Innovation as a Complex Dynamical System

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TECHNOLOGICAL LEADERSHIP INSTITUTE

Agenda

- Introduction
- Selected tools for innovation and technology management
- Dealing with uncertainty . . . And how people deal with it!
- A dynamical systems perspective on innovation and technology management
- The Technological Leadership Institute at the Univ. of Minnesota

The Difference Between “Invention” and “Innovation”

By Tom Grasty

What's The Difference Between Invention And Innovation?

Jacob Morgan, CONTRIBUTOR

I write about and explore the future of work! FULL BIO

Opinions expressed by Forbes Contributors are their own.

PARTNER CONTENT BILL WALKER

INNOVATION VS. INVENTION: MAKE THE LEAP AND REAP THE REWARDS

Invention Is a Flower, Innovation Is a Weed

The inventor of Ethernet and founder of 3Com shares some lessons with young innovators.

by Bob Metcalfe November 1, 1999

Sources (from top, left-to-right): forbes.com, huffpost.com, wired.com, technologyreview.com

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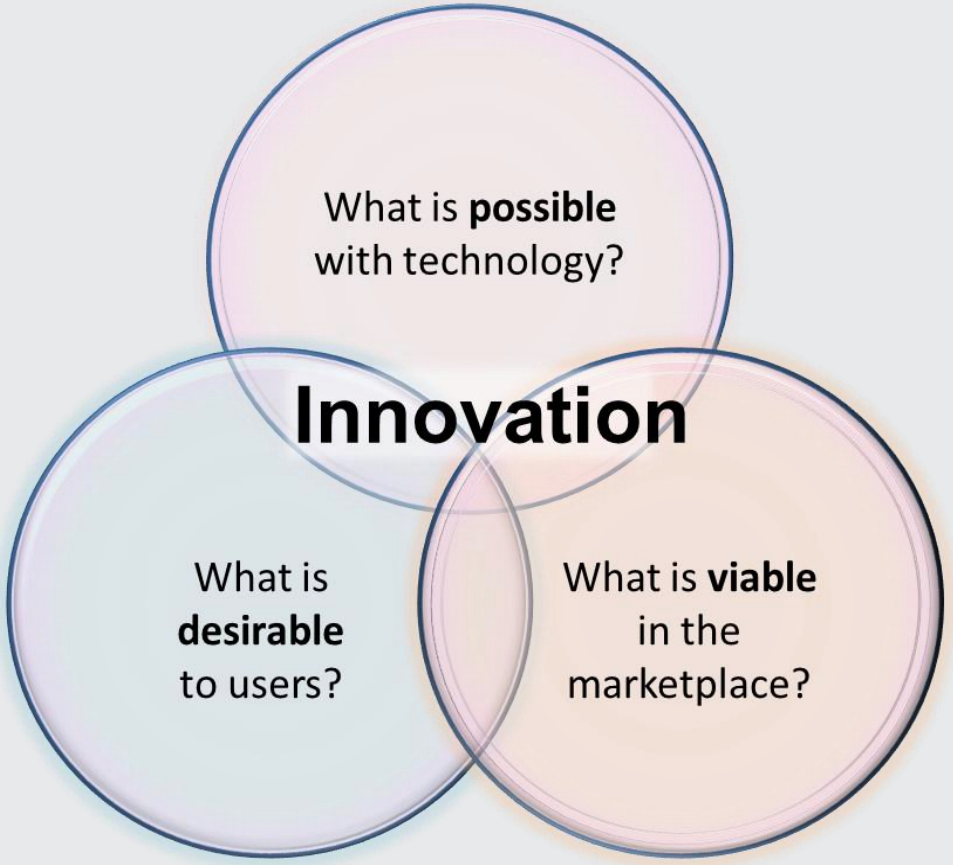
Innovation ≠ Invention



How technology drives economic progress:
Schumpeter's "Invention – Innovation – Diffusion" trilogy

"So when did the focus change from invention to innovation? . . . [The Austrian economist Joseph Schumpeter] defined invention as an act of intellectual creativity undertaken without any thought given to its possible economic import, while innovation happens when firms figure out how to craft inventions into constructive changes in their business model."
– E. Green, "The History of a Buzzword," *The Atlantic*, June 20, 2013

A buzzword today . . . and yesterday!

The Rise of a Buzzword

Google Books Ngram Viewer,
6 May 2018

Schools of Thought on Innovation

- Technology-forward vs. market-back innovation?
- Understanding customer requirements vs. creating new customer needs?
- Organic innovation vs. acquisitions?
- Innovation teams embedded in product businesses vs. separated from them?
- Open innovation vs. “skunk works”?

What is the right organization or approach for innovation . . . It depends!

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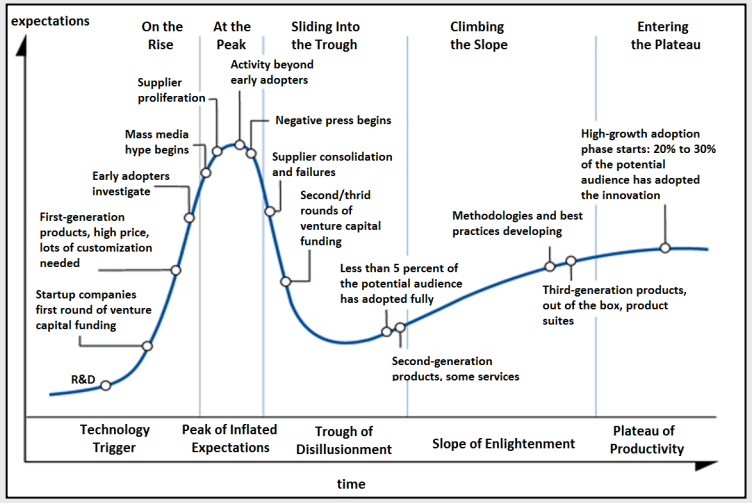
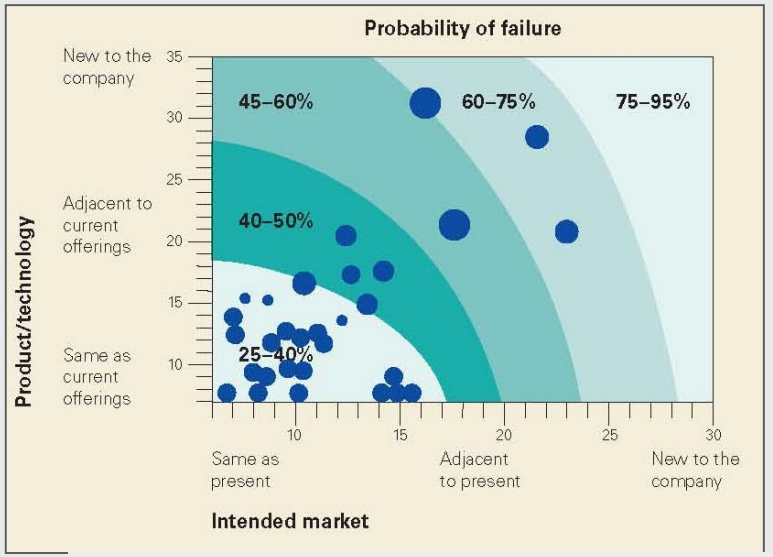
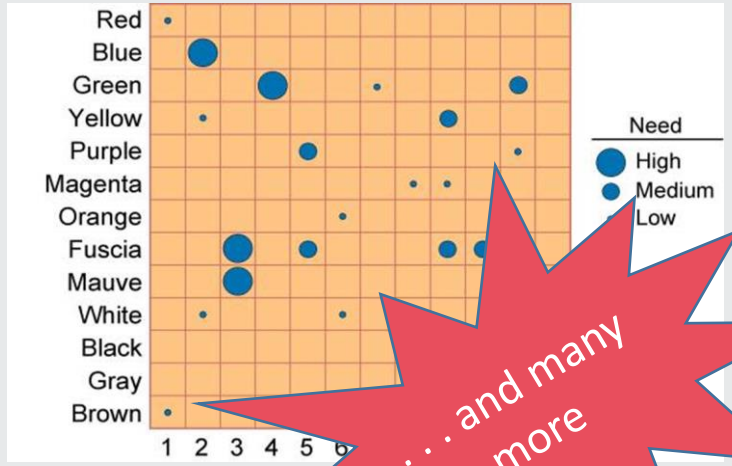
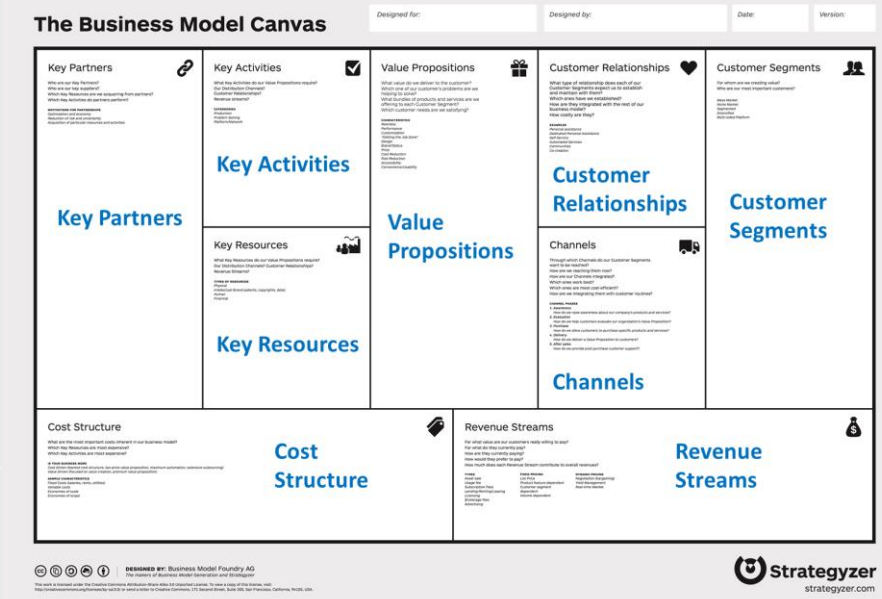
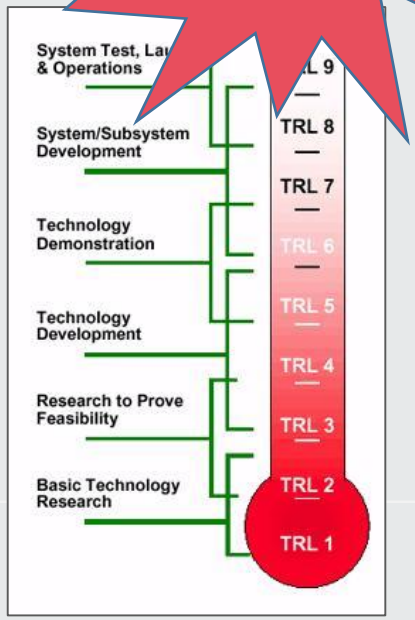
Tools for Innovation (Selected)



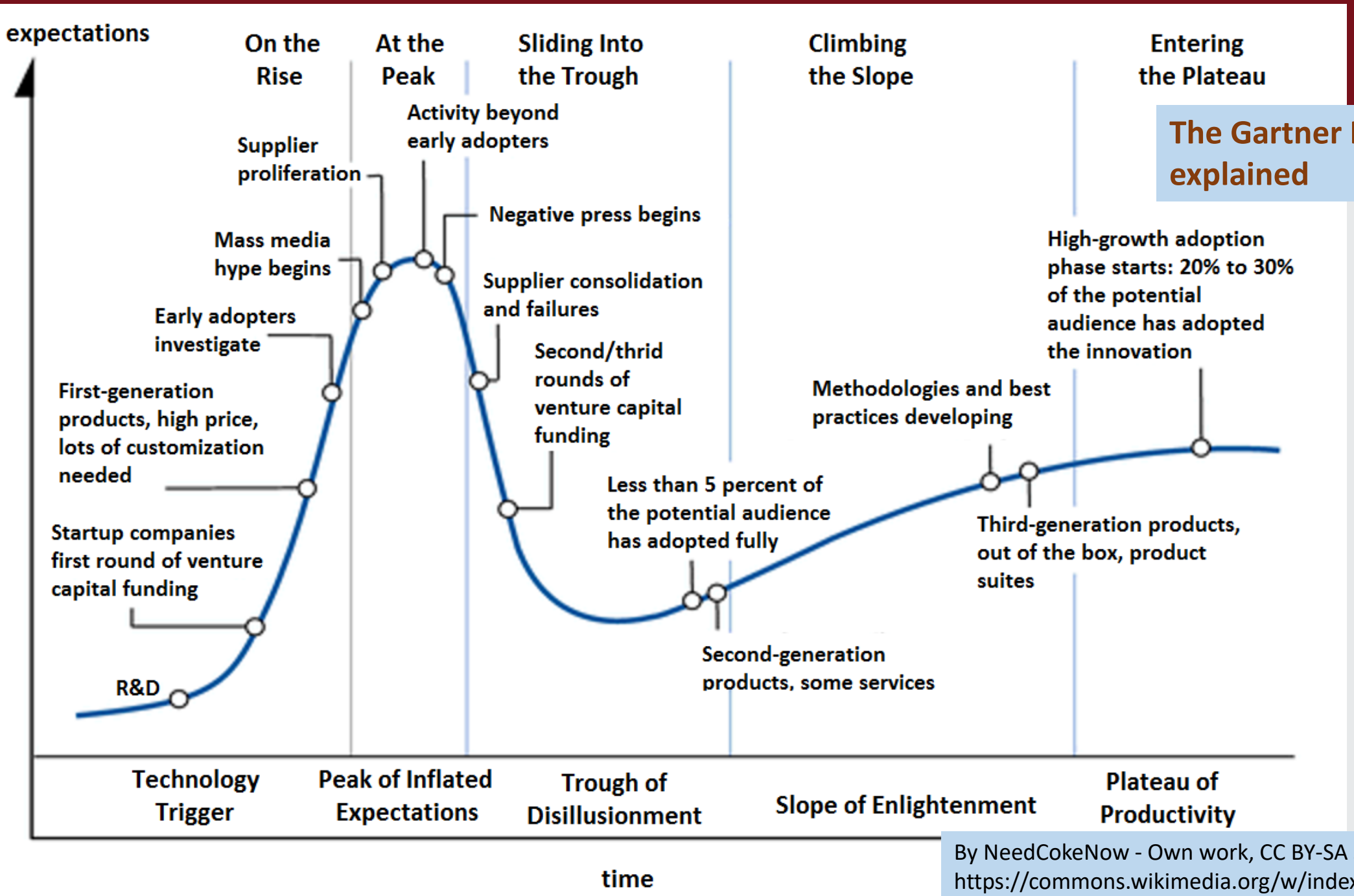




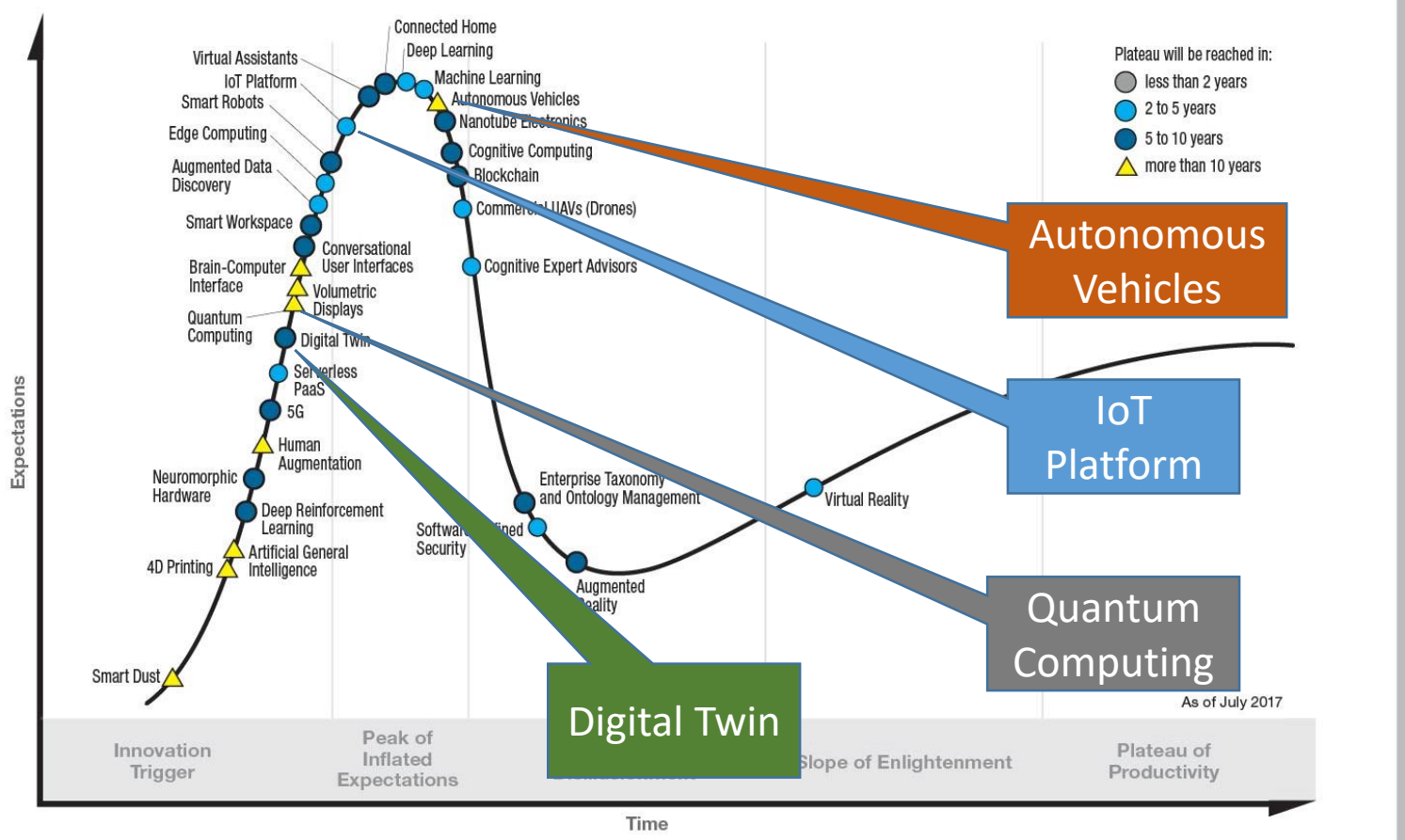




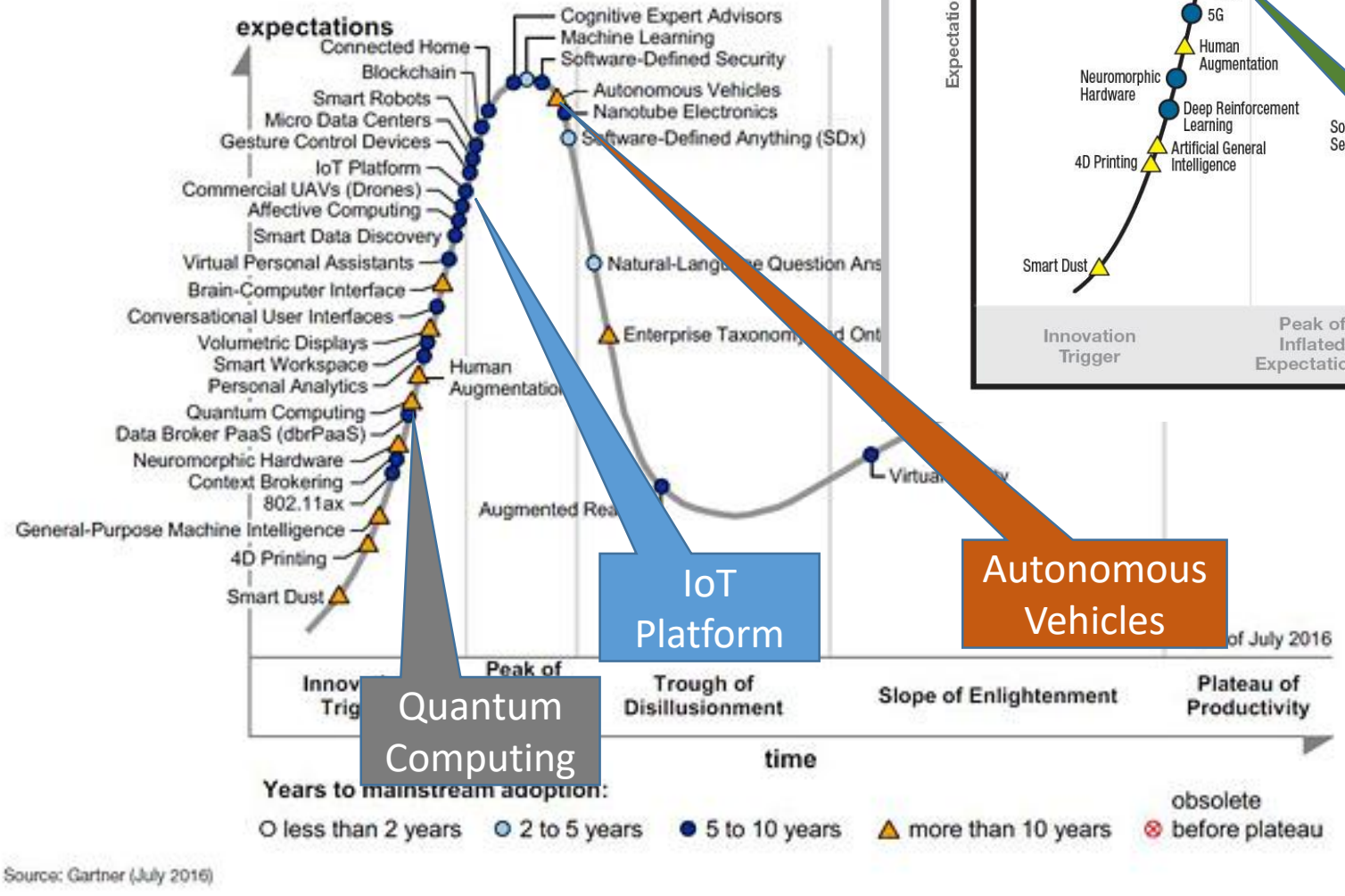
The Gartner Hype Cycle explained



Gartner Hype Cycle for Emerging Technologies, 2017



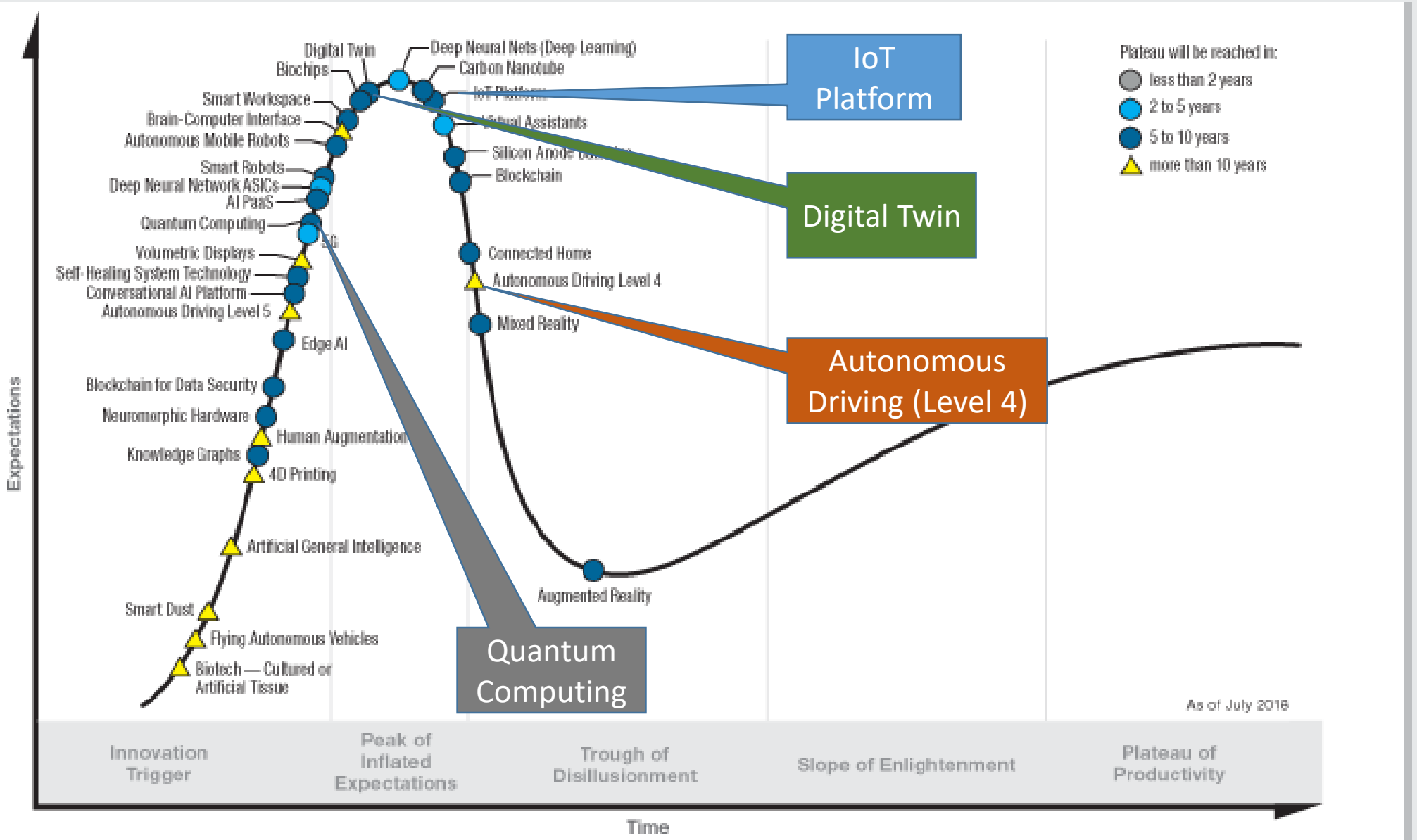
Gartner Hype Cycle for Emerging Technologies, 2016



Source: Gartner (July 2016)

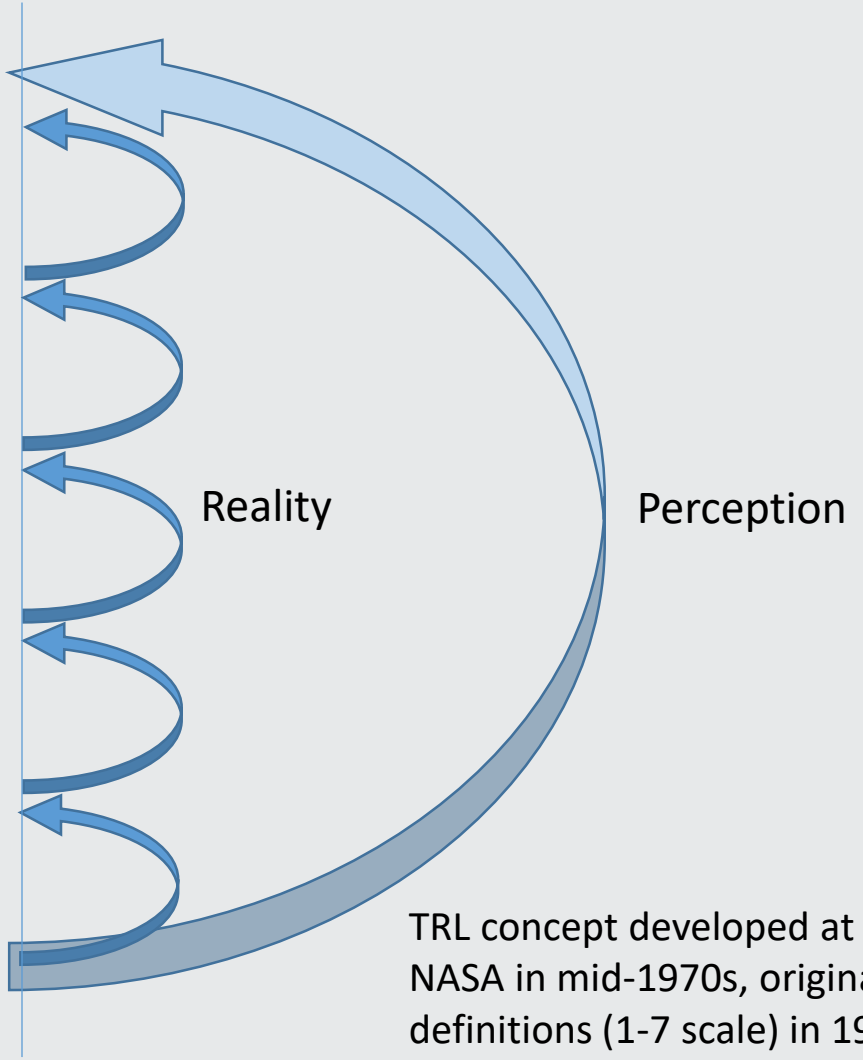
HIP INSTITUTE

Gartner Hype Cycle for Emerging Technologies (2018)



Technology Readiness Levels (TRLs)

TRL	9	Actual Technology Proven Through Successful Use in an Operational Environment	Real World
	8	Actual Technology Completed and Qualified Through Tests and Demonstrations	
	7	System Prototype Demonstration in an Operational Environment	
	6	System/Subsystem Model or Prototype Demonstrated in a Simulated Environment	Simulated World
	5	Component Validation in a Simulated Environment	
	4	Component Validation in a Laboratory Environment	Research Lab
	3	Analytical and Experimental Critical Function and/or Characteristic Proof-of-Concept	
	2	Technology Concept and/or Application Formulated	
TRL	1	Basic Principles Observed and Reported	



TRL concept developed at NASA in mid-1970s, original definitions (1-7 scale) in 1989

DOD HW/SW TRLs

TRL	HW Technology Definition	SW Technology Definition
TRL 1	Basic principles observed and reported	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept	Analytical and experimental critical function and/or characteristic proof of concept
TRL 4	Component and/or system validation in laboratory environment	Module and/or subsystem validation in a laboratory environment (i.e., software prototype development environment)
TRL 5	Laboratory scale, similar system validation in relevant environment	Module and/or subsystem validation in a relevant environment
TRL 6	System/subsystem model or prototype demonstration in a relevant environment	Module and/or subsystem validation in a relevant end-to-end environment
TRL 7	System prototype demonstration in an operational environment	System prototype demonstration in an operational high-fidelity environment
TRL 8	Actual system completed and qualified through test and demonstration	Actual system completed and mission qualified through test and demonstration in an operational environment
TRL 9	Actual system proven through successful mission operations	Actual system proven through successful mission-proven operational capabilities

http://www.sei.cmu.edu/reports/10tr044.pdf

Real-Win-Worth – Innovation Scoring Template

Is it "real"?

- Is the market real?
  - Is there a need or desire for the product?
  - Can the customer buy it?
  - Is the size of the potential market adequate?
  - Will the customer buy the product?
- Is the product real?
  - Is there a clear concept?
  - Can the product be made?
  - Will the final product satisfy the market?

Can we "win"?

- Can the product be competitive?
  - Does it have a competitive advantage?
  - Can the advantage be sustained?
  - How will competitors respond?
- Can our company be competitive?
  - Do we have superior resources?
  - Do we have appropriate management?
  - Can we understand and respond to the market?

Is it "worth" doing?

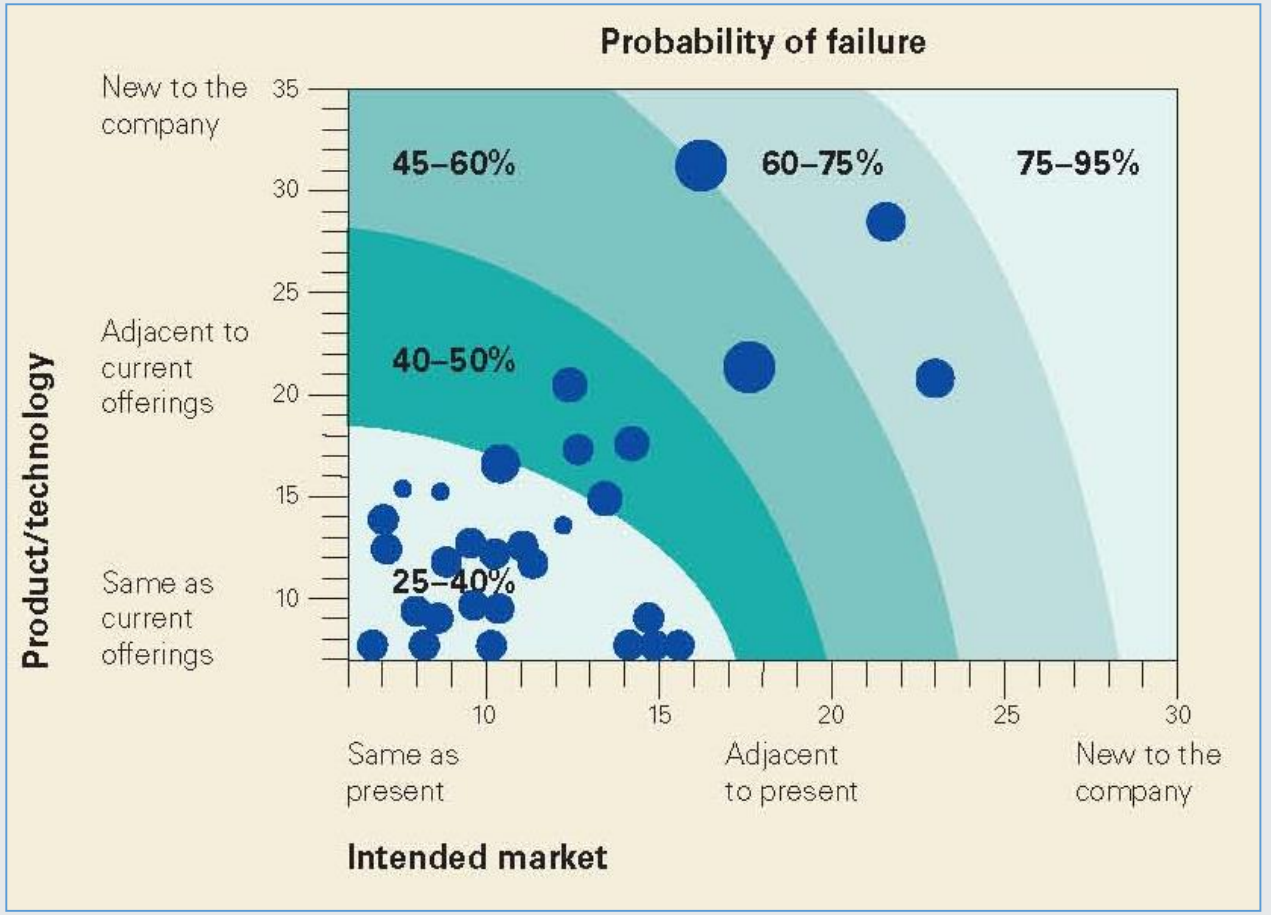
- Will the product be profitable at an acceptable risk?
  - Are the forecasted returns greater than costs?
  - Are the risks acceptable?
- Does launching the product make strategic sense?
  - Does the product fit our overall growth strategy?
  - Will top management support it?

Architects' role in innovation includes helping define answers to these questions!

George S. Day (2007), Is it real? Can we win? Is it worth doing? *Harvard Business Review*, December.

Innovation & Risk

- **Intended market fit with current markets served:**
  - **Customer's behavior and decision-making processes**
  - **Distribution and sales activities**
  - **Competitive set (incumbents or potential entrants)**
  - **Brand promise**
  - **Current customer relationships**
  - **Knowledge of customers' behavior and intentions**
- **Product and technology relative to capability**
  - **Current development capability**
  - **Technology competency**
  - **Intellectual property protection**
  - **Manufacturing and service delivery system**
  - **Required knowledge and science bases**
  - **Necessary product and service functions**
  - **Expected quality standards**



George S. Day (2007), Is it real? Can we win? Is it worth doing? *Harvard Business Review*, December.

Corp. Innovation: Incremental vs. Breakthrough

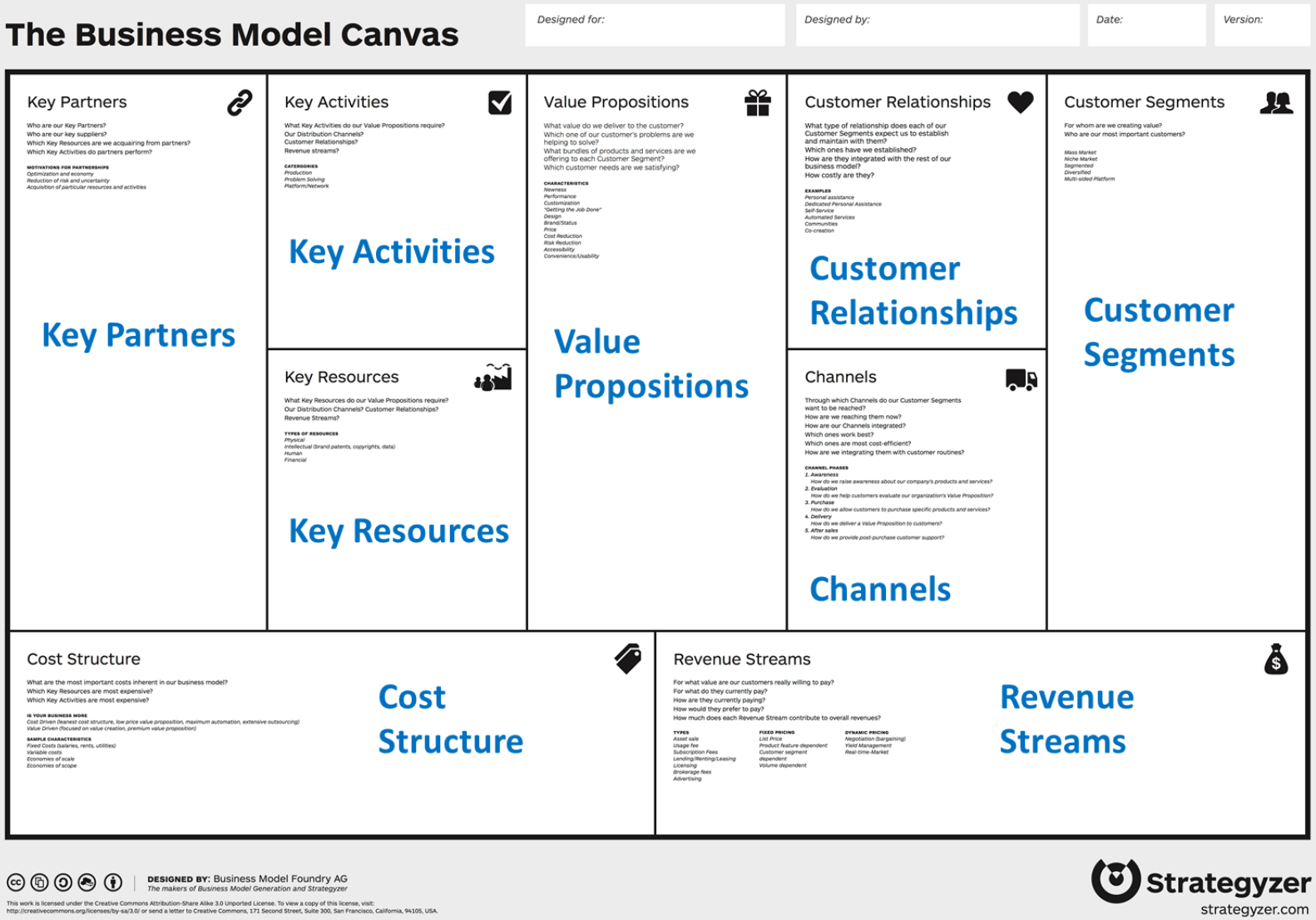
"We cannot rely on [established] industries to convert [risky] scientific advances into new products and processes"
– W.R. Maclaurin (1946), as quoted by B. Godin (2008)

Organic breakthrough innovations by large established companies are rare . . . but valuable!

- **3M Post-It sticky notes**
- **Honeywell ring-laser gyro**
- **Chrysler minivan**
- **HP ink-jet printers**
- **TI digital light processing**
- **Corning Gorilla Glass**
- **Samsung OLED display**

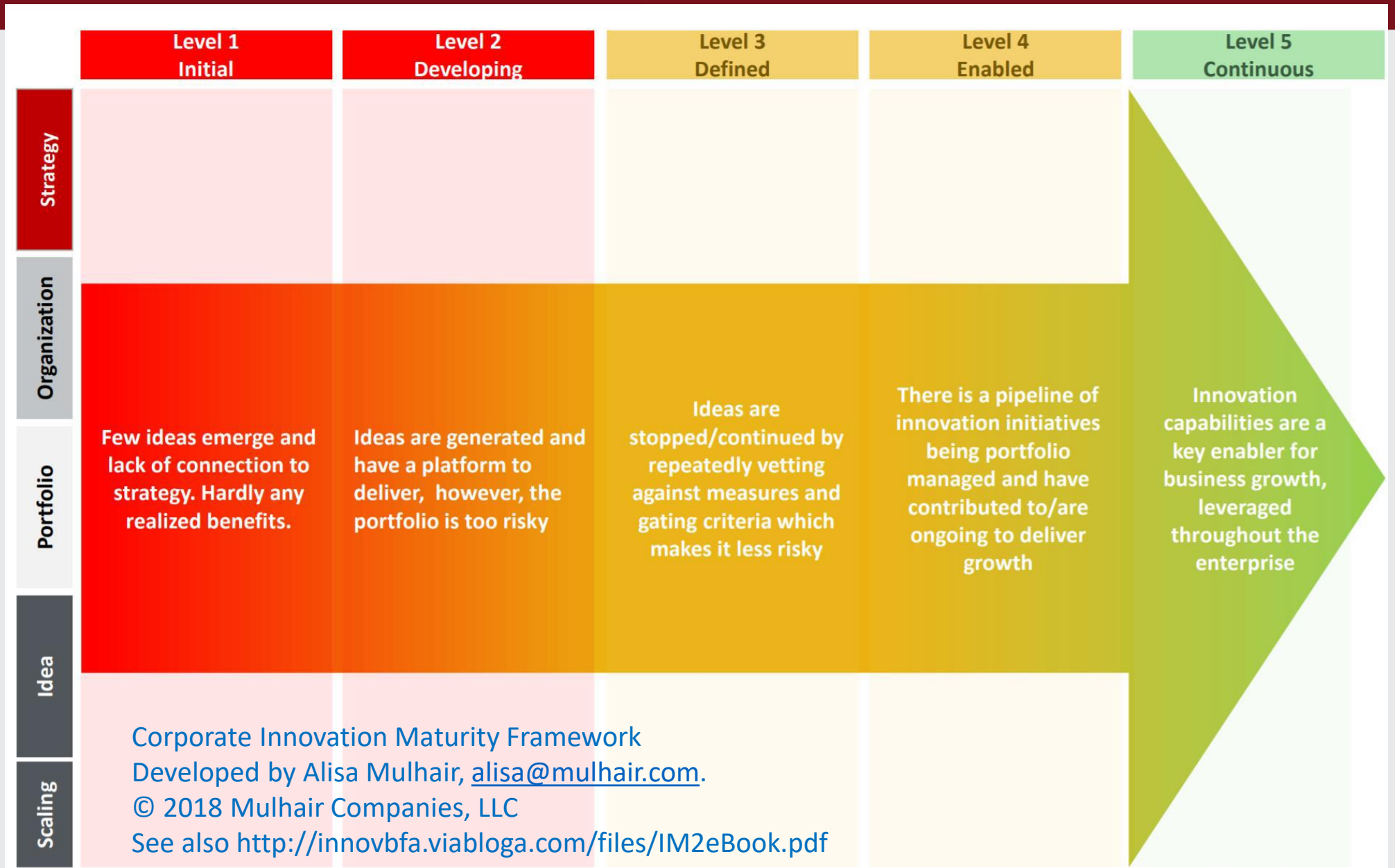
W.R. Maclaurin (1946), "Investing in Science for the Future," *Technology Review*, May
B. Godin (2008), "In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation," Working Paper No. 2, Project on the Intellectual History of Innovation, Montreal, Canada

The Business Model Canvas



Strategyzer
strategyzer.com

The Journey to Innovation Maturity



Corporate Innovation Maturity Framework
Developed by Alisa Mulhair, alisa@mulhair.com.

See also http://innovbfa.viabloga.com/files/IM2eBook.pdf

Sub-areas of Innovation Operating Model Pillars

Strategy	Organization	Portfolio Management	Idea Generation and Development	Scaling
Set compelling, credible objectives and investment priorities	*Build an innovative organization and a collaborative culture*	*Improve the size, shape and speed of the innovation portfolio*	*Create profitable new approaches that meet customer needs better than the competitors*	*Strengthen testing, learning and scaling skills*
1 Innovation goals and strategies	4 Networks and partnerships	7 Portfolio management	10 Idea generation	13 Scaling and launch strategy
2 Strategic alignment	5 Structure and roles	8 Project management	11 Idea screening and development	14 Feedback loops and adaption
3 Assessment	6 Culture	9 Governance & decision making	12 Prototyping and testing	

See also http://www.bain.com/publications/articles/taking-the-measure-of-your-innovation-performance.aspx

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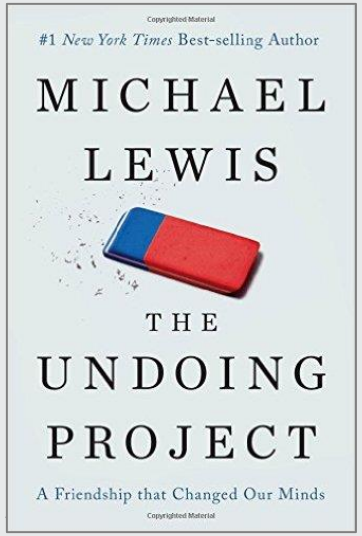
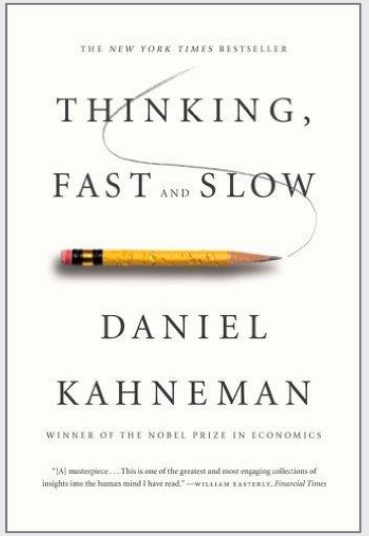
Understanding—and Embracing—Uncertainty!

- The more complex the problem we are attempting to solve or the system/product we are attempting to develop . . . the more strategic and global our outlook . . . the more multifunctional and multidisciplinary our teams → the greater the uncertainties we are faced with!

- Uncertainty arises from many sources: technical and marketing developments, macro and industry trends, socio and economic environment, a rapidly changing world in many respects . . .

- But we also need to understand how people (that's us too!) how we make decisions in the face of incomplete and conflicting information—Prospect Theory a guide





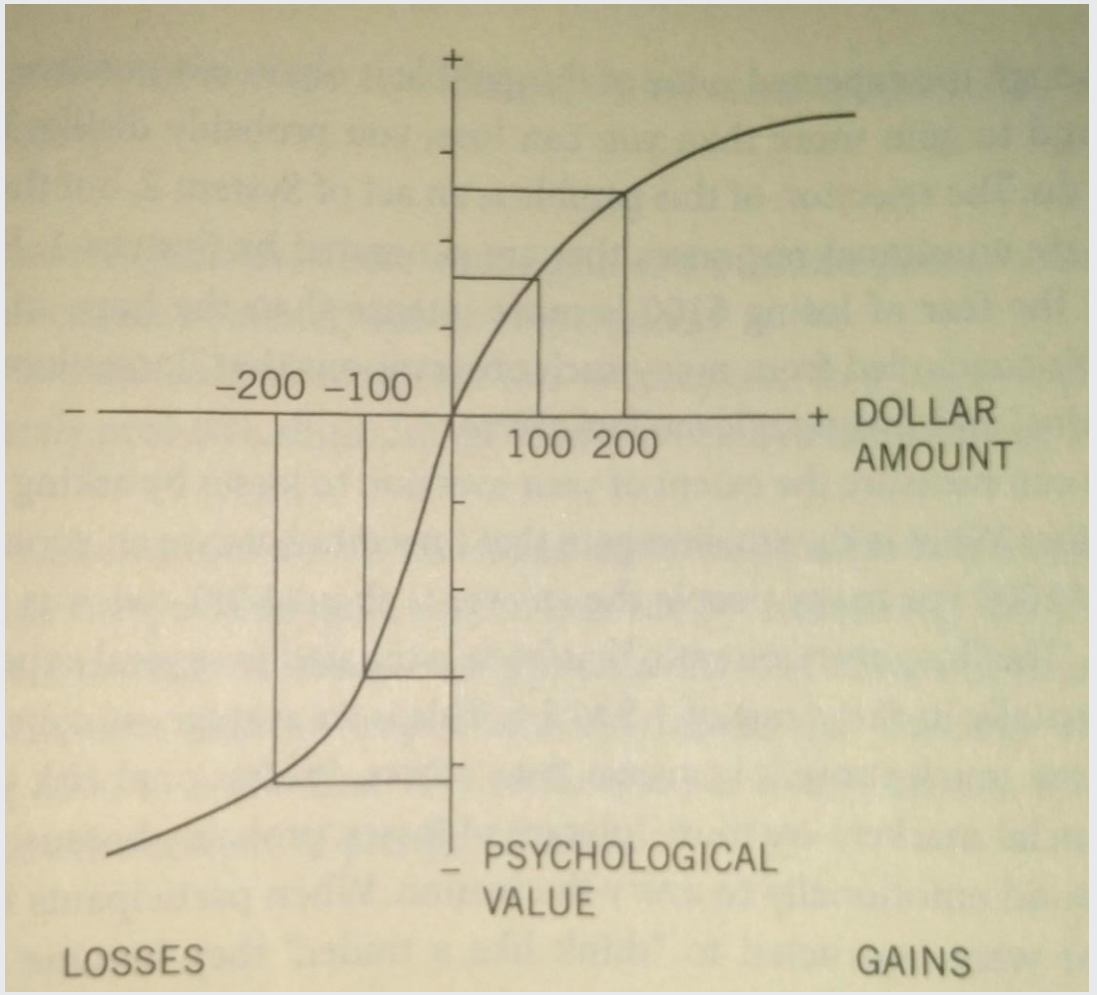
Our intuitions fail us!

- Are the following three sequences of baby births (boy/girl) observed at three different hospitals equally likely?
  - BBBGGG | GGGGGG | BGBGGB
- Correct answers to questions such as the following were ***more likely*** if presented in a barely legible rendition:
  - A patch of lily pads doubles in size daily on a lake. If the patch covers the lake in 48 days, how long would it take for the patch to cover half the lake?
- "How happy are you these days?" THEN "How many dates did you have last month?"
  - Correlation between answers almost zero in this order, very high in reverse order

Experimental Results

- You are offered a gamble on the toss of a coin:
  - If the coin shows tails, you lose $100
  - If the coin shows heads, you win $150
- Is this gamble attractive? Will you accept it?

People are asymmetrically loss-averse



D. Kahneman, *Thinking Fast and Slow*, 2011

Healthcare example

The Asian Disease

- Imagine that the United States is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:

Case 1
- If Program A is adopted, 200 people will be saved
- If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved

Case 2
- If Program A' is adopted, 400 people will die
- If Program B' is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die

Which of the two programs would you favor? Majorities favor A in Case 1 but B' in Case 2

How would you "frame" an opportunity to your management?!

Experimental Results

- **Which would you choose in each of Gambles A and B:**
  - **Gamble A: 61% chance to win $520,000 OR 63% chance to win $500,000**
  - **Gamble B: 98% chance to win $520,000 OR 100% chance to win $500,000**
- **Most people prefer the first option in A and the second option in B . . . violating rational choice**
- **“Certainty” effect at work in human psychology**

Subjective Assessment of Probability

- People's perception of probability is nonlinear
- Unlikely events are overweighted ("possibility effect")
- "Certainty effect" at other end of scale even more striking

The same amount of progress in project development (e.g., increased probability of on-time completion) is viewed as more important at project beginning and end, and less important otherwise

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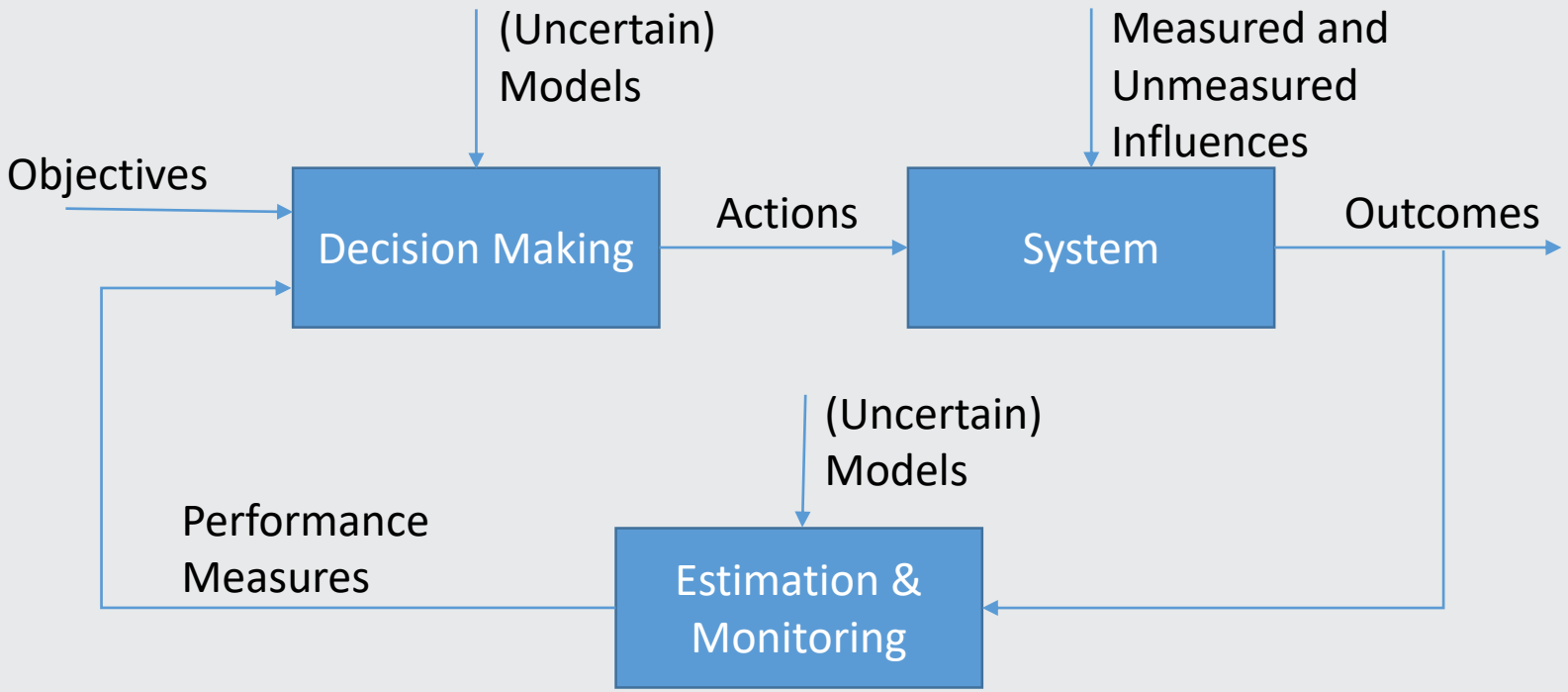
The Pervasiveness & Impact of Control Systems



Success stories:

- Aerospace
- Automotive
- Biomedical
- Chemical processes
- Homes and buildings
- Power grids
- Many other complex engineering systems

Control science is the only rigorous paradigm for optimal decision making in uncertain, complex dynamical systems!

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Success Stories
FOR CONTROL

Advanced Energy Solutions for Power Plants

Fuel costs, energy conversion efficiencies, and environmental impacts of fossil-fueled plants have become priorities in both developed and developing countries. Advanced Energy Solutions (AES), a product of Honeywell Process Solutions, is an advanced process control product that significantly improves power plant efficiency and reduces plant emissions.

AES provides combustion control in boilers; coordinates multiple boilers, turbines, and heat recovery systems for optimal operation of entire power plants; and provides dynamic balancing of power production to demand.

Success Stories
FOR CONTROL

Advanced Control for the Cement Industry

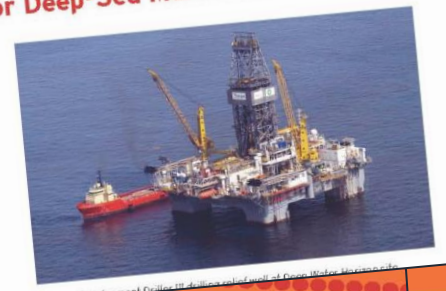
The cement industry of the 21st century

Success Stories
FOR CONTROL

Dynamics and Control for Deep-Sea Marine Risers

A marine riser is a pipe that connects a floating platform such as an oil rig or drillship on the ocean surface to the sea floor. Used as a fluid conveyer, it transports undersea energy resources from the seabed to the platform on the surface. Marine risers are also used in relief operations for transporting mud, cement, and other materials to the seabed.

Due to winds, waves, and water currents, the floating platform on the sea surface responds in six-degree-of-freedom motions.



Success Stories
FOR CONTROL

Control in Stroke Rehabilitation

Stroke is the foremost cause of disability in developed countries. Less than 15 percent of patients with upper-limb impairment following stroke regain full function, which restricts their ability to perform everyday reaching and grasping tasks. Functional electrical stimulation (FES) used to assist stroke patients in moving their impaired limbs has been shown to increase upper-limb function; however, the benefits of FES are greatest when combined with maximal voluntary effort from the patient to perform the movement. This presents a control problem:

Success Stories
FOR CONTROL

ad Grade Estimation for Advanced Driver Assistance Systems

vehicles are equipped with many

Success Stories
FOR CONTROL

H-infinity Control for European Telecomm

Telecommunication Satellite Challenges and Needs

Geostationary telecommunication satellit and large (deployable) antennae together are rotating with respect to the Earth-poi

Success Stories
FOR CONTROL

Advanced Control of Pharmaceutical Crystallization

Nearly all pharmaceutical manufacturing processes use crystallization as the primary means for

Success Stories
FOR CONTROL

Autopilot for Small Unmanned Aerial Vehicles

Small unmanned aerial vehicles (UAVs) have numerous applications in civilian sectors. These

Success Stories
FOR CONTROL

Coordinated Ramp Metering for Freeways

Freeways were originally conceived to provide virtually unlimited mobility to road users, but the continuous increase in car ownership and demand has led to a steady increase (in space and time) of recurrent and nonrecurrent freeway congestion, particularly in and around metropolitan areas. Freeway congestion causes excessive delays, increases fuel consumption and environmental pollution, and deteriorates traffic safety.

Ramp metering, the most direct and efficient

Success Stories
FOR CONTROL

Controlling Energy Capture from Wind

Wind energy is currently the fastest growing power-generation technology worldwide, reaching a 30% annual growth rate and an installed capacity of 300 GW. To realize these achievements, wind turbine designs have overcome multiple technical challenges to be competitive with predominant energy sources. Control technology has played a crucial role in this quest. The control system dynamically adapts to a wide range of wind conditions and maintains structural integrity while maximizing energy production. In addition, the controller must manage weather conditions, abnormal wind disturbances, and fault scenarios that may occur unexpectedly during the life span of the

Success Stories
FOR CONTROL

Trip Optimizer for Railroads

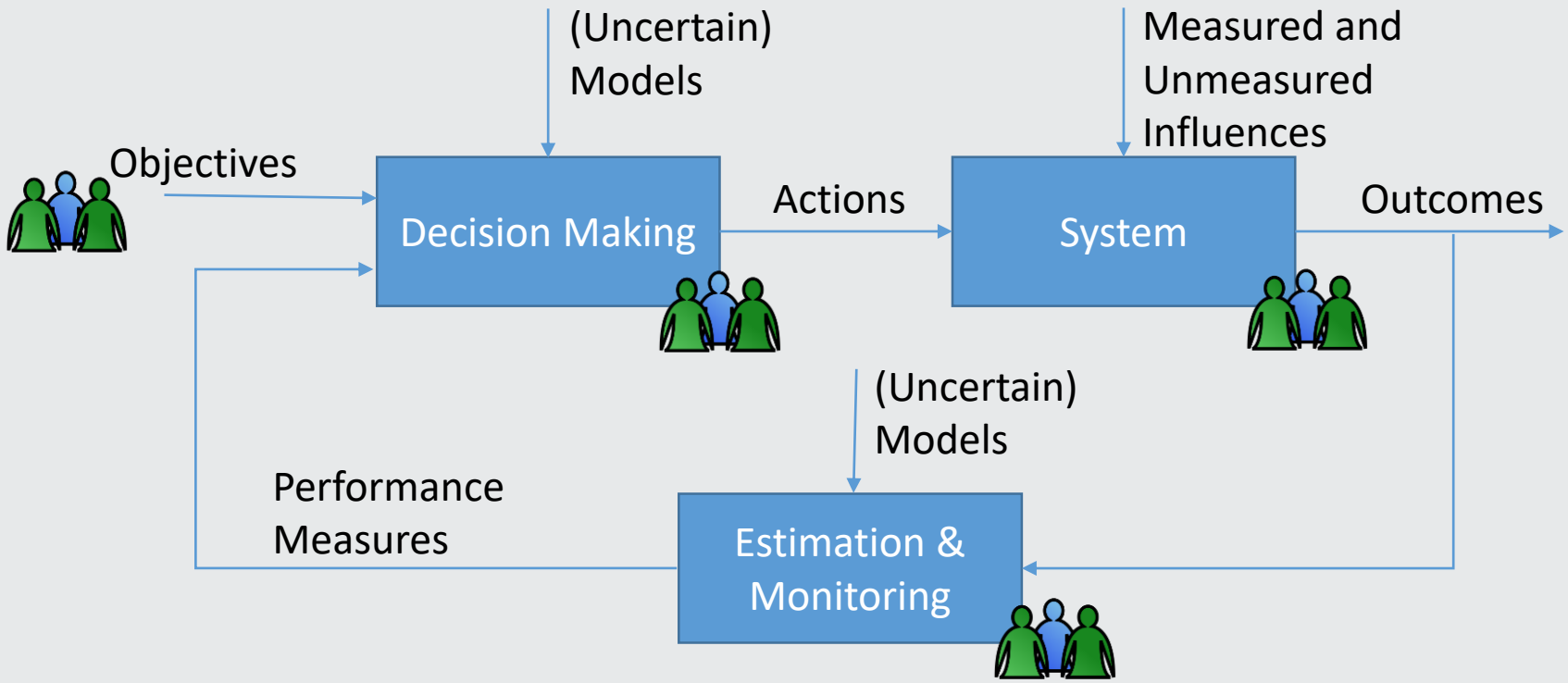
On-time arrival with the least fuel expenditure is a key priority for freight and passenger railroads worldwide. North American railroads consumed 4 billion gallons of fuel in 2008, 26% of operating costs.

Trip Optimizer is an easy-to-use control system that allows the crew or dispatcher to achieve on-time arrival with the least possible fuel use.

Optimal driving solutions are computed onboard and

The Impact of Advanced Control, 2nd ed., T. Samad & A. Annaswamy (eds.), IEEE Control Systems Society, 2014; www.ieeecss.org/general/IoCT2-report

Innovation as a Dynamical System



Program and project management

Technology research and development

Portfolio management

New product introduction

Innovation processes

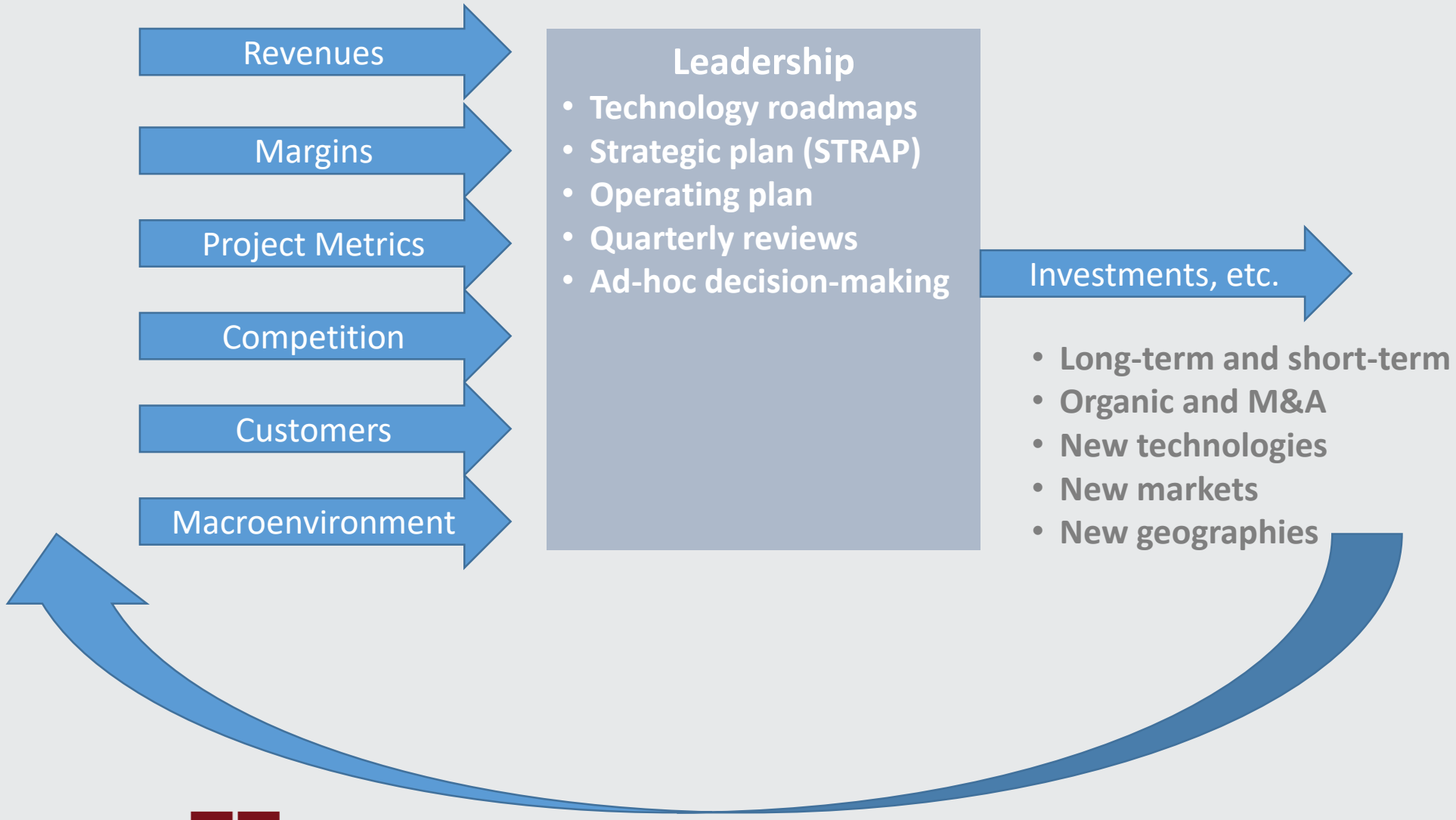
. . . And many other topics in the management of technology

Relevance goes beyond engineered systems . . . But human-in-the-loop factors must be incorporated

Key Insights from Control Science

- ***Feedback*** **and** ***feedforward*****—counteracting uncertainty and improving response time**
- ***Models*****—and** ***data analytics*****—are essential for improving performance**
- ***Uncertainty*****, noise, and** ***disturbances*****: rigorous methods available to handle each**
- **Fundamental distinctions—and tradeoffs—between** ***performance*** **/** ***robustness*** **/** ***adaptation***
- **Control loops and** ***stability*****: Good control can make an unstable system stable; poor control can make a stable system unstable**
- ***Sampling rates*** **should be sensitive to system dynamics—over-sampling can result in over-reaction**
- **The right variables for effective decision-making may not be measured or measurable—*estimation* and *monitoring* necessary**
- **Hierarchical and multi-level control—theory extends to *systems of systems***

The Role of Leadership—Decision-Making Under Feedback and Uncertainty



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TLI: Developing Innovators and Leaders

- **TLI established in 1987 with an endowment from the Honeywell Foundation**
- **Second M.S. in the Management of Technology (MS-MOT) program in the nation; the first in a public university**
- **Curriculum focused on technology, business fundamentals, innovation, and leadership**

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TLI Educational Offerings

- Master of Science degrees:
  - MS in Management of Technology (MS-MOT)
  - MS in Medical Device Innovation (MDI)
  - MS in Security Technologies (MSST)
- Graduate Minors:
  - Cyber Security
  - Management of Technology
  - Security Technologies
- Short Courses:
  - Innovation, Leadership and Communication
  - Technology Management
  - Cyber Security

MBA Alternatives for Technology Professionals

We're recruiting for next year's class—visit http://tli.umn.edu or drop by our booth at MACC!

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