DARPA's Approach to Innovation:

an Alternative Model for Funding Cutting-Edge Research and Development

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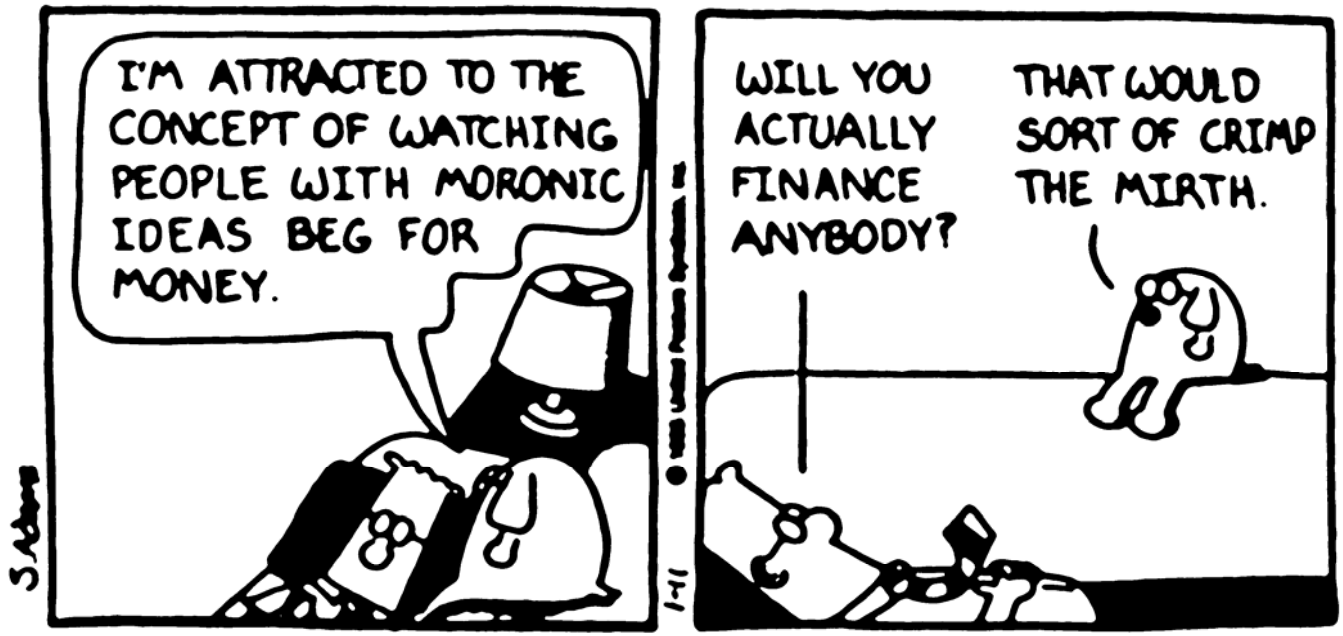
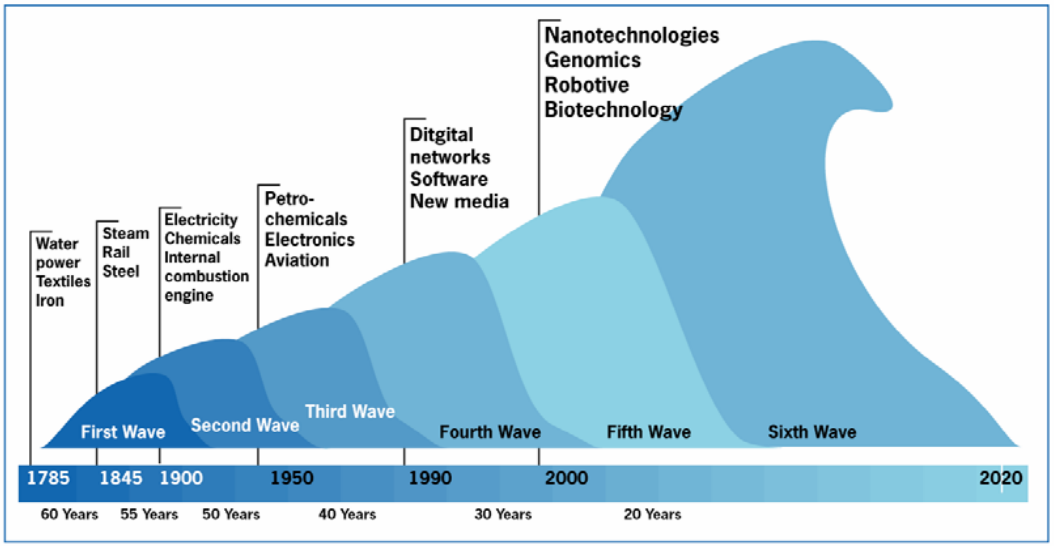


Today's Changing World: *Exceptional challenges … and opportunities*

Schumpeter's Accelerating Waves



Our world is

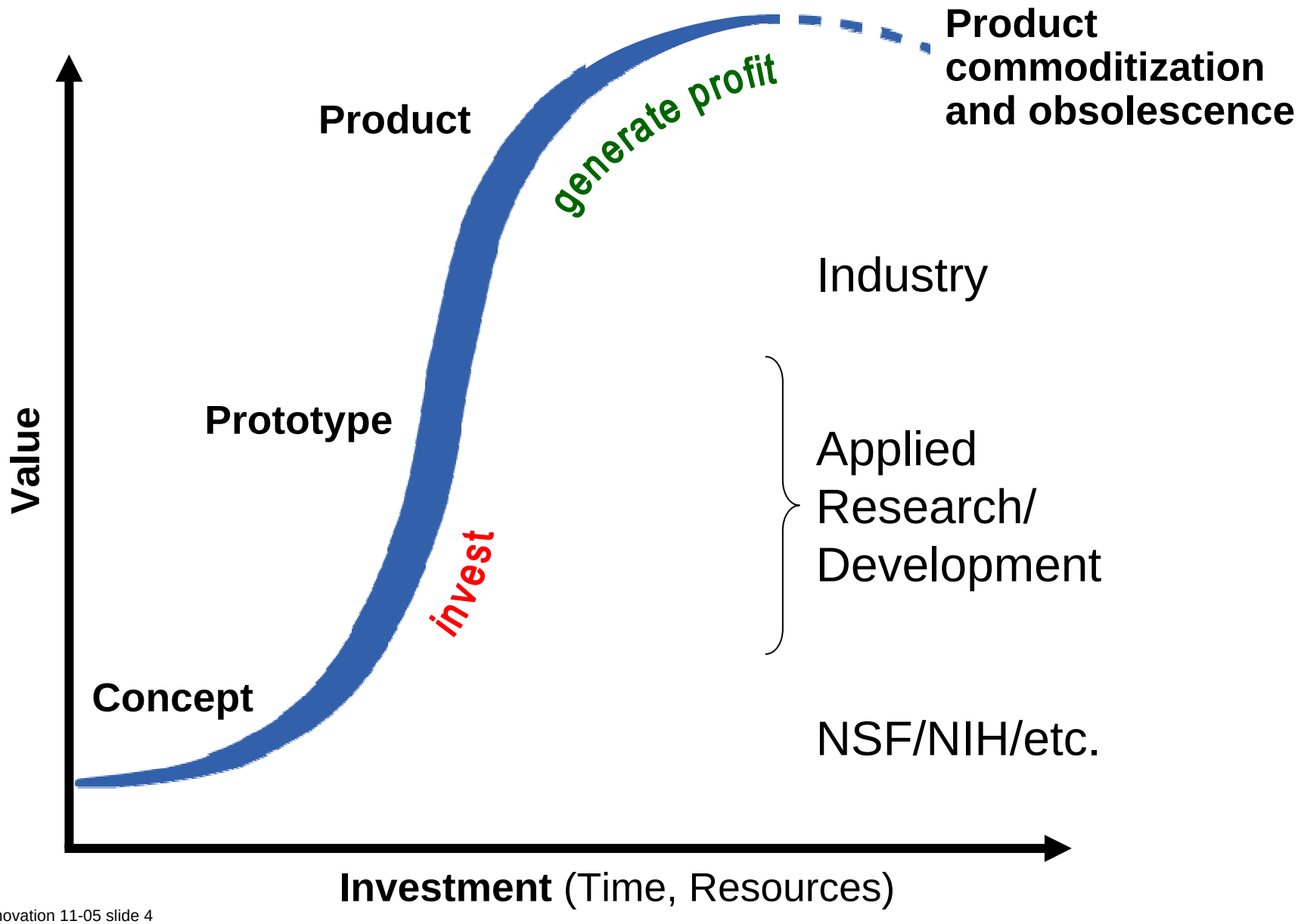
- increasingly complex and chaotic
- dynamic, accelerating
- non-linear
- increasingly multidisciplinary
- growing exponentially (e.g., Moore's Law, Metcalf's Law)

Successful innovation is not the result of luck or lone genius – rather it is the result of a disciplined, continuous improvement process with an unrelenting focus on creating the highest customer value

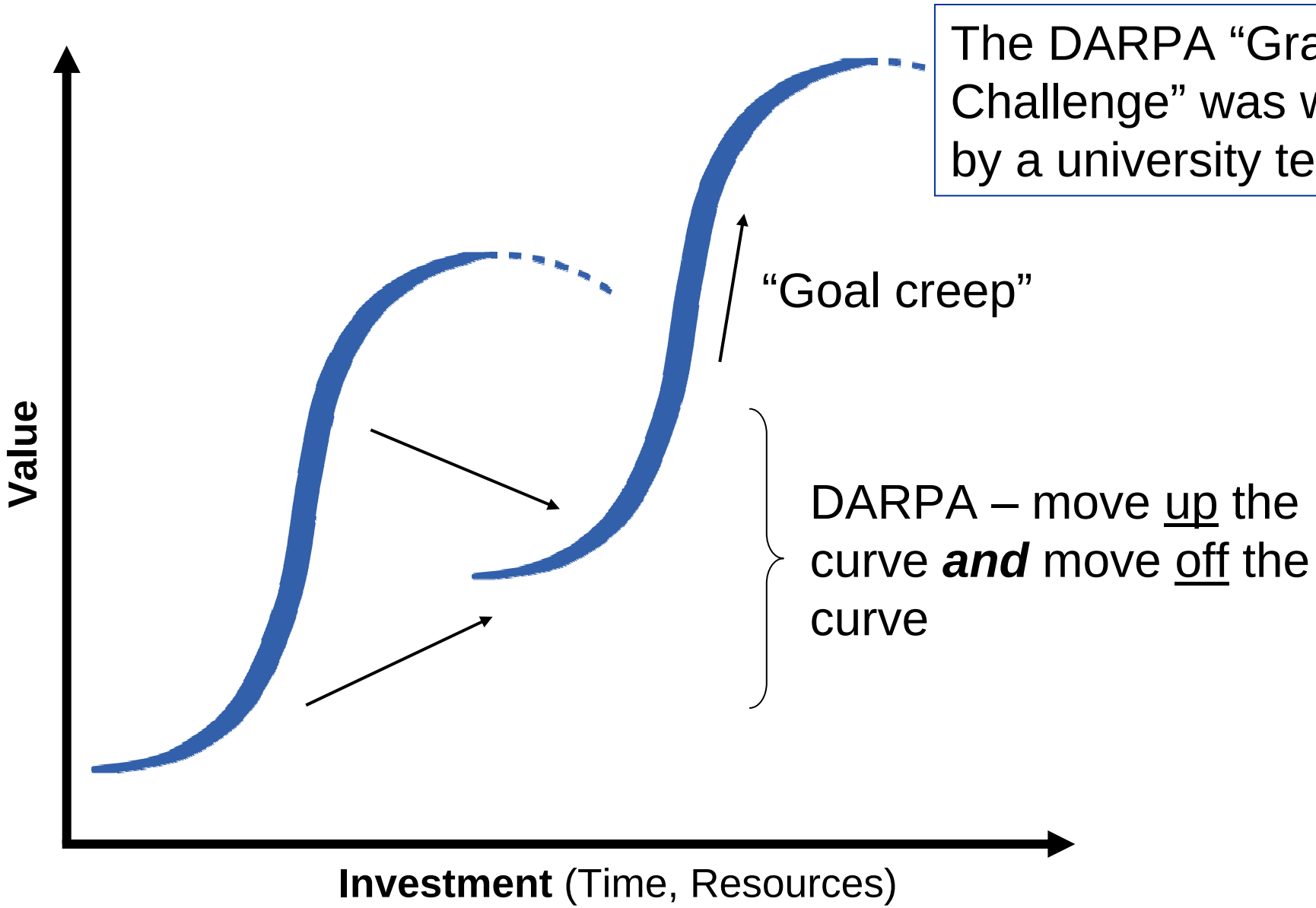
Success Requires New Ways of Operation: *DARPA*

- DARPA
  - Defense Advanced Research Advanced Projects Agency
  - Founded in 1958 in response to Sputnik
- Mission
  - Avoid technological surprise
  - Innovation in support of national security
- Focus: High-payoff technologies and military concepts with an emphasis on Joint
  - Broader horizon than commercial analogues
  - More focused than traditional university research
  - Not bound by military requirements
  - High-risk is the price to pay
- Characteristics
  - Significant authority with minimal near-term responsibility
  - Large budgets
  - Agility
  - “Top cover”

Moving up the Value Curve



Moving ***Off*** the Value Curve: *Making future technologies available today*



DARPA's Approach to Innovation

Strategy

- Flexibility, ability to quickly exploit emerging situations is the highest priority
- Emphasize high technical risk, high focus investments
- Competition for ideas, reward for quality performance
- An investment firm, *not an R&D lab*, no established constituency
- Methodically search for and exploit externally generated ideas
- Proactive program management

> "No matter how smart you are, most of the smartest people in the world are outside your company."
> *– Bill Joy, Sun Microsystems*

Operation

- Flat, small organization, no long-term investments in facilities or themes
- Constant rotation of programs, program managers and Directors (provided by industry, other government agencies, customers)
- Highly flexible contracting and hiring capabilities

DARPA Investment Criteria

- What are you trying to accomplish?
- How is it done today and with what limitations?
- What is truly new in your approach which will remove current limitations and improve performance? By how much?
- If successful, what difference will it make?
- What are the mid-term, final exams or full-scale applications required to prove your hypothesis? When will they be done?
- What is the DARPA "exit strategy?"
- How much will it cost?

DARPA still supports *high-payoff*, core technologies

- Information Technology
- Materials, Mathematics, Biology
- Micro/nano systems
- "The Intersection of Biology, Information, Materials and Microsystems"

Defense Sciences Office: *In Practice*

Respond to technological opportunity ("Miracle Identification")

- Program Manager must be a proactive "Techno-Scout"
- Catalyze the creation of new technologies
- Focused effort, clear understanding of military needs
- Proactive: technical and fiscal flexibility

Emphasize a multidisciplinary technical approach

- Office is technically diverse
- Teaming of universities, Service and federal laboratories, small businesses, large industry, etc.
- Mixed risk – combine basic, applied research and development
- Seek opportunities at interfaces between conventional disciplines

Recognize defense / commercial industry as customer

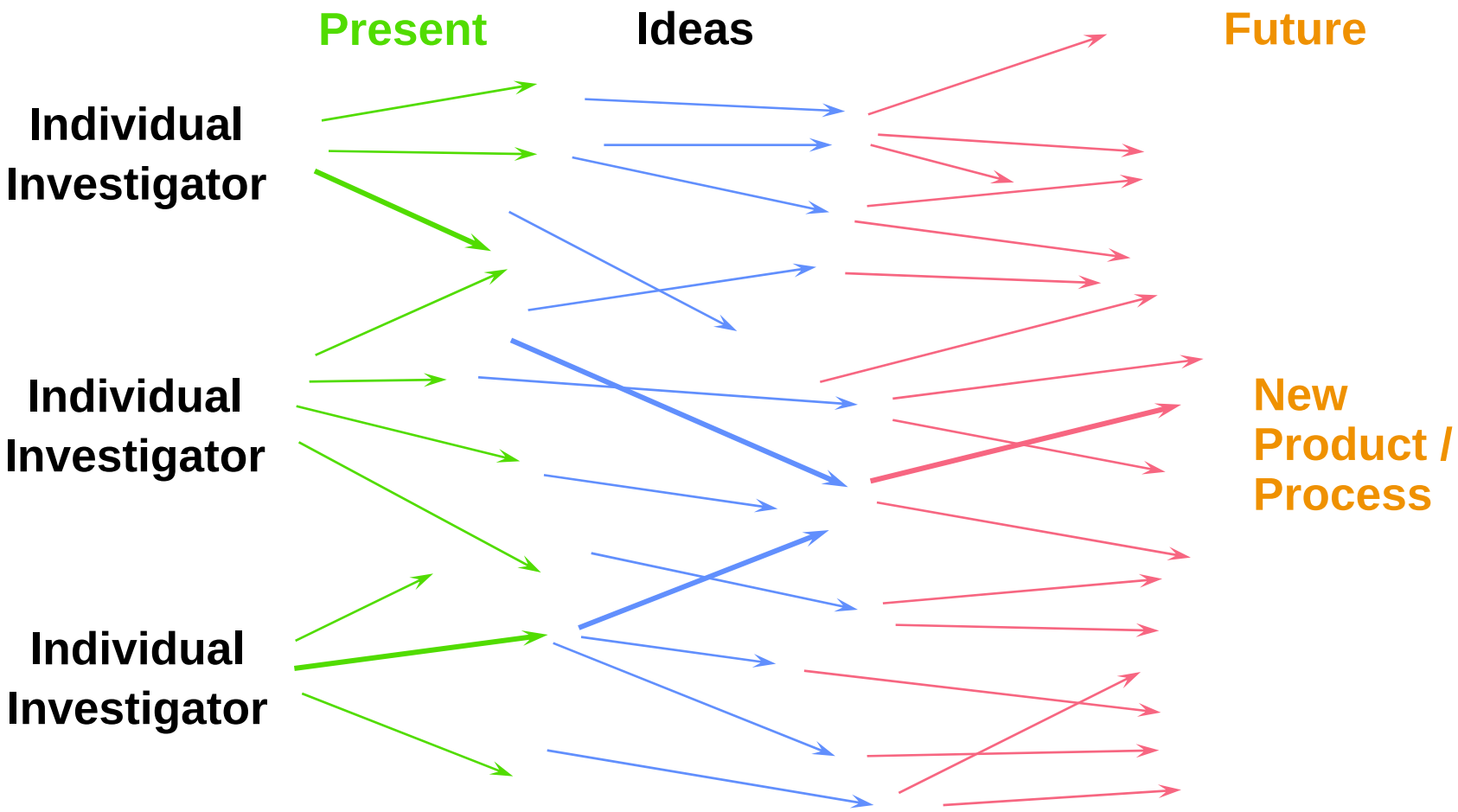
- Military as consumer
- Work synergistically with industry (e.g., consortia, cost share, etc.)
- Always conscious of an exit strategy

3-D Chessboard Analogy to Program Management

- You know what the goal is -- *checkmate!*
- Start off with many different pieces in different places and with different capabilities (all useful)
- Coordinated attack (e.g., teaming)
- Moving target (e.g., customer demand)
- Changing obstacles and opportunities
- The game is won by the *proactive* player

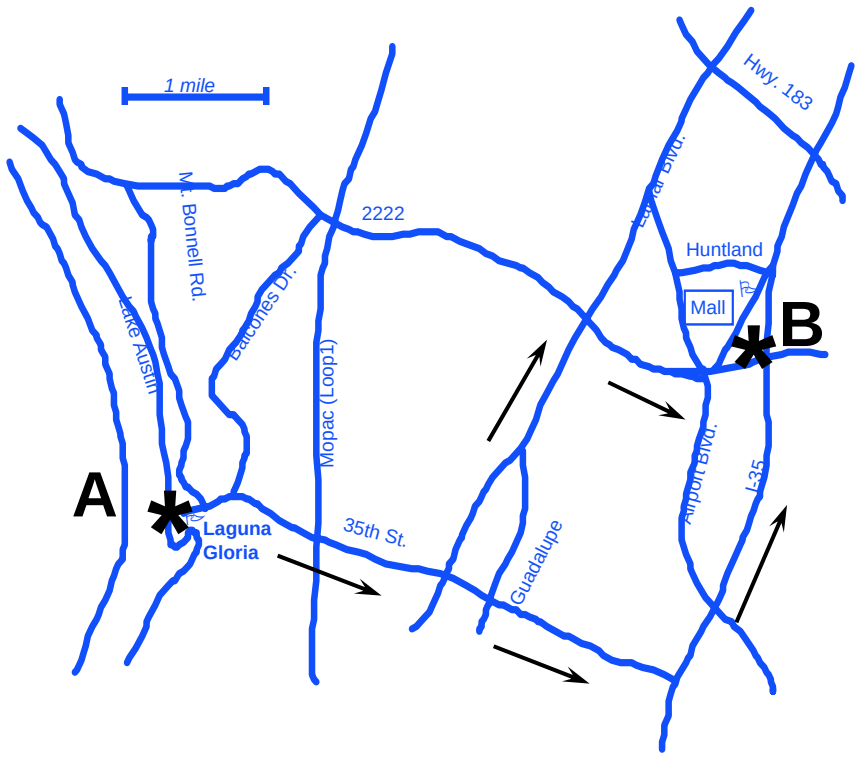
So how does one get it right?

Technology Development: *Typical Approach*



Individual research leads to a vast array of potential technologies and discoveries, only a fraction of which are combined to form useful new products / processes.

A Roadmap to Research is NOT the Answer



DARPA's role is to build that airplane!

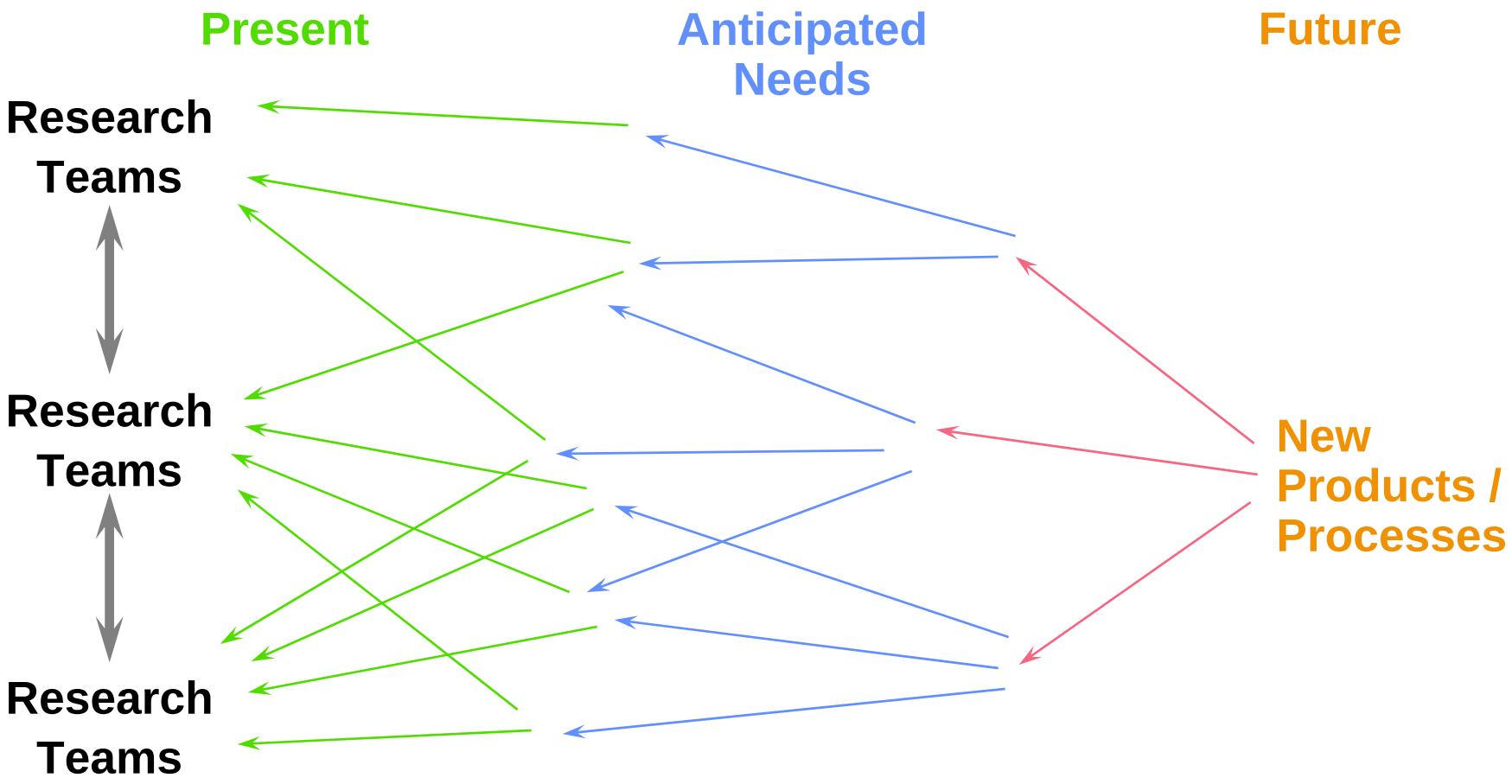
Good Points

- Plan from A to B
- Path around obstacles
- Provides direction
- Defines distance

But ...

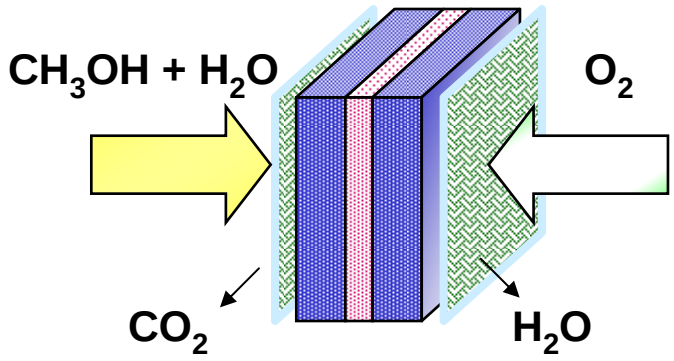
- Assumes everyone starts from the same place
- Assumes the destination remains fixed
- Assumes no new roads will be built (or that an airplane will be invented)
- No time information

Technology Development: *End-game Approach*



By first defining the desired product / process and the anticipated technology needs, research teams can better coordinate their efforts and a higher rate of return on technology development can be realized *faster.*

Direct Methanol Oxidation Fuel Cells: *Research and Development Issues*



Catalyst Formulation
Catalyst Synthesis
Surface Chemistry
Support Effects
Anode Kinetics
Cathode Kinetics
Reaction Mechanism
Membrane Synthesis
Membrane Transport Properties
Theory
Modeling
In situ Diagnostics
Electrochemical Corrosion
.
.
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Methanol Crossover
Catalyst Performance
Catalyst Fabrication
Carbon Support
Membrane Performance
MEA Fabrication
Pressurized Operation
Methanol Concentration
Fluid Flow
Heat Transfer

Catalyst Performance
Methanol Crossover
Membrane Performance
MEA Fabrication
Optimum Temperature
Optimum Fuel

Catalyst Deactivation
Corrosion
Water Management
Membrane Stability
Fuel Impurities

Low-Cost Separator Materials
Low-Loaded/Low-Cost Catalysts
Low-Cost Membranes
MEA Fabrication
Simple Assembly
Balance-of-Plant

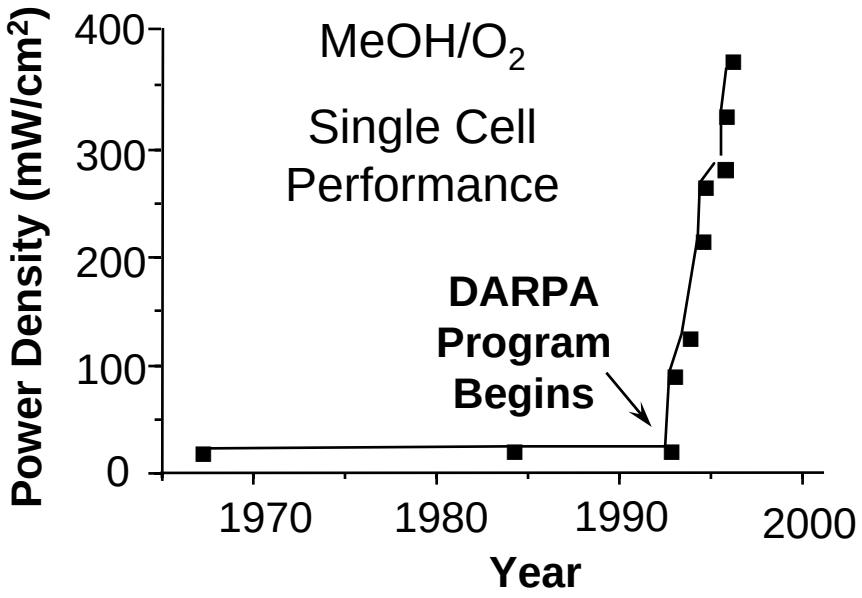
Increase Power Density

Increase Efficiency

Improve System Life

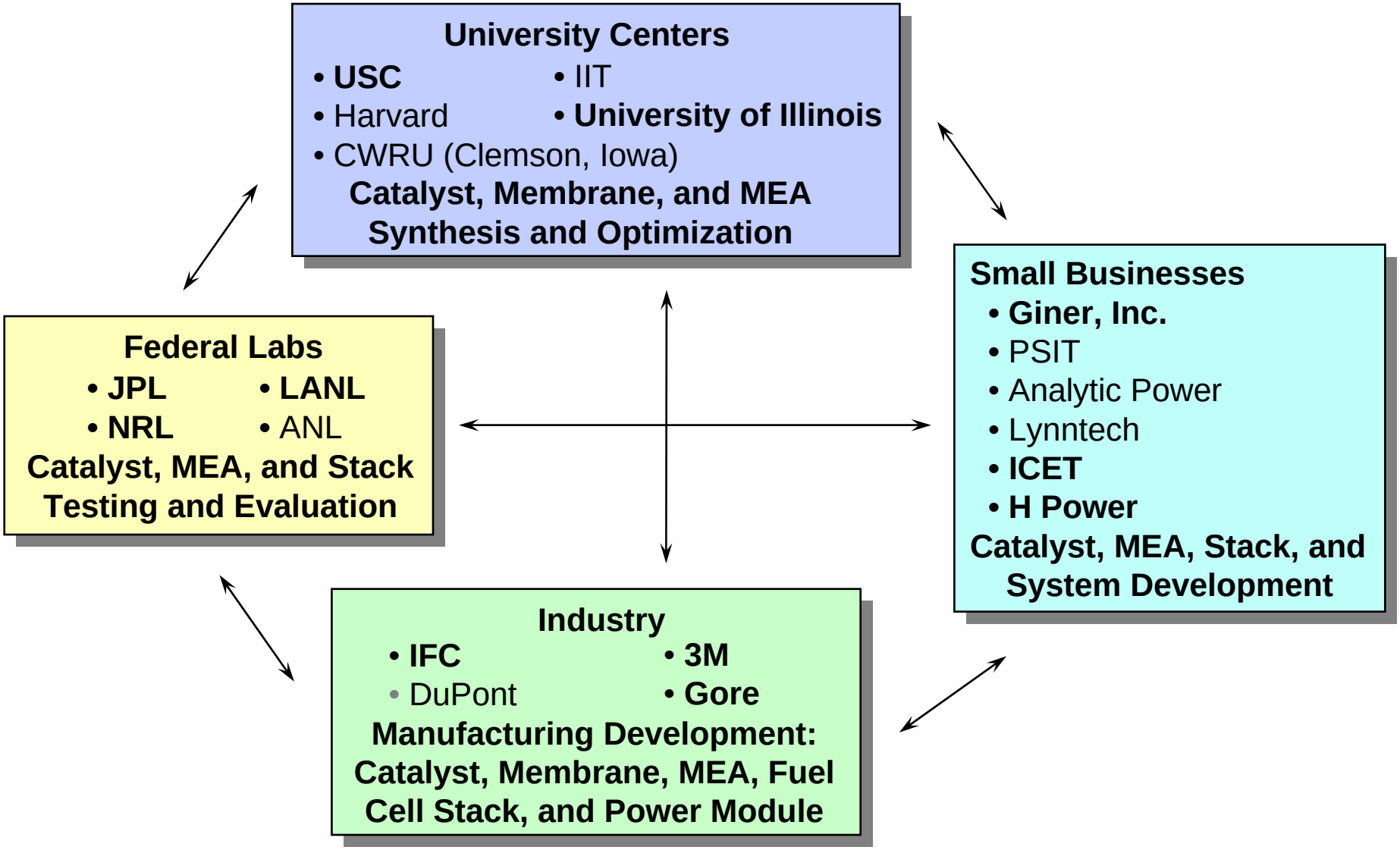
Decrease Cost

Direct Methanol Oxidation Fuel Cell



Team:
- Universities
- Industry
- Federal Labs
- Small Businesses

DARPA Direct Methanol Fuel Cell Program:
Team Approach ("Cooperation")



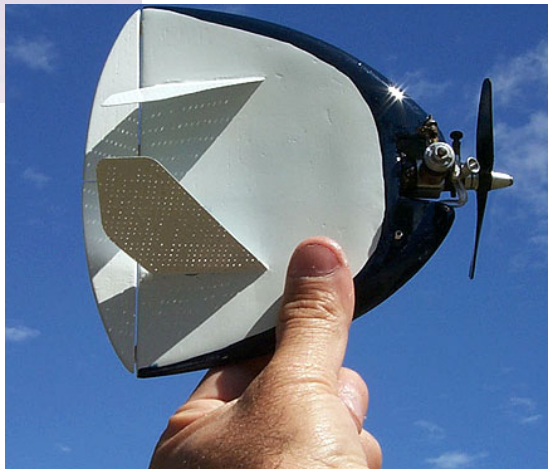
Micro Air Vehicle Development:
Overstressing the system

Potential Missions

- Surveillance/reconnaissance
- Communications
- Chem/bio sensing

Components

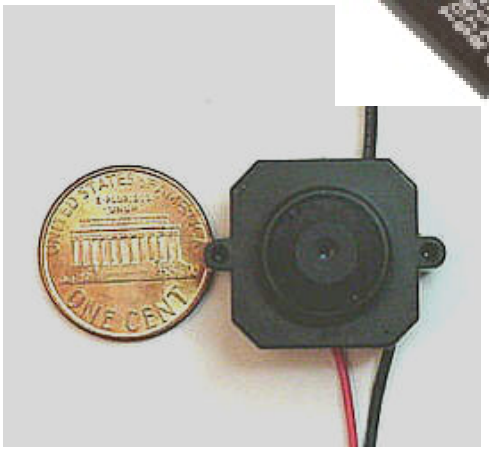
- Motors/batteries
- Sensors
  - Camera
  - Infrared
  - Radar
  - Chem/bio
- Radios
- GPS
- Gyros/control systems
- Software

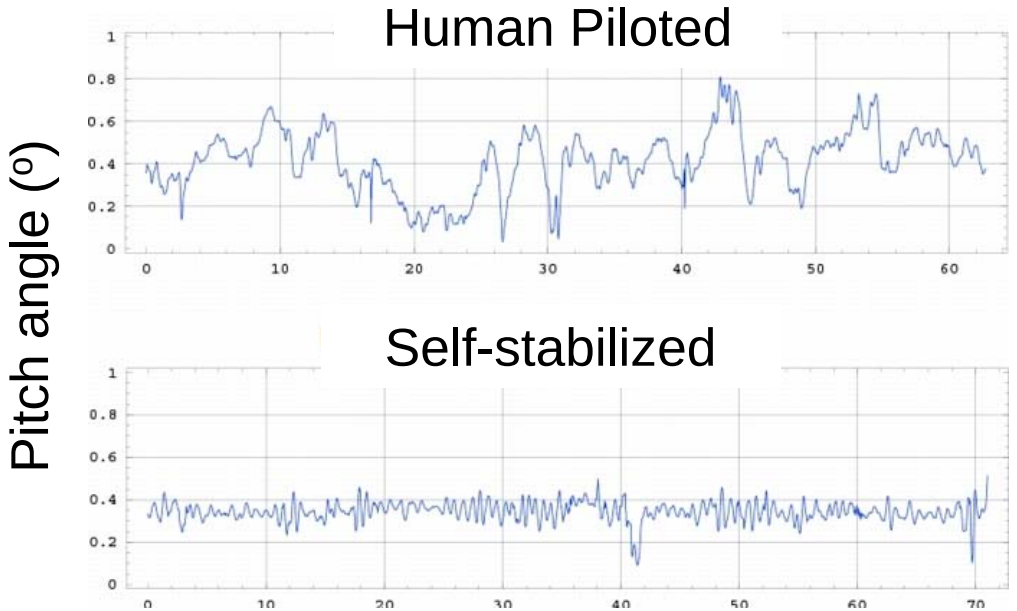


Micro Air Vehicles: *Reality*

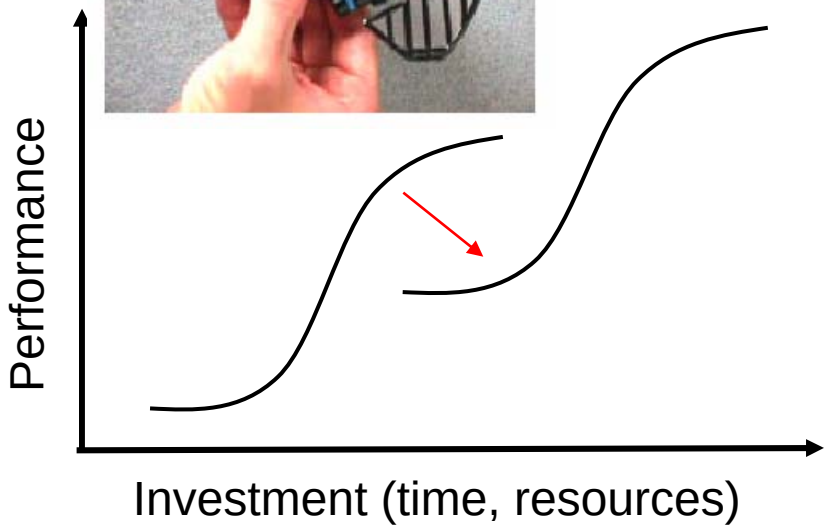
1 hour, 47 min flight time

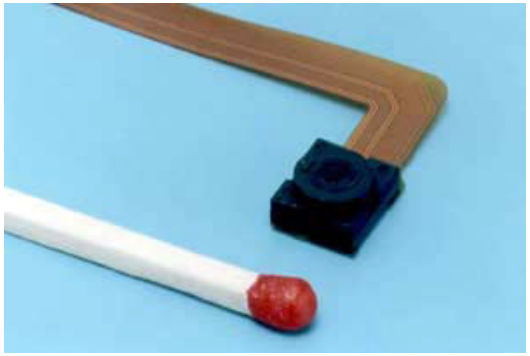
Visible Imagery





The Next Generation: *Nano Air Vehicles*





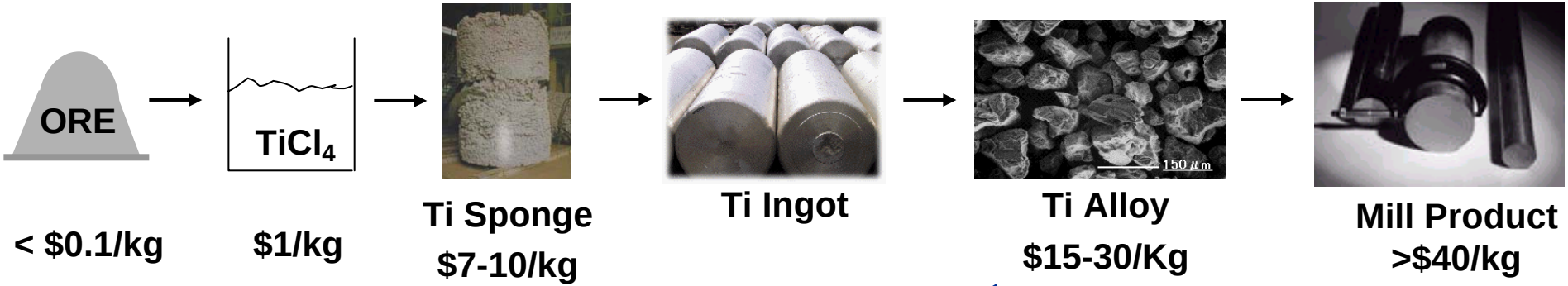
- **Goals**
  - 7.5 cm maximum dimension
  - 10 gram total weight with 2 gram payload
  - 1000 m range at 5 – 10 m/sec and return
  - >60 second hover

- **Develop and demonstrate**
  - Aerodynamic design tools
  - Lightweight efficient propulsion and power
  - Navigation, communications and control
  - Advanced manufacturing and packaging

Low-cost Titanium Production:
Stimulating new ideas and new applications

The titanium value chain

Applications



< $0.1/kg

$1/kg

$7-10/kg

$15-30/Kg

>$40/kg

TiO_2
$1/kg

DARPA Program
<$4/kg Ti

Stimulating the Discovery Process

FFC
(Cambridge)
Process
~$7/kg

50 g/day

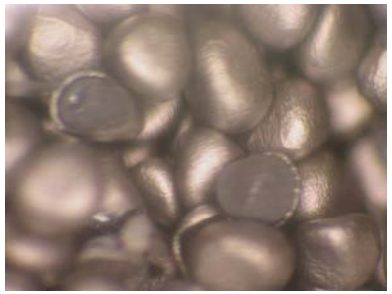
5 kg/day

50 kg/day

500 kg/day

DARPA Program ⇒ $6/kg

New Discovery!
Ti <$4/kg
Alloy <$6/kg



New applications

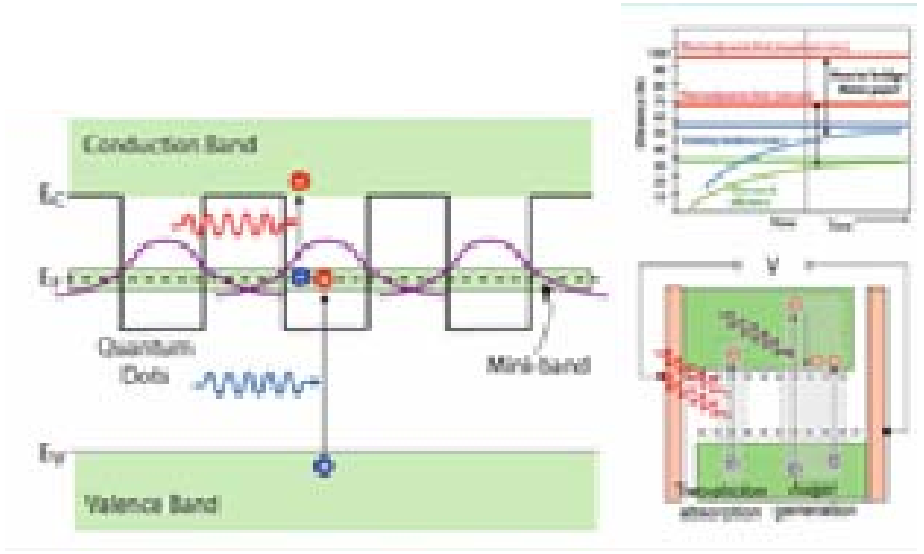
- Military
- Automotive
- Sports/leisure
- Industrial

Universities Stepping up to the Plate: *Very High Efficiency Solar Cells*

- Demonstrate at least 50% efficiency in a photovoltaic device based on nanoscale, inorganic, three-dimensional meta-structures

- Deliver at least 1,000 units, 10 cm^2 per device, producing at least 0.5 W each with a standard solar fluence of 1 kW/m^2

- Team
  - Lead: University of Delaware
  - 15 Universities and industries
  - $33.6M from DARPA + $19.3M cost share



Tech Transfer into the Military is a *Real* Challenge

- Scientists are trained to
  - Postulate hypothesis describing some aspect of the physical world
  - Design an experiment to test the hypothesis
  - Measure outcomes, analyze, etc. and ***iterate***

- Military understands that experimentation is necessary, *but doesn't know how to experiment*
  - Military cannot fail – it must always win
  - Military trains and conducts demonstrations, not experiments
  - Military must have a predictable outcome – ***success***

Successful technology transfer requires iteration with the user

Summary

- DARPA is a mission oriented agency with a focus on projects *not* programs
  - Combine basic research, applied research, development and demonstration – “mixed risk” portfolio
  - Program managers have the technical and fiscal authority to steer efforts – more important than money
  - Strong connection with the user community
  - Successful performers must be flexible
- Today’s important problems are inherently multidisciplinary and hence require a team approach
  - Funding is generally larger than from NSF, DOE BES, NIH, etc.
  - Deliverables (more than reports) are expected
  - Projects may not last the full “lifetime” of a graduate student
- University researchers have been successful in winning and leading major DARPA projects

Keep a *realistic* perspective!