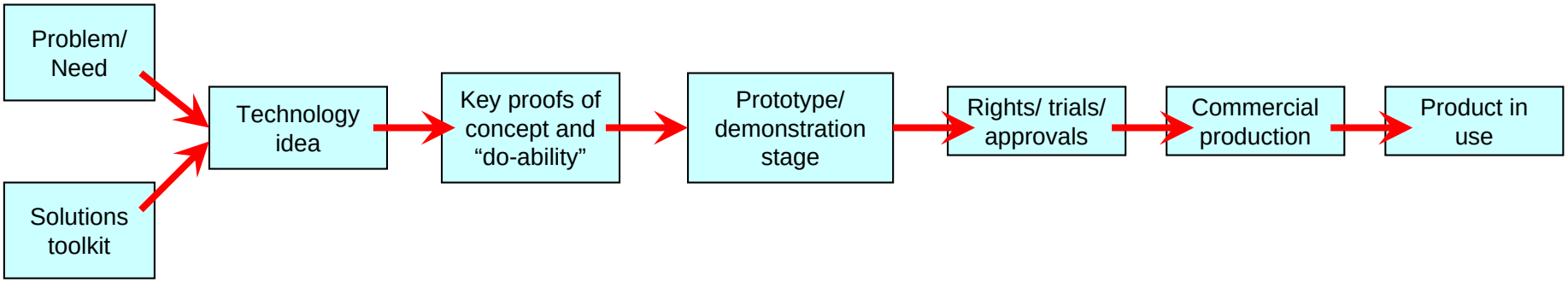
Knowledge exists, Technology exists

Knowledge exists, Technology needs to be developed

Knowledge exists, No clue about Technology

Problem exists, Knowledge needs to be developed

Technology Innovation: A simplistic model



Invention

80% of work, time, investment

All the inventions that are remembered have successfully navigated this process!

Innovation is 80 % perspiration, 20 % inspiration !

FROM CONCEPT TO MARKET : SOME USEFUL LESSONS

- **The power of partnership**
- **Staying with an idea long enough**
- **Communication to multiple interest groups**
- **The power of cross functional teams to deliver the product to the market**

Investment in idea generation and curiosity driven research always pay off

FROM CONCEPT TO MARKET : SOME USEFUL LESSONS

- **Learn to walk the last mile**
- **Putting the team together and energizing the team**
- **Patience , perseverance and failure tolerant**
- **Who gets the glory and who gets the blame**
- **The role of a champion; the leader as a champion**
- **Going beyond the written contract**
- **Passion to succeed; Are you ready to stake your reputation?**

Science is an individual effort; technology is a collective endeavor

INNOVATION

It is the means by which a person creates new wealth producing resources or endows existing resources with enhanced potential for creating wealth

Peter F. Drucker

HBR 1985

INVENTION AND INNOVATION

- An invention is an idea that can solve a practical problem in a new way, while innovation is the action needed to put it into practice
- The greater the scientific knowledge of the inventor, the greater is his or her range of potential inventions
- Innovation may take place centuries after the invention because the knowledge was not in the right place, the materials and processes were lacking or because there was not a big reward
- Predicting the future of invention/innovation is important, bit it is rarely correct

FAILURES OF VISION

1876 - 'This "telephone" has too many shortcomings to be seriously considered as a means of communication.' - ***Western Union internal memo***

1895 - 'Heavier-than-air flying machines are impossible.' - ***Lord Kelvin, President, Royal Society***

1899- 'Everything that can be invented has been invented.' - ***Charles Duell, Commissioner of the US Office of Patents***

Contd…..

FAILURES OF VISION

1920 - 'The wireless music box (radio) has no imaginable commercial value. Who would pay for a message sent to nobody in particular?' - *David Samoff's associates, in response to his urgings for investment in the radio*

1943 - 'I think there's a world market for maybe five computers.' - *Thomas Watson, chairman of IBM*

1949 - 'Computers in the future may weigh no more than 1.5 tons.' - *Popular Mechanics*

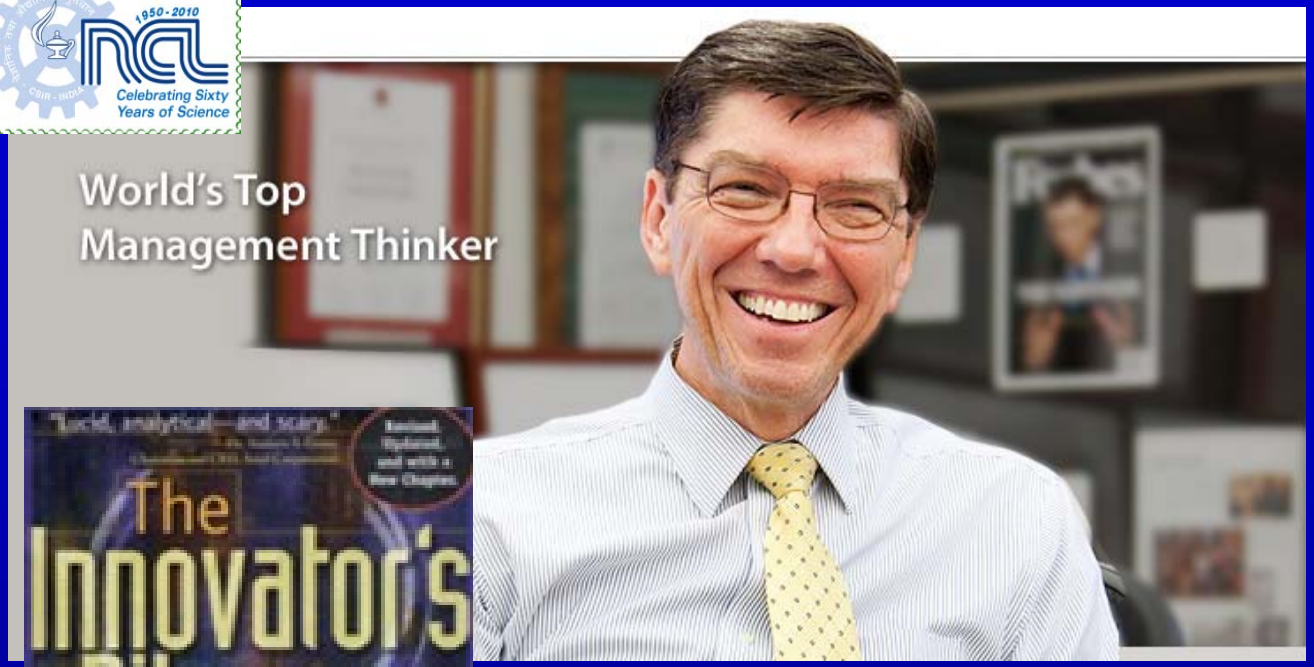
1977 - 'There is no reason anyone would want a computer in their home.' - *Ken Olson, president, chairman and founder of Digital Equipment*

1981 - '640K ought to be enough computer memory for anyone.' - *Bill Gates, chairman of Microsoft*

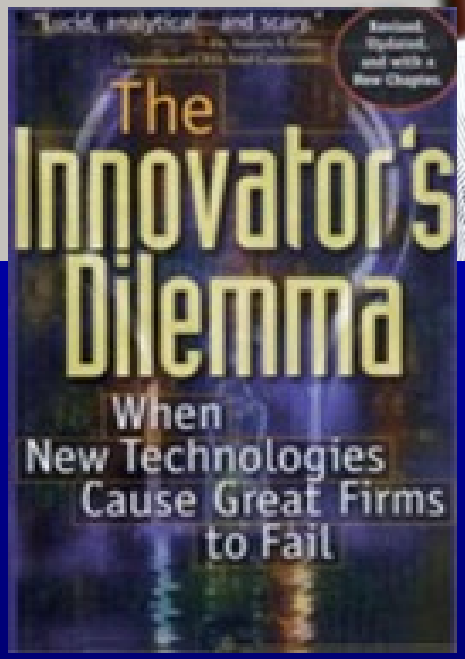
“SCIENCE ALONE IS NOT TECHNOLOGY

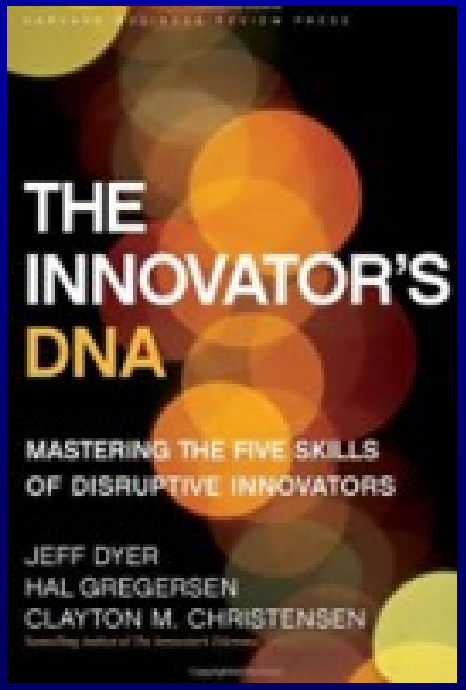
TECHNOLOGY ALONE IS NOT INNOVATION

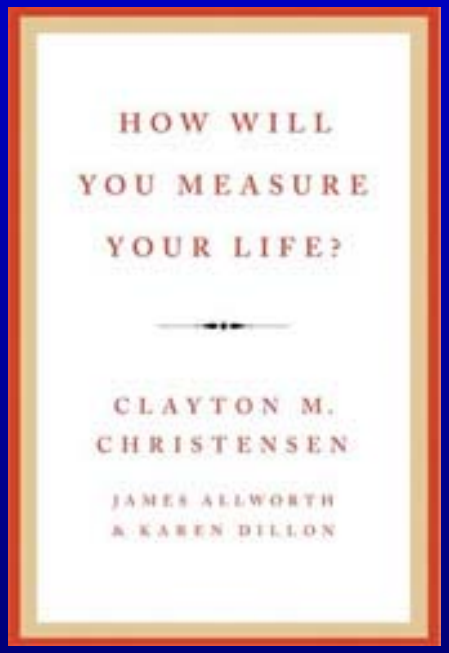
Akio Morita
Chairman of the Board
Sony Corporation



Professor Clayton Christenson
Harvard University







THE INNOVATOR'S DNA : CLAY CHRISTENSON (2011)

- **Five habits of disruptive innovators:**
  - **-Associating**
  - **-Questioning**
  - **-Observing**
  - **- Networking**
  - **- Experimenting**
- **Innovators excel in connecting seemingly unconnected things**
- **Creative associations come when you broaden your experience**
- **Best innovators are "T" shaped individuals**
- **Innovators constantly ask why can't things be done differently**
- **Define an innovation premium for companies, that is look at the proportion of their market value that cannot be accounted for by their current products.(e.g Apple's Innovation Premium is 52%)**

Most innovative companies are run by mega-minds who set hubristic goals

TYPES OF INNOVATION

- **Incremental innovation**
  - **Quality improvement**
  - **Efficiency improvement**
  - **Cost minimization**
  - **New applications**
- **Radical or breakthrough innovation**
  - **“Game Changer” technology**
  - **Creation of new products that never existed before**

To be successful in business, we must acquire technology at a lower cost than our competitors

THREE STAGES OF INNOVATION

- **Reconnaissance**
  - **Scouting for new markets and technological possibilities**
- **Evaluation**
- **Investment**

Opportunities are often uncovered by people who were not looking for them

SOURCES OF INNOVATION

- **Unexpected occurrences**
- **Exploitation of incongruities**
- **Process needs**
- **Industry and market changes**
- **Demographic changes**
- **Changes in perception**
- **New knowledge**

THE CREATIVE PROCESS

- Preparation
- Incubation
- Illumination
- Verification

SEVEN HABITS OF INNOVATION

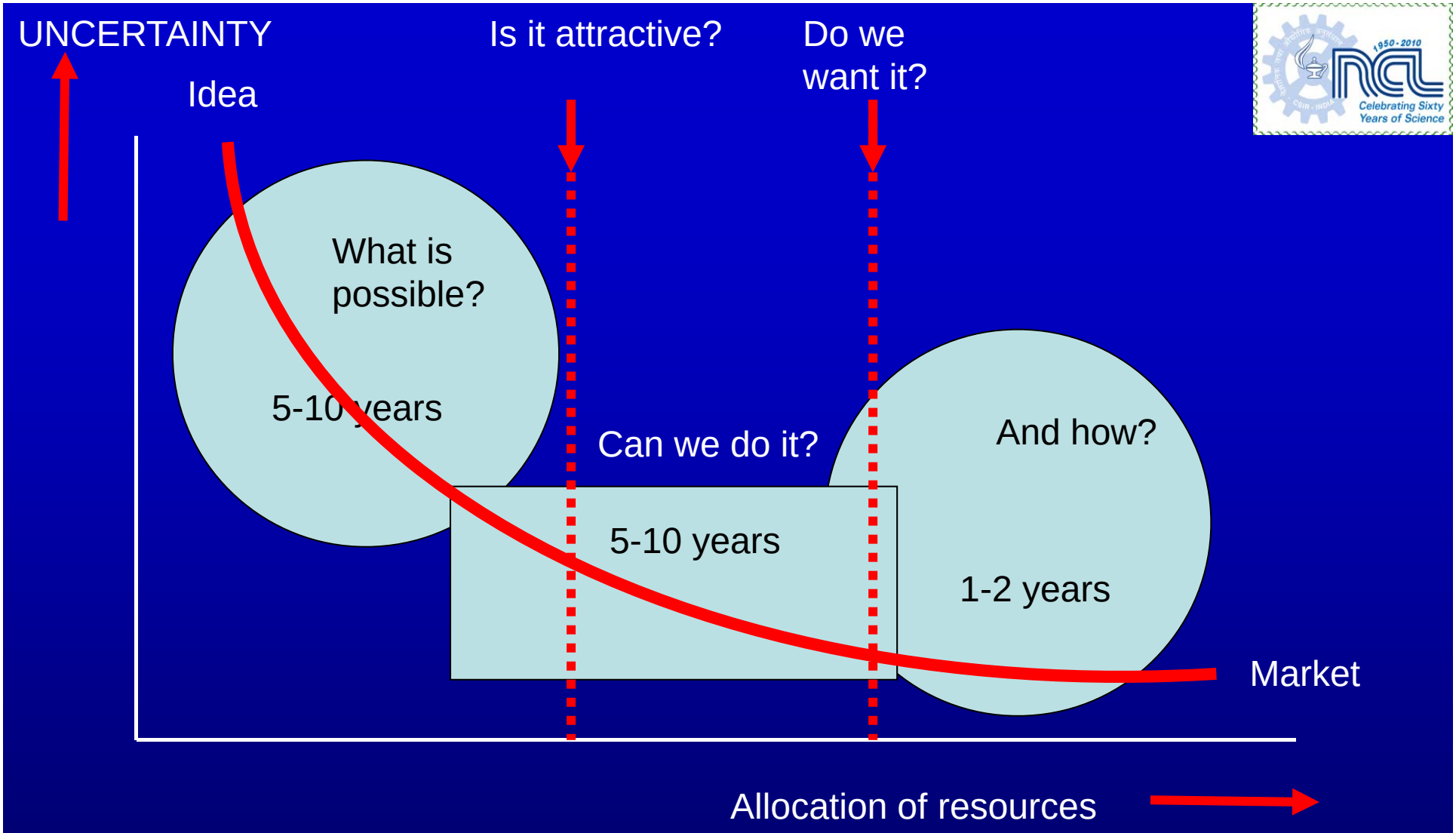
1. Challenging assumptions, defining the problems correctly, “out of box” thinking
2. Welcoming chance intrusions, practising serendipity
3. Listening to the depth of your mind
4. Suspending judgement
5. Using the stepping stones of analogy
6. Tolerating ambiguity
7. Ideas banking

KEY PLAYERS IN INNOVATION

- **Creative thinker**
- **Innovation**
- **Inventor**
- **Entrepreneur**
- **Intrapreneur**
- **Champion**
- **Sponsor**

KEY DRIVERS OF SUCCESS IN INNOVATION

- **Committed champions**
- **Personality of champions**
  - **“Out of box” thinkers**
  - **Intimate knowledge of organizations**
- **Accessibility to top management**
- **Significant or serendipitous events**
- **Idea generation through networks**



Allocation of resources. The blue box model relates uncertainty of product feasibility and commitment to (financial) resources allocated over time. It is characterized by three distinctive phases that address differently-oriented questions

EMERGING MODELS OF INNOVATIVE ORGANIZATIONS

- **From hierarchal or linear to distributed networks**
- **Fluid network of many interacting parts, with many nodes, but no singular leader**

Leadership will need skills to create partnership, govern loose networks and lead by influence rather than control and command

THE STARFISH ORGANIZATION
(The Starfish and the Spider : The Unstoppable Power of Leaderless Organizations by O. Brafman and R.A.Bckstrom

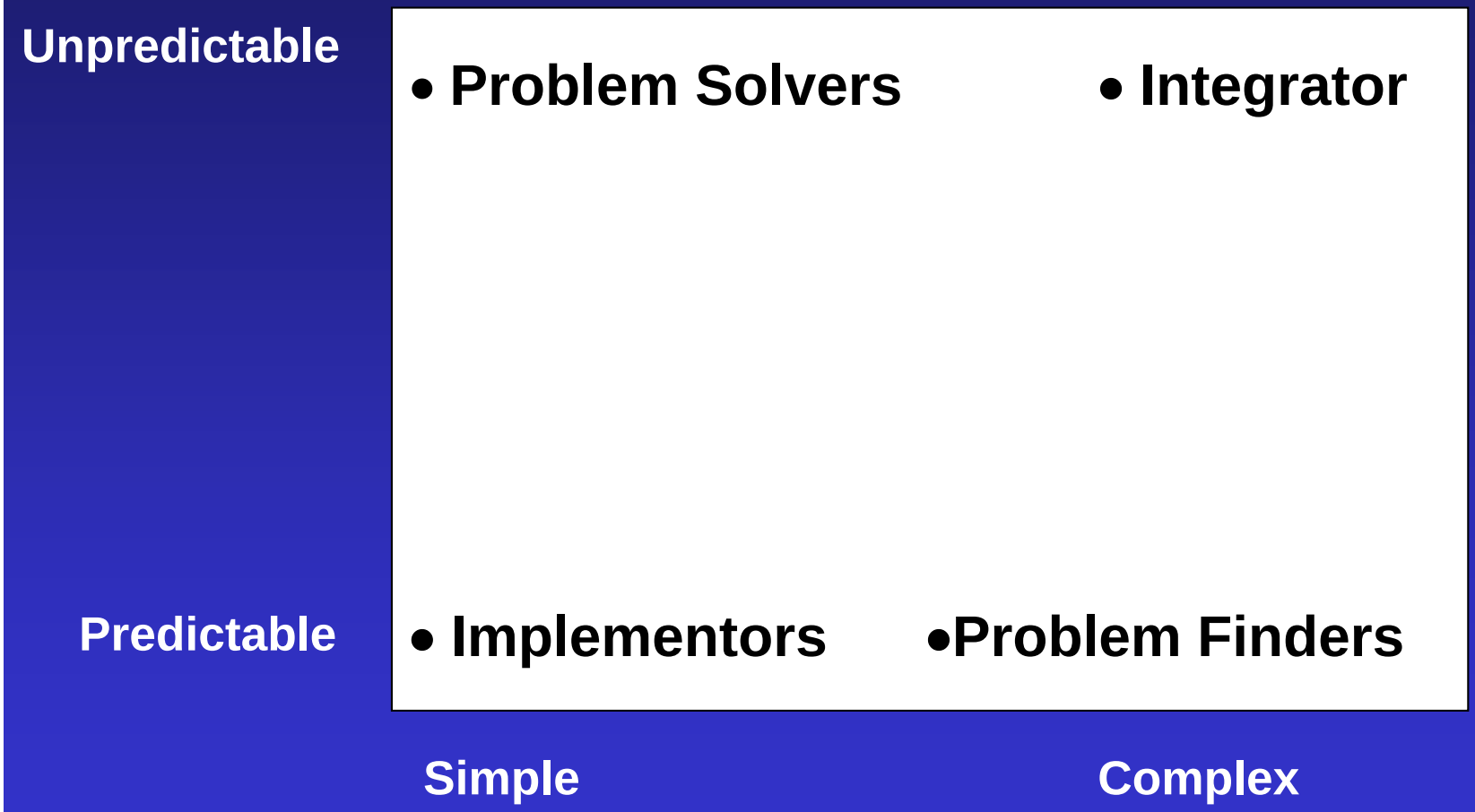
- **Being small gives competitive advantage**
- **Communities of networks creates better value of human resources**
- **Creativity thrives in chaos; order and structure squelch creativity**
- **Knowledge is spread throughout the organization; the best knowledge is at the fringe of the organization**
- **The spirit of sharing thrives; everyone wants to be a contributor**
- **In a starfish organization, people will do what they will do; the role of management is to connect people and ideas**

If you cut off a spider's head, it dies; but if you cut off a starfish's leg, it grows a new one .Traditional top down organizations are like spiders

INNOVATION AND CROSSFUNCTIONAL TEAMS

- **Cross functional diversity provides multiplicity of ideas essential to creative thinking**
- **However, merely including a large number of functional areas in a team does not improve performance. While more ideas may be generated problem solving becomes difficult**
- **For a team to succeed, one must have a strong "superordinate identity" to the team. Often team members retain deep rooted functional allegiance**
- **Strength of interpersonal ties among team members influences innovativeness. High social cohesiveness a deterrent to innovation**
- **Close monitoring of activity is a powerful motivator for enhancing innovation**

ATTRIBUTES OF AN INNOVATION TEAM



FACTORS INHIBITING INNOVATION

- **Negative attitude**
- **Fear of failure**
- **Stress**
- **Following rules**
- **Making assumptions**
- **Over reliance on logic**

WHY PROJECTS / TEAMS FAIL

- **Inadequate understanding of customer needs**
- **Failing to work across traditional boundaries**
- **Poor quality of data/information based on which decisions were made**
- **Lack of mentorship**
- **Inadequate definition of tasks and responsibilities**

LEADERSHIP ROLE IN INNOVATION PROCESS

- **Leadership that is failure tolerant; views failure as complement to success, not opposite**
- **Leadership that is fully engaged in the innovation process; Focused on increasing organization intellectual capital**
- **Leadership that is collaborative, not controlling**
- **Leadership that is less evaluative, more interpretative**
- **Encourage communication; Create avenues for ideas to “bubble up”**

LEADERSHIP GRID

Country Club	**Team Leader**
Impoverished	**Authoritarian**

PEOPLE

TASK

A good leadership is one whose presence is barely known or felt

We must learn to happily progress together or miserably perish together. Man can live individually but can survive only collectively

Atharva Veda

FUTURE OF INNOVATION

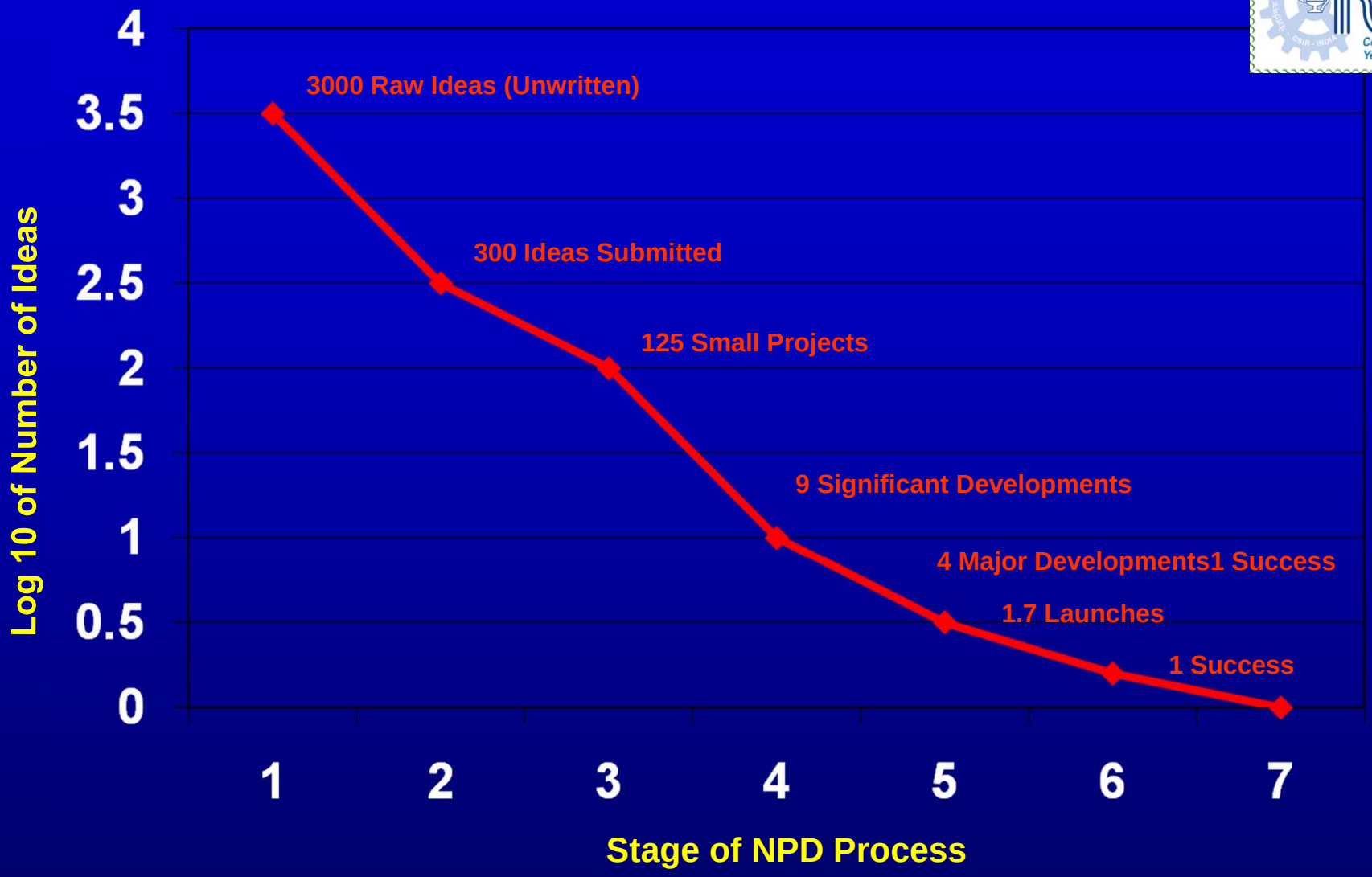
- **Innovation will move from large enterprises to small companies**
- **Disruptive innovation will most likely emerge from publicly funded institutions**
- **Larger companies will need to build entrepreneurial, agile R&D teams through an open innovation or venture models**
- **Partnership and collaboration in R&D will become necessary criteria for success based on shared responsibilities, risks and benefits**

MINDSET FOR TECHNOLOGY INNOVATION

- **Willingness to invest in risky projects**
- **Persistence to build capabilities**
- **Tenacity to stay in the midst of failures and obstacles**
- **Capability to manage all the above in a systematic way**

SUCCESS IN INNOVATION REQUIRES…..

- **A belief that "innovation is not a prerogative of a talented few, but the everyday task of making non-obvious connections**
- **Getting people to view perspectives from other's eyes**
- **Setting 'stretch' goals**
- **Creating a culture of taking risks; Innovation is a gamble. One must learn to play for high stakes**
- **Ensure that there is no fear of failure. Failure is an integral part of innovation. One cannot learn without making mistakes**
- **An open and transparent organizational culture**



This "universal industrial success curve" illustrates the number of "substantially new" product ideas surviving between each stage of the new product development (NPD) process

Hitting a Bulls Eye in a game of Dart is determined by laws of probability. The more number of throws, greater the chances of hitting the Bulls Eye

Similarly, the larger the number of invention or ideas, greater is the probability that one of them will turn out to be a true innovation

Key : Constant flow of new ideas

INNOVATION MANAGEMENT " WINDS OF CHANGE

- **Quick response of R&D external forces (economics, markets, environmental regulations, customer preferences, competing technologies etc.)**
- **Notion of "captive" knowledge becoming increasingly obsolete, whether within a laboratory or a country; information technologies will make information more pervasive**
- **Flattened R&D organization; move away from "command and control" to delegate and empower"**
- **Shift from "national" enterprises to "transnational" enterprises**

The rate at which organizations learn may become the only sustainable competitive advantage

Old Model	Attributes	New Model
Hierarchy	Organization	Network
Self sufficiency	Structure	Interdependencies
Security	Work expectations	Personal growth
Autocratic	Leadership	Inspirational
Homogeneous	Workforce	Culturally diverse
By individuals	Work	By teams
Domestic	Markets	Global
Cost	Advantage	Time
Profits	Focus	Customers
Capital	Resources	Information
Board of directors	Governance	Varied constituents
What's affordable	Quality	No compromises

INTEGRATING TECHNOLOGY DEVELOPMENT PROCESS

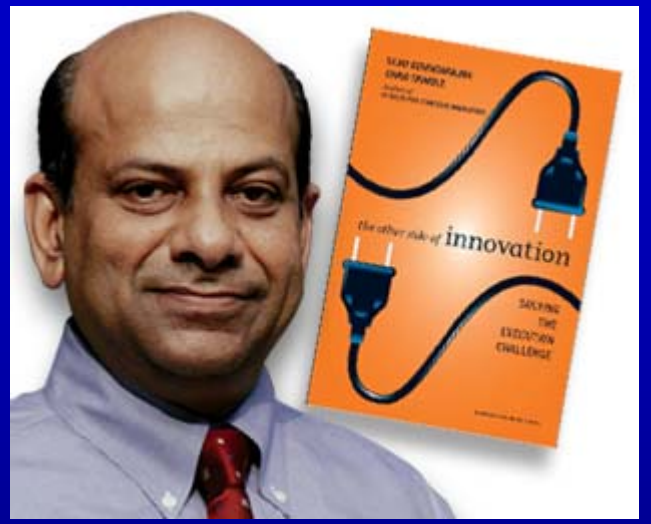
Traditional R&D pipeline

- **A linear process**
- **Similar to baton passing in a relay race**

Increasing complexity of technology development requires

- **An integrated process**
- **Concurrent approach to development**
- **Multidisciplinary team**
- **Create a system focus with shared goals**

THE OTHER SIDE OF INNOVATION : SOLVING THE EXECUTION CHALLENGE (HBS) : VIJAY GOVINDARAJAN, CHRIS TIMBLE



- I for ideation, I for invigoration and I for Incubation
- We miss the I for implementation
- Genius is 1 % inspiration and 99% perspiration
- Innovation is not equal to ideas
- Innovation is Ideas + Execution or Implementation
- Innovation is not just creativity; you can have lots of ideas but do not know what to do
- Organizations are not designed for innovation, but for efficiency
- Efficiency and scalability depend on predictability and repeatability
- Learn to effectively balance the performance engine with the innovation engine
- Innovation often requires short term sacrifice in order to gain long term advantage

CHANGING TOPOGRAPHY OF INDUSTRY

- **Globalization of business**
- **Shifting manufacturing geographies**
- **Growing concerns for sustainability**
- **Changing customer expectations driven by new demographics**
- **Changing work force requirements**
- **Impact of ICT**
- **Industry consolidation**

FORCES OF CHANGE IN THE INDUSTRY

- **Unprecedented rise in fuel and raw material costs**
- **High cost of new product introductions; difficulties in identifying new growth platforms**
- **Increasing regulatory (environment, health and safety) frameworks**
- **Faster technology diffusion / commoditization of products leading to quicker price / margin erosion**
- **Supply chain is taxed by breadth of markets, products and geography**
- **Increased global segmentation in terms of technology providers , low cost producers and large domestic markets**

GLOBAL ISSUES

- Difficulties in identifying new growth platforms
- Difficulties in creating value and high entry barriers for new product introductions
- Globalization of economy, reduced barrier to movements of goods services
- Increased global segmentation in terms of technology providers , low cost producers of feed-stocks and large domestic markets

THE OTHER DEMOGRAPHIC DIVIDEND

(THE ECONOMIST 2010)

- **Emerging markets are teeming with young entrepreneurs**
- **Median age in India will be 28 in 2020 compared to 37 in China, 38 in USA, 45 in Western Europe and 49 in Japan**
- **Direct correlation between age and entrepreneurial pre-disposition; young people are more innately inclined to overthrow the existing order than older people**
- **Drivers ICT, opportunity to leapfrog technologies. Not hampered by legacy systems and mindsets**
- **Entrepreneurial energies are moving eastwards. The next Facebook is increasingly likely to be founded in India rather than in middle aged America or Europe**

PRINCIPAL DILEMMAS

"Either – or" to "both – and"

Low cost – high quality
High economic growth with low environmental impact
More growth with more inclusion
Flexibility to industry and fairness to workers
Include the non- included without excessive government subsidies
Inclusive and sustainable

INNOVATING FOR THE EMERGING MARKETS

- **Go beyond cost arbitrage; aggressively participate in the Indian market**
- **Apply 70:50:30 rule; 70% performance at 50% price and 30% cost of equivalent products in other markets**
- **Test new innovation models that can be globally replicated**
- **Build a real life globally adaptive organization with a learning opportunity relevant to the needs of 6 billion people**

1950 - 2010

Celebrating Sixty Years of Science

THANK YOU