Managing Your Career in the 21st Century

Industry Trends and Outlook

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With thanks to

Dave Wisler
GE Aircraft Engines

American Institute of Aeronautics and Astronautics (AIAA)

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The Curriculum Vitae of an Aerodynamicist

John H. McMasters
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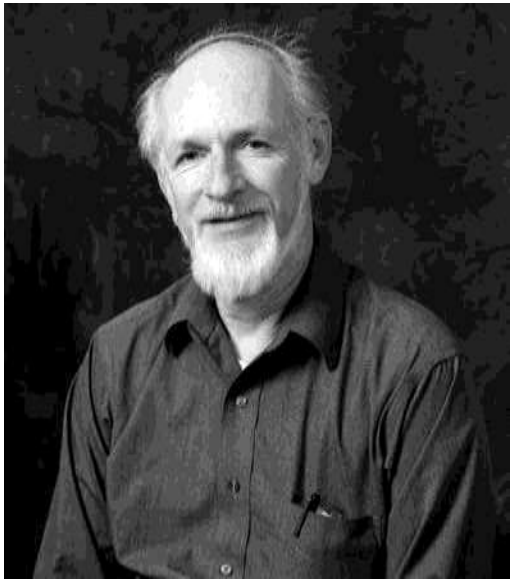
Once upon a time there was a mother duck and a father duck who had five baby ducklings. The first was a really ugly duckling who knew that one day he would probably grow up to be a swan.

Well, the really ugly duckling never did grow up – he only matured into just a really ugly duck. And so it goes (going on 87).



John at age 21

"He had only one vanity, he thought he could give advice better than any other person."

Mark Twain (writing about John McMasters)

Introduction – Issues

- Spate of studies and articles on "declining state" of aerospace
  - end of the Cold War (⟶ globalization)
  - maturation of aero technologies
  - competition for resources (money and talent)
  - explosive growth in other, newer technologies
- We have a lack of a compelling vision of our future
- We need to replenish and sustain a rapidly aging technical talent pool (particularly in design)
- What will be the long-term consequences of 9/11/01, the war on terrorism, etc.??

Today's Situation

- **The aerospace industry (and the aeronautics business in particular) is changing – as is the nature of engineering practice itself, but…..**
- **The world hasn't gotten physically smaller [nor safer] –while the world population is soaring in the face of a finite supply of natural resources.**
- **The IT revolution has made global commerce feasible - and potentially *increased* the demand for air travel (virtual reality, etc. aside)**
- **While the laws of economics can be bent (to some degree), the laws of physics *cannot* !**

Too Frequently Heard in Recent Years….

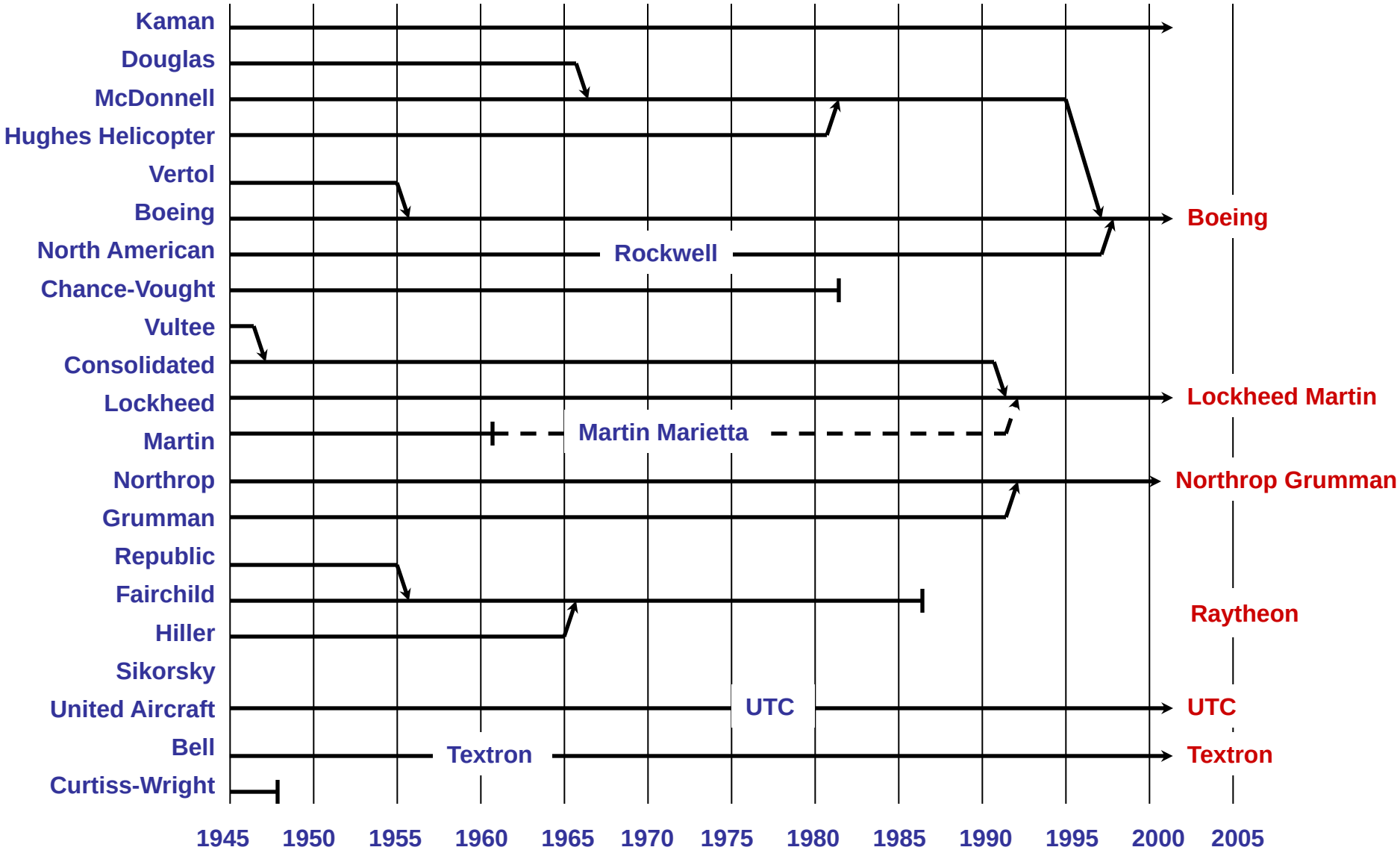
(at AIAA conferences, on campus visits, in the office, etc.)

"All our [commercial] airplanes look pretty much alike anymore, isn't there anything new (and exciting) left to do?"

"I've had a great career in aerospace, but the way things are going…., I just can't encourage my son (or daughter) to go into the business."

"We've been enormously successful for a very long time, what's wrong with what we've been doing? Why change?"

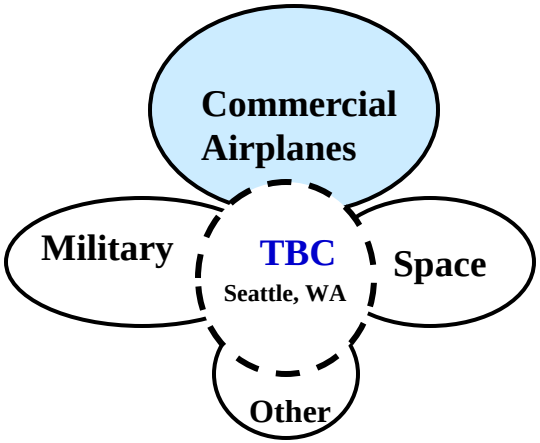
Consolidation of U.S. Military Aircraft Manufacturers



"World Views" of The Boeing Company

1997-98

Heritage Boeing
(Puget Sound-centric)



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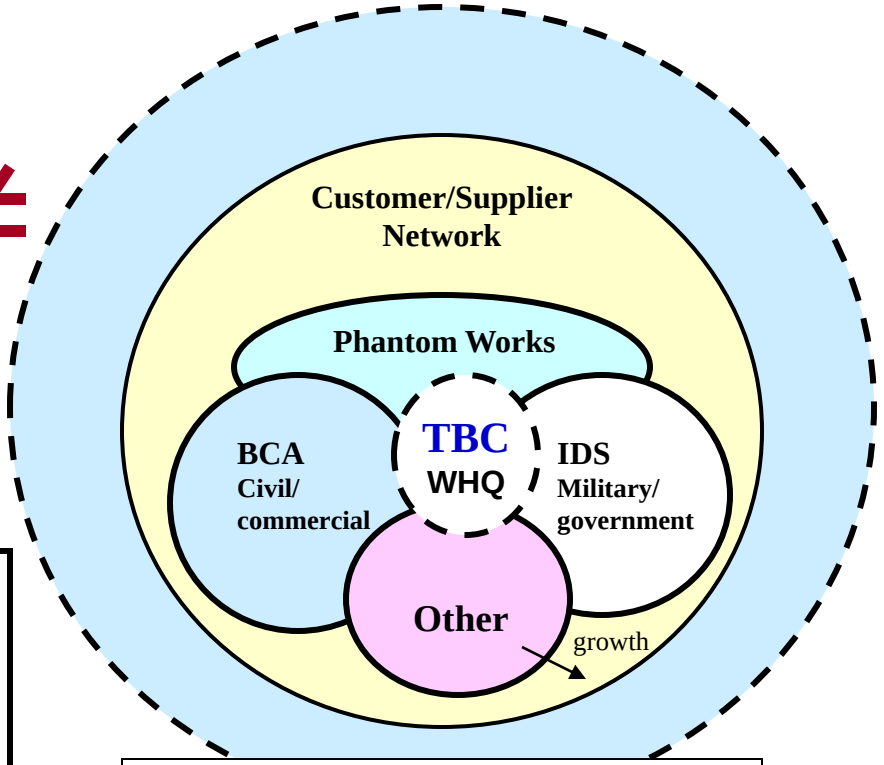
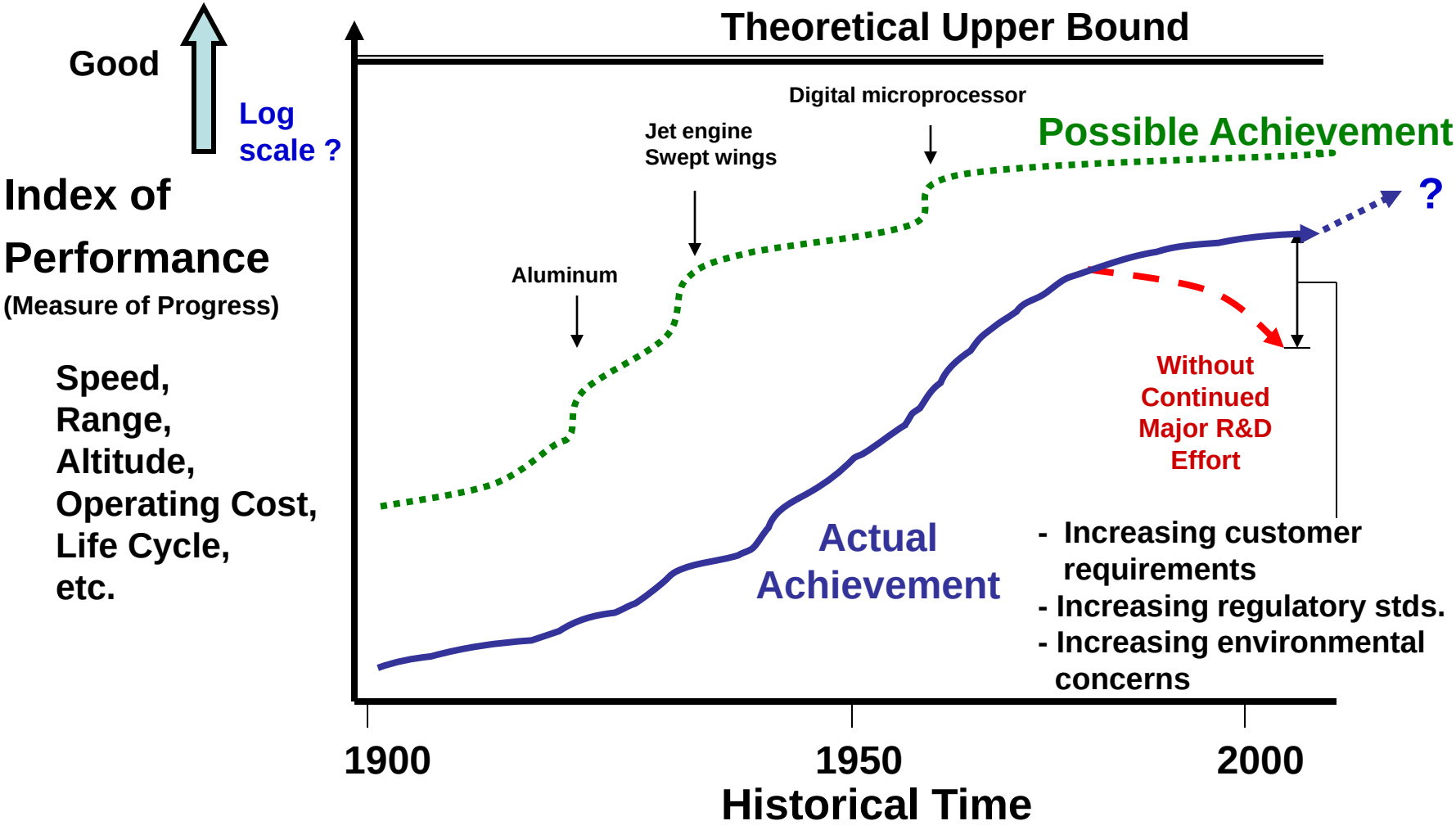
Emerging Boeing (Global) Enterprise



Boeing Core Competencies

- Large-Scale System Integration
- Lean Global Enterprise
- Detailed Customer Knowledge and Focus

[Aeronautics] Technology Progress



Options and Opportunities

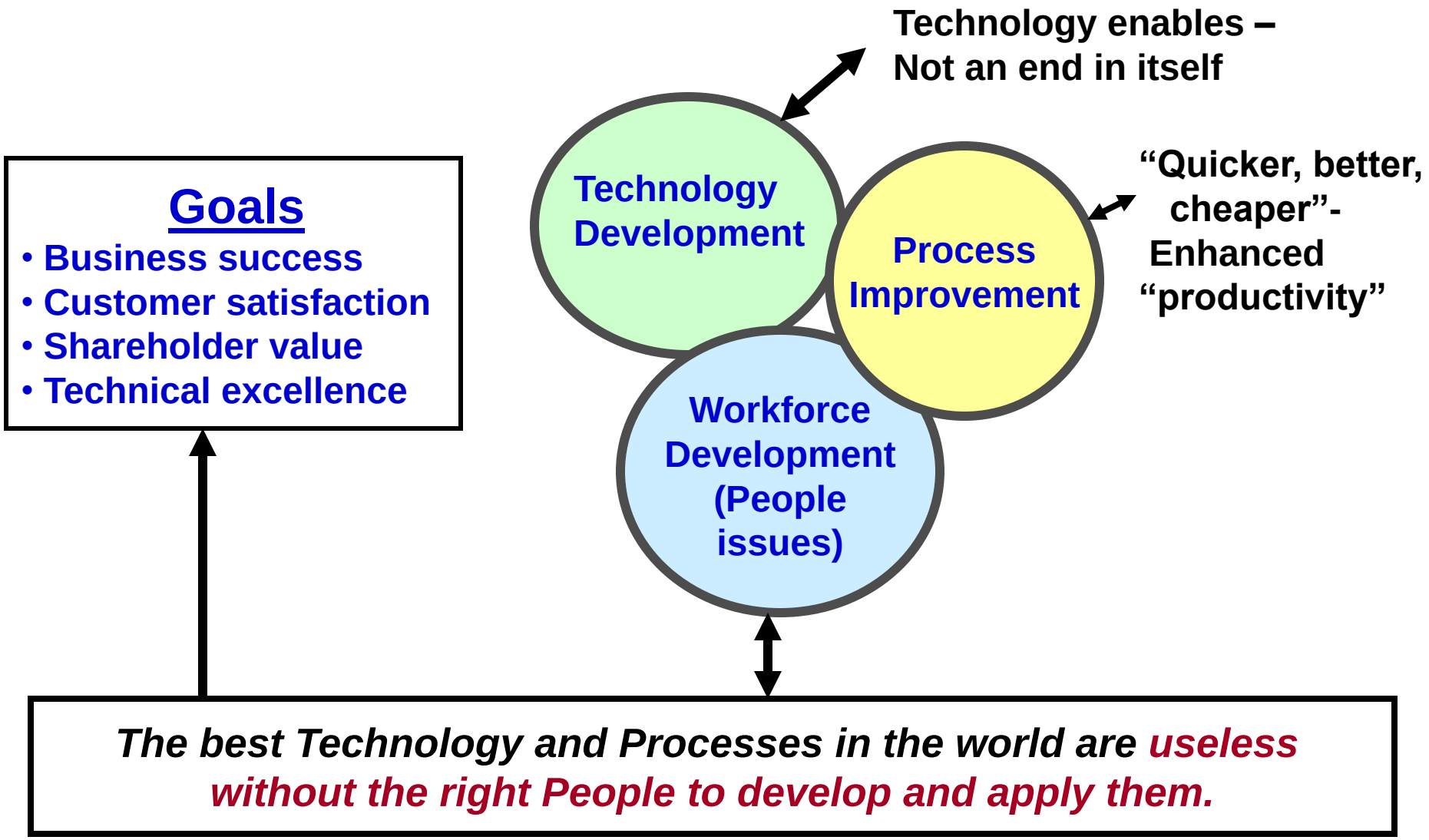
- Continue evolving current lines of development – as long as a market exists for the results

- Schedule a breakthrough or an invention – expand the range of the "possible"

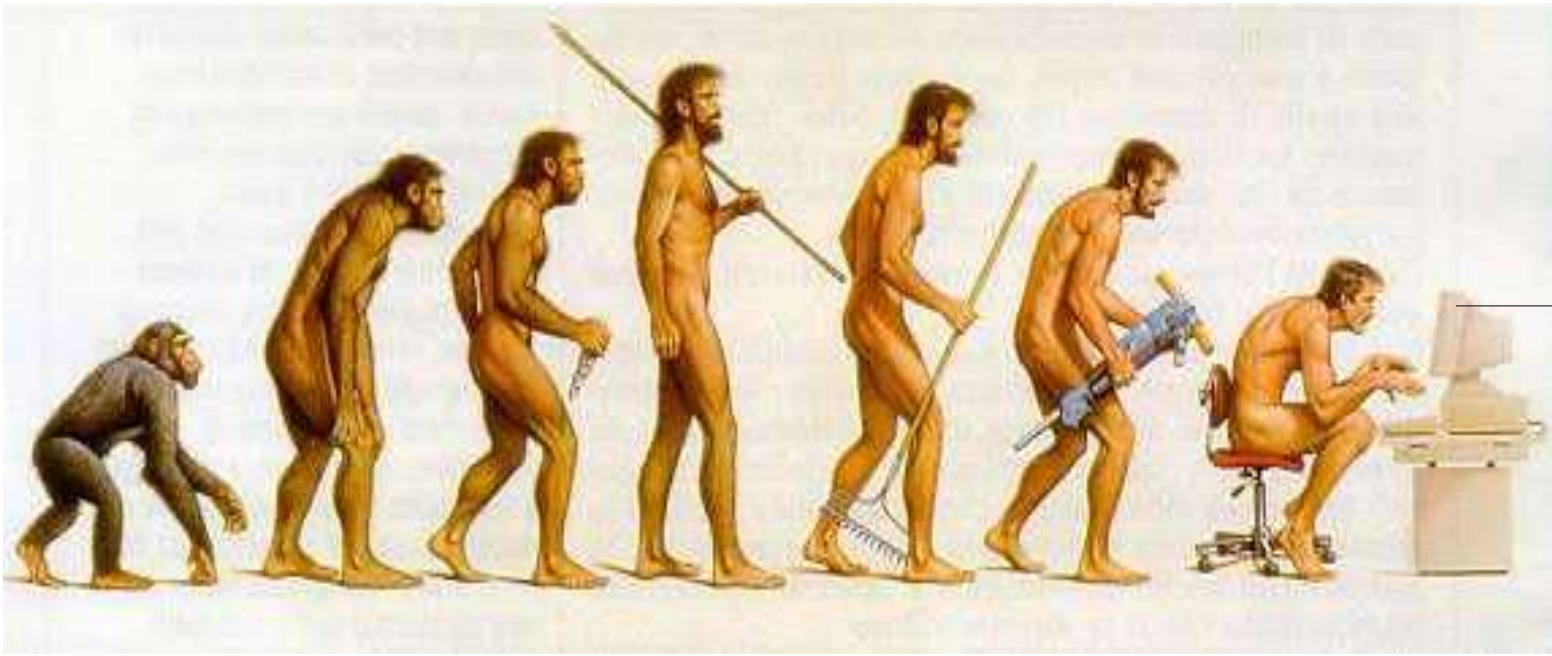
- Start a whole new game – where the gap between "possible" and "actual" is again very large

- **All of the above !**

Where Should We Place Our Priorities ?



Speaking as a designer committed to building a better future through strategic technical workforce development…



Up the value chain to business success

?

?

Extinction

Propithecus sp. | Homo habilis | Homo erectus | Homo sapiens | Homo sapiens faber | **Homo boeingensis**

With thanks to Prof. Larry Leifer, Center for Design Research, Stanford University, 2002

Changing Times in Aerospace

Original Mantra (1903-1990):

Faster, farther, higher (and safer).

Post Cold War Mantra (1990-2000):

Quicker (to market), better, cheaper (and safer).

Issues - Opportunities

- **How many engineers do we need in our future ?**
- **What do we need them to be able to do ?**
- **Where/how do we get them ?**

- **What can *WE* do *?***

Many things change, but some do not….

Kelly Johnson

~~NIH~~

Johnson's promise to his employees:

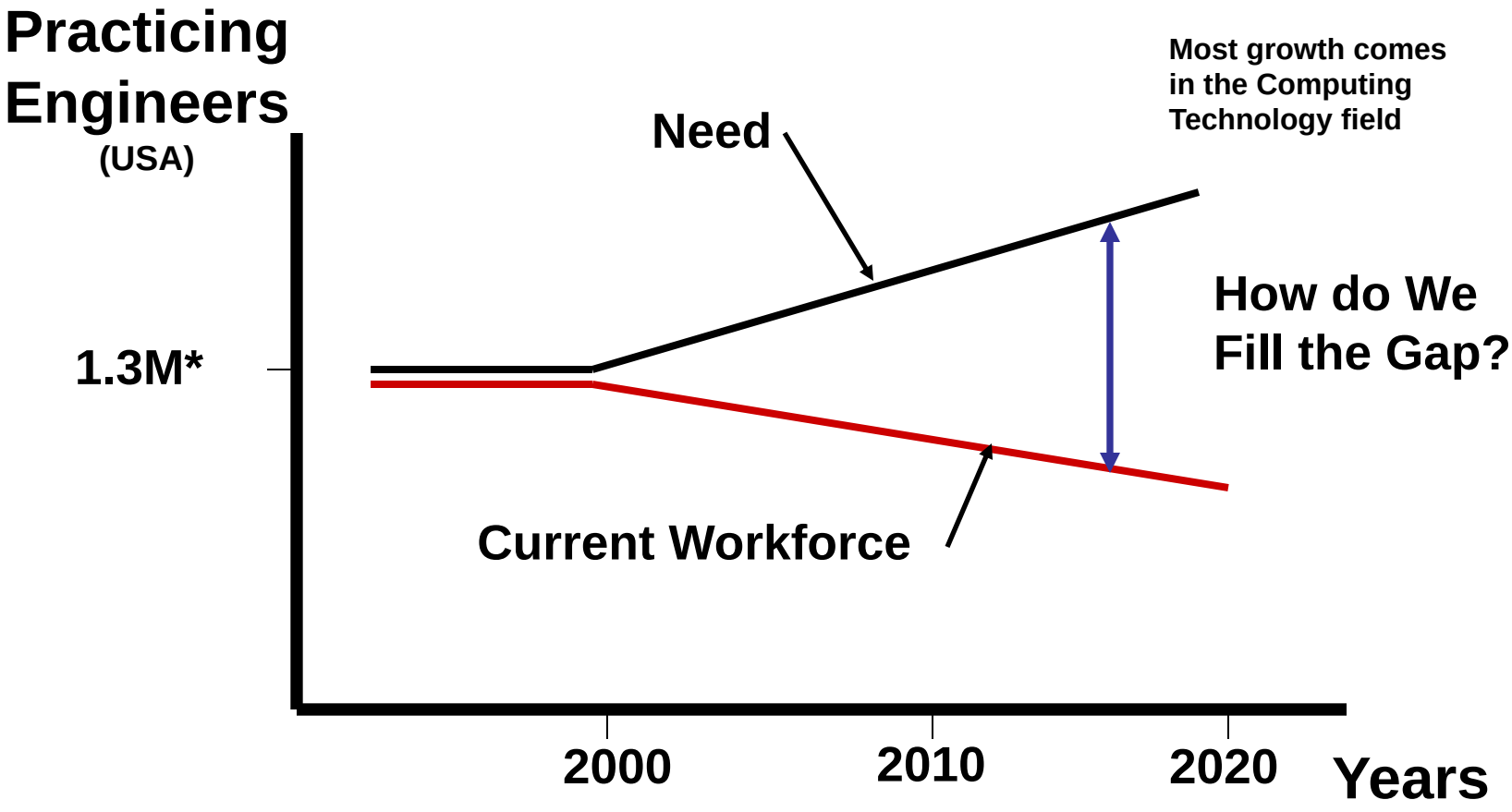
> "I owe you a ***challenging, worthwhile job***, providing ***stable employment, fair pay***, a ***chance to advance***,..I owe you ***good management*** and ***sound projects to work on***, ***good equipment*** to work with and ***good work areas***"

Johnson's philosophy:

> "If you can't do it with brainpower, you can't do it with manpower."

Future Engineering Need & Supply

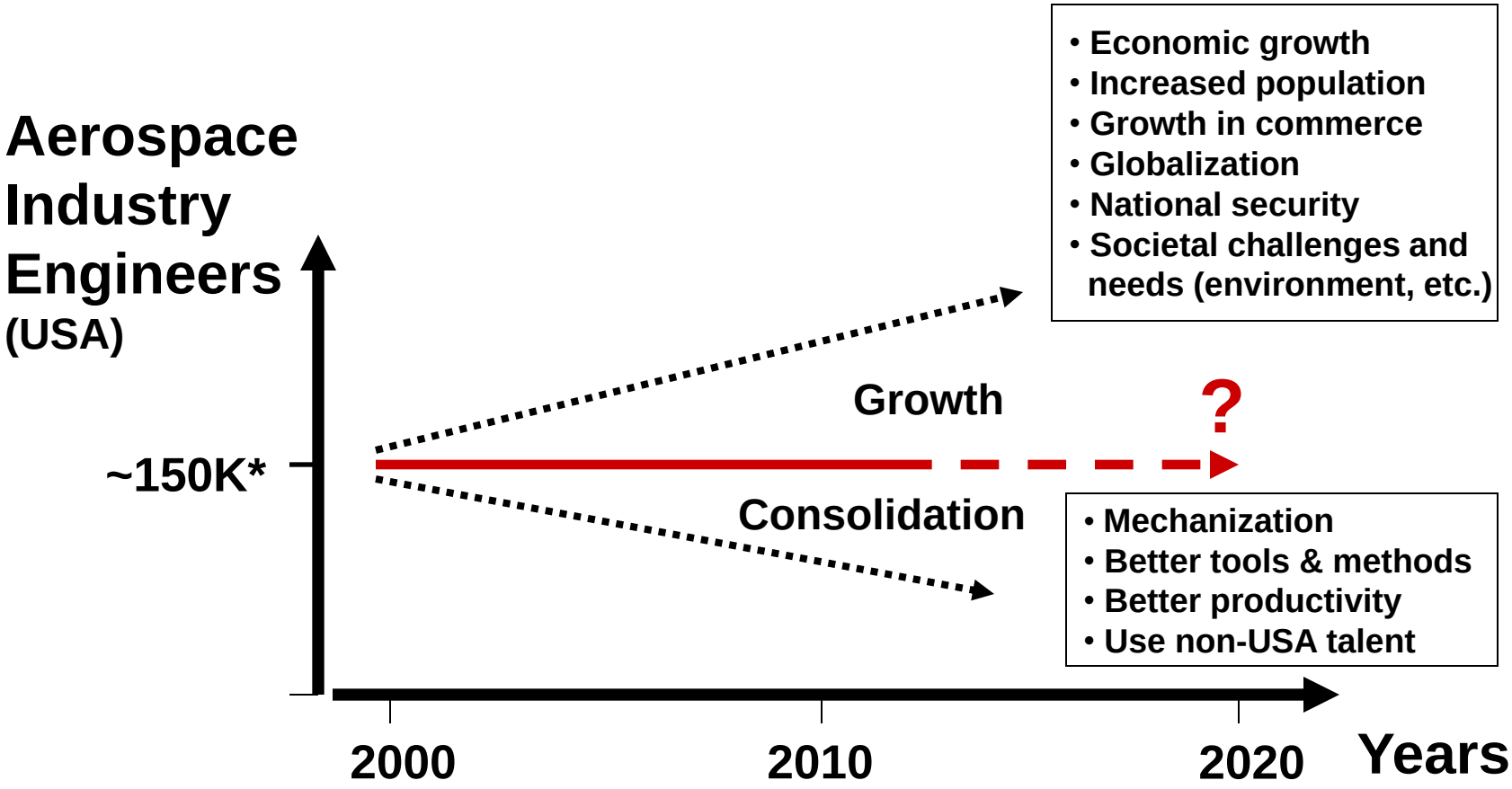
1/1/02



* Note: Total workforce with Science & Engineering education exceeds 10M, 30+% work in S&E;
Engineering accounts for 1.9M degrees and 1.3M working in the field, (NSF Science and Engineering Indicators 2000)

Aerospace* Engineering Need & Supply

Aerospace is a small segment of the Engineering Profession



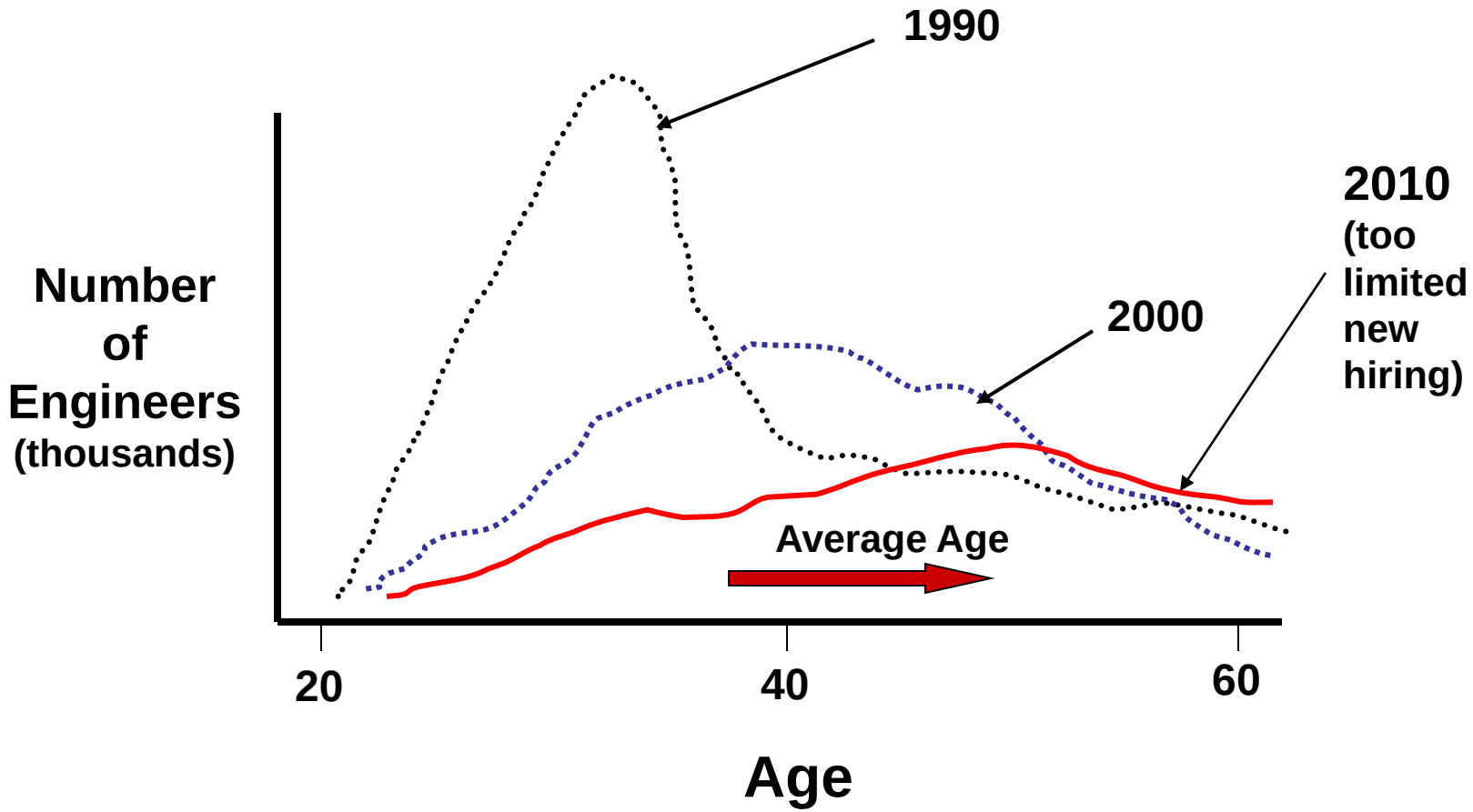
* **"Aerospace Engineering" needs include aerospace, mechanical, electrical, computing, etc. in the USA**

Data based on Bureau of Labor Statistics

Engineers Needed

(If we don't do something now, we'll have worse problems in the future.)

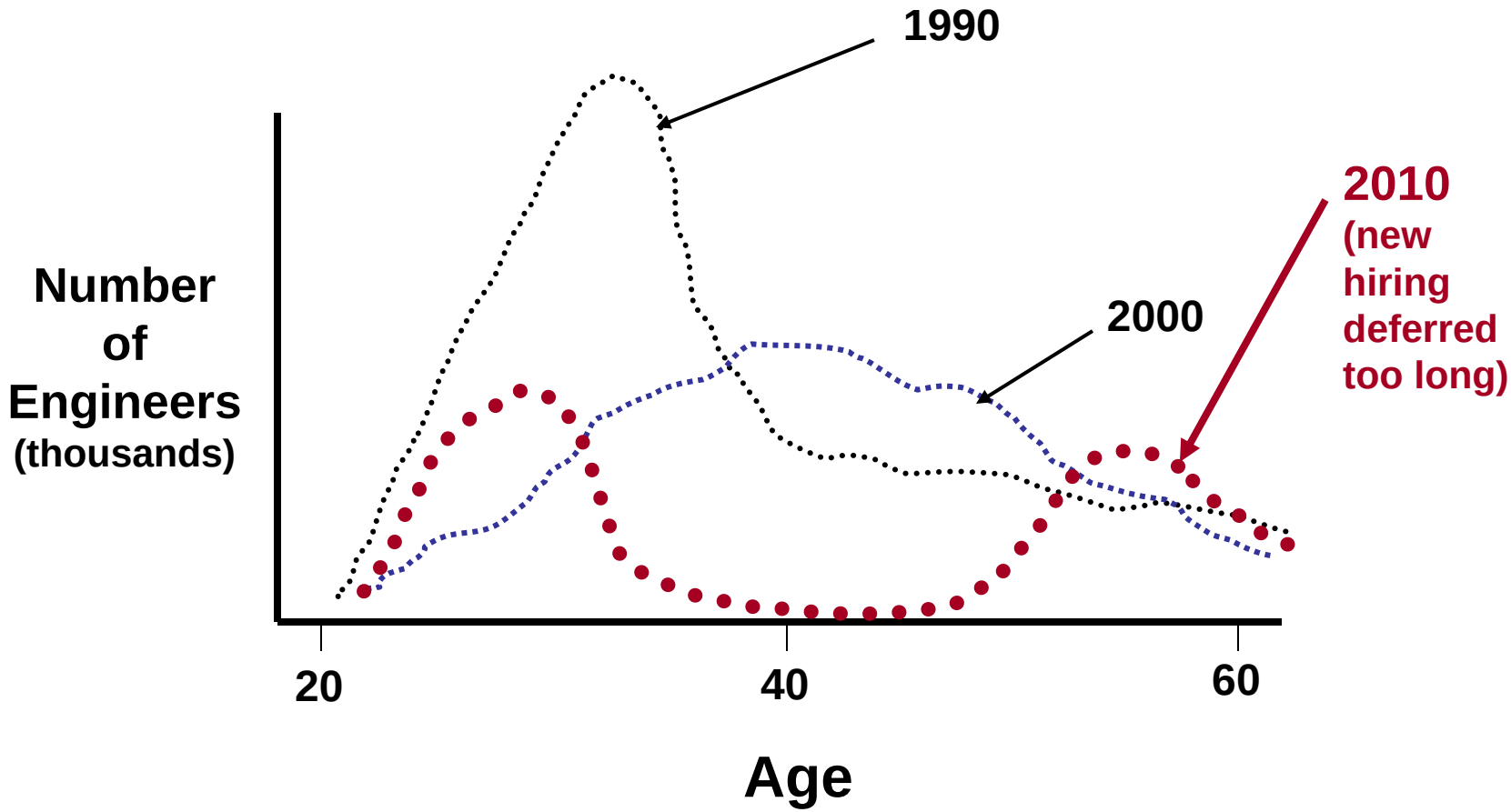
Notional Forecast



Engineers Needed – The Aging Problem

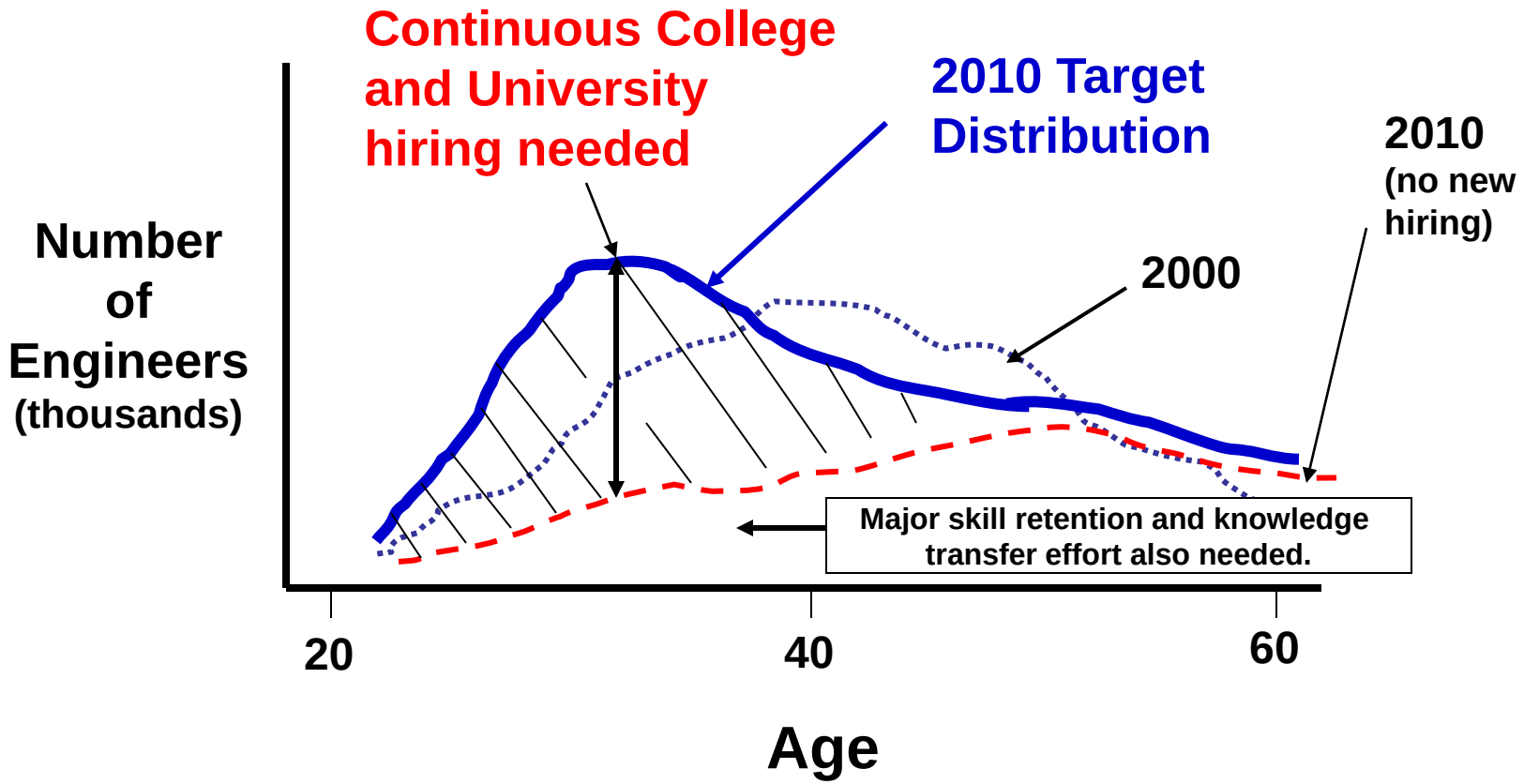
(If we don't do something now, we'll have worse problems in the future.)

Notional Forecast



Engineers Needed
(What we need to do from now on ?)

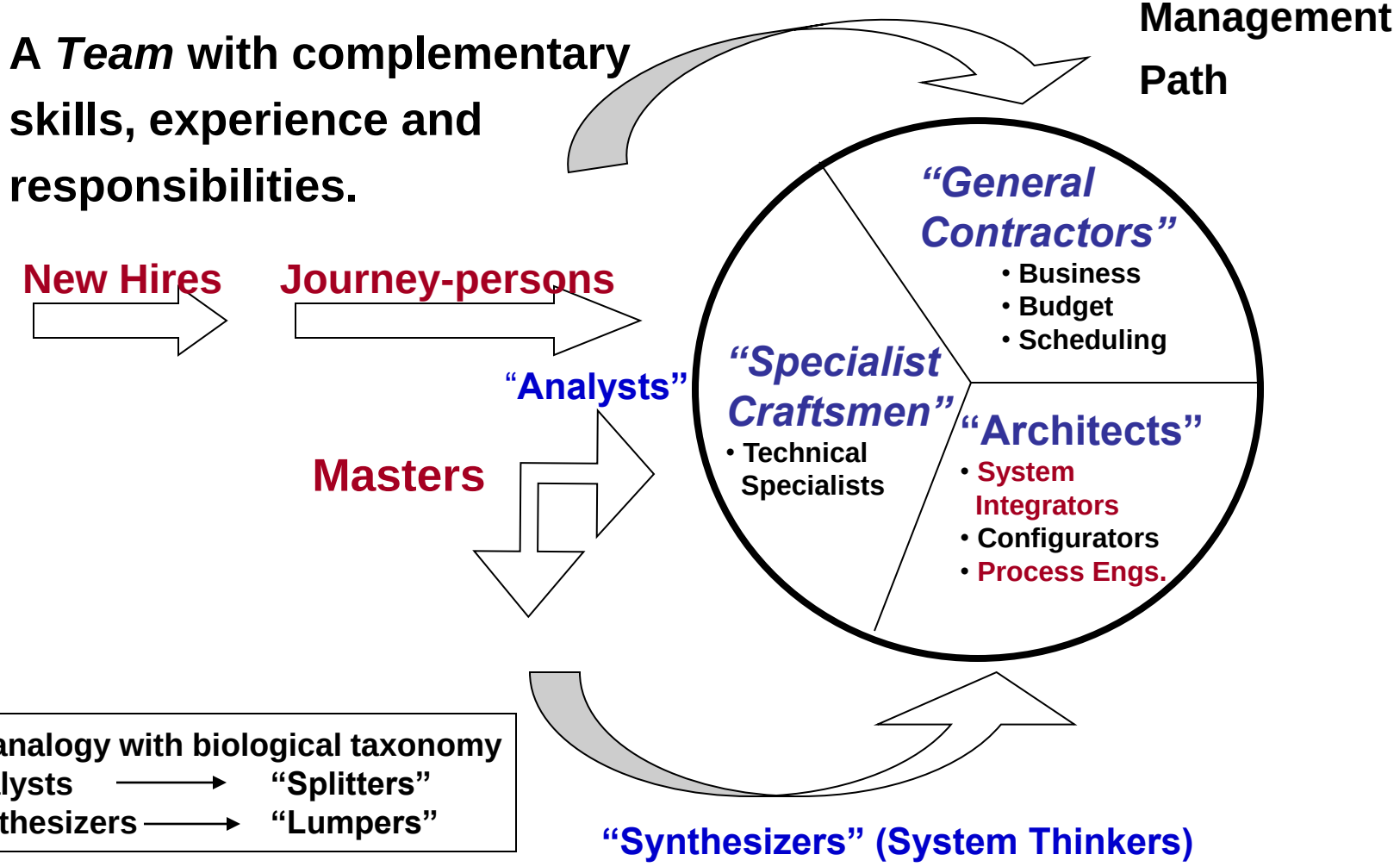
Notional Forecast



If You're Going to Build Houses (or Airplanes or Whatever), You Need Three Kinds of People

(A Multiple Technical Career Path System.)

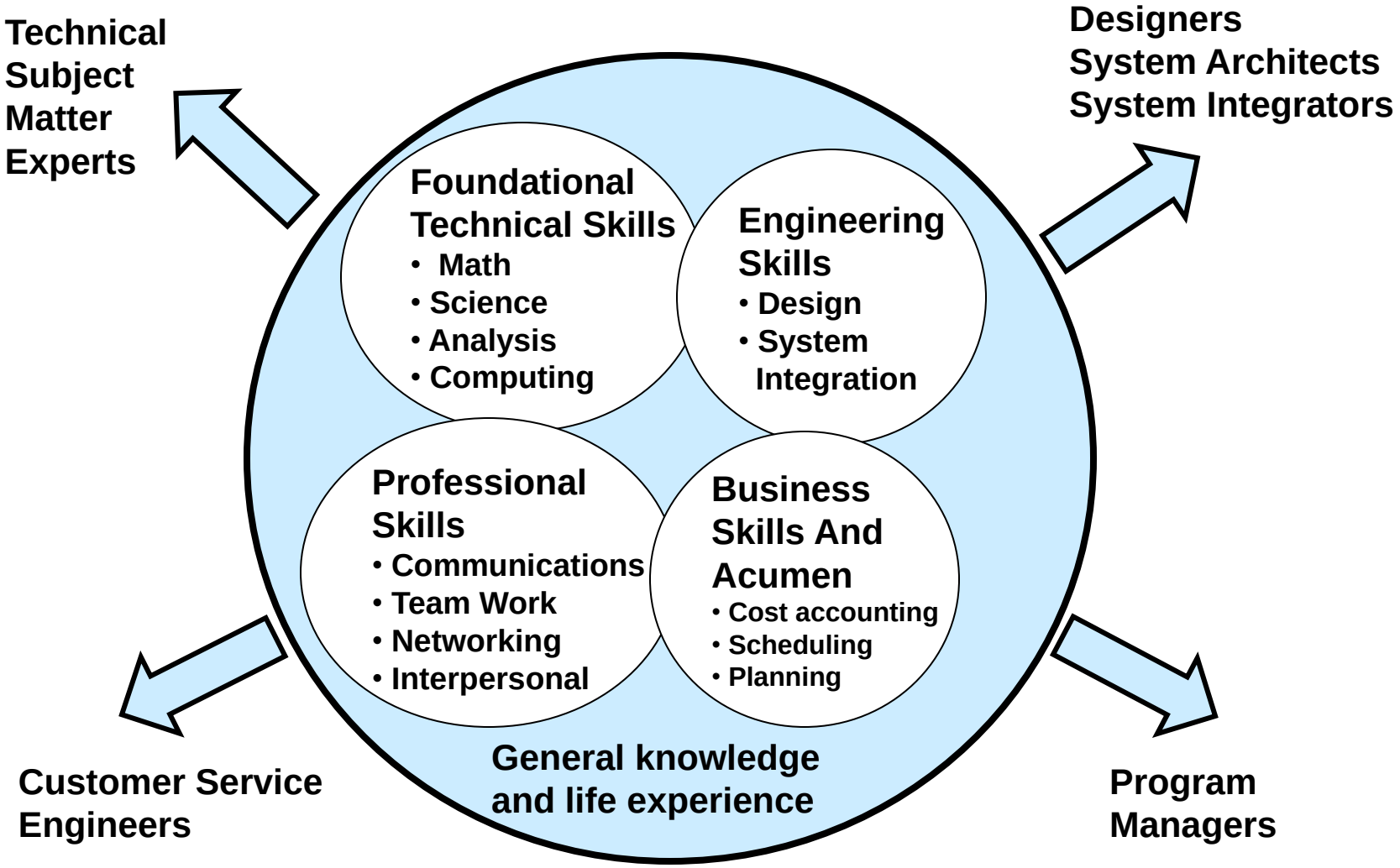
A *Team* with complementary skills, experience and responsibilities.



By analogy with biological taxonomy
Analysts → "Splitters"
Synthesizers → "Lumpers"

A Well-Rounded Engineer

Knowledge of Many Skills with Career Choices Based on Talent, Ability and Interest



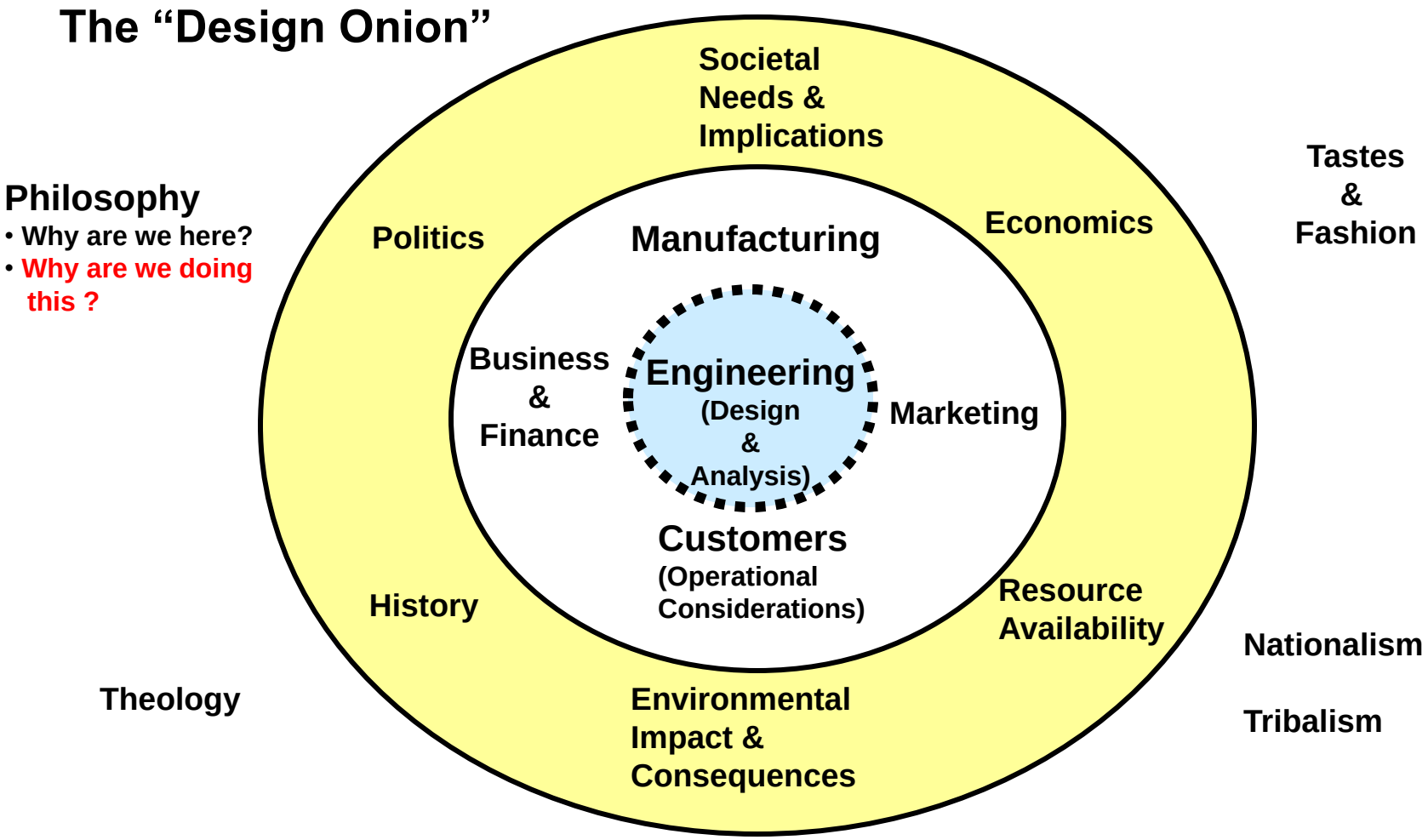
Boeing List of "Desired Attributes of an Engineer"

- A good understanding of engineering science fundamentals
  - Mathematics (including statistics)
  - Physical and life sciences
  - Information technology (far more than "computer literacy")
- A good understanding of design and manufacturing processes
  (i.e. understands engineering)
- A multi-disciplinary, systems perspective
- A basic understanding of the context in which engineering is practiced
  - Economics (including business practice)
  - History
  - The environment
  - Customer and societal needs
- Good communication skills
  - Written
  - Oral
  - Graphic
  - Listening
- High ethical standards
- An ability to think both critically and creatively - independently and cooperatively
- Flexibility - the ability and self-confidence to adapt to rapid or major change
- Curiosity and a desire to learn for life
- A profound understanding of the importance of teamwork
- Global awareness (knowledge of at least one language other than English)

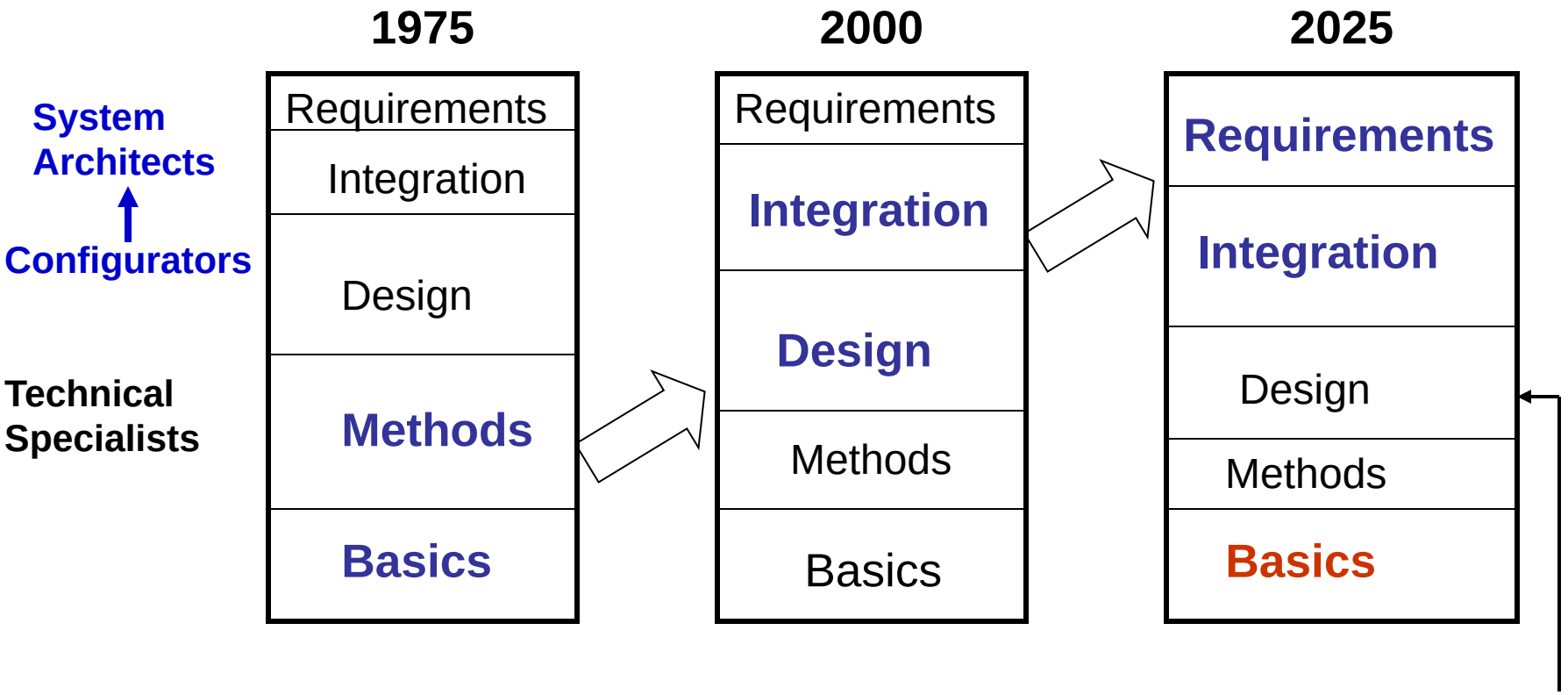
http://www.boeing.com/companyoffices/pwu/attributes/attributes.html

Diversity –wanted and needed

Engineering Isn't Done For Its Own Sake, It Is Practiced in a Context



Increased Demand on Core Technical Workforce



Knowledge Management (Knowledge Capturing & Re-Use)

Boeing Definition of Systems Engineering

Systems Engineering (SE) –

An interdisciplinary collaborative approach to derive, evolve, and verify a life cycle balanced system solution that satisfies customer expectations and meets public acceptability. Systems Engineering is a generic problem-solving process that provides the mechanisms for identifying and evolving the product and process definitions of a system.

System Engineers Come In Three Distinctive Flavors

- **System Analysts –**

  Individuals who can decompose a complex system in a well ordered, disciplined fashion to allow necessary component tasks to be performed

- **System Integrators-**

  Individuals who can integrate the work of of various groups dealing with sub-elements of a large system so that the sum of the parts produces the desired result

- **System Architects-**

  Individuals who can transform a set of requirements and constraints into a well defined system that meets customer needs

While in general there are no "differential equations" for systems engineering *per se*, there is a high level of intellectual content in executing the processes involved and much of it is "technical".

Evolving Trends In Engineering Education and Practice

Industry Needs–University Responses

Industry Practice

- Heavy emphasis on experiment
- Limited to slide rule mathematics
- Heavy reliance on handbook methods
- Strong linkage of engineering to manufacturing
- Limited company funded research

- Continued reliance on testing
- Early computational capabilities
- Gap between engineering and manufacturing "cultures"
- Increased company-funded R&D
- Increased need for technical and scientific knowledge

- Massive computational/simulation capabilities
- Testing shift "experiment" to validation
- "Integrated Product Teams" mandatory
- "Lean" concepts close engineering and manufacturing gaps
- Heavy emphases on Processes, Costs, "Value"

Engineering Curricula

- "Vocational" orientation
- Limited mathematics
- Emphases on:
  - data gathering
  - problem solving
  - design (and drafting)
  - manufacturing

Engineering "General Practitioners"
- Mechanical
- Electrical
- Civil
- Chemical

Technical Specialists
("Engineering Science Technicians")

- Emphasis on technical knowledge
- Emphasis on theory and mathematics
- Decreasing emphasis on design and manufacturing
- "Publish or perish"

System Integrators/ Product "Architects"
(Multidisciplinary Perspective)

- Retain strengths in math and physics
- Enhanced IT emphasis
- Emphasis on design and manufacturing
- Emphases on breadth, context, and process:
  - Economics, business, project management
  - Environmental and societal issues
  - Teamwork and communication skills
  - Career-long learning

Rapid Industrial Expansion
Transform from Agrarian to Manufacturing Economy

Cold War Era
Big science, rapid technological advances, international perspective

Information Age
Emerging post-Cold War global economy, enabled by transportation and communications technology

1900 — WW 1 — WW 2 — 1950 — Sputnik — Berlin Wall — 2000 — 9/11

Evolving Trends In Engineering Education and Practice

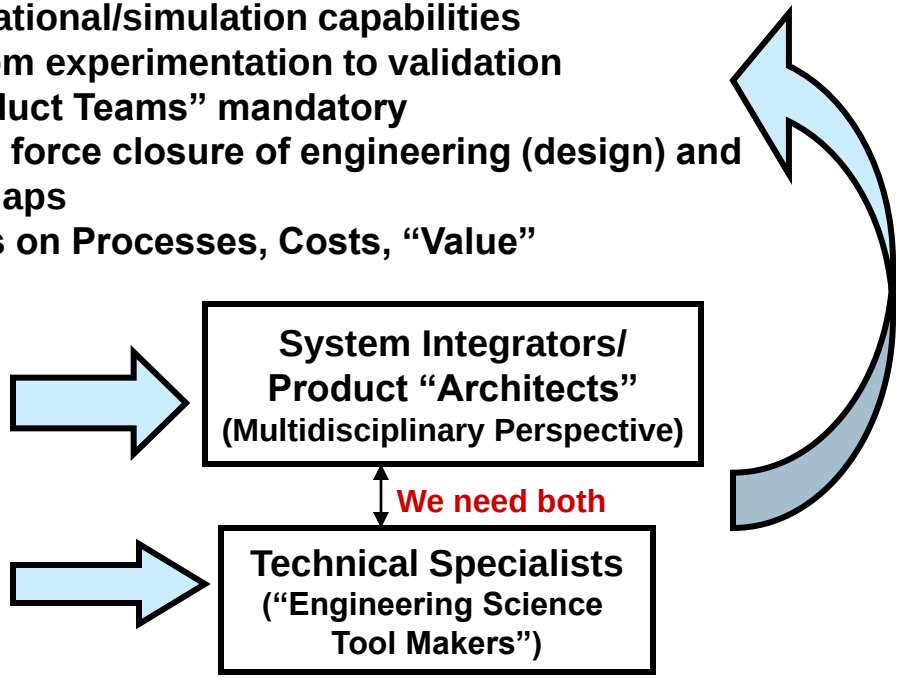
Industry Needs - University Responses [1990 - 20??]

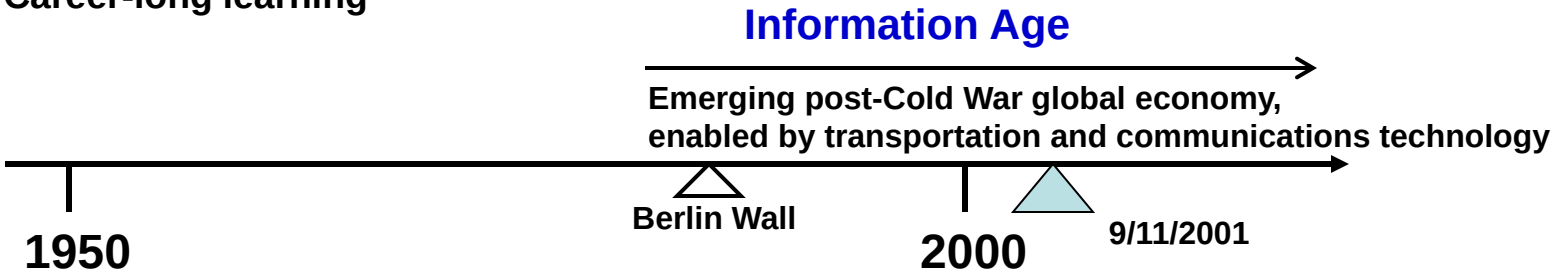
Industry Practice [Major Industrialized Nations]

- Massive computational/simulation capabilities
- Testing shifts from experimentation to validation
- "Integrated Product Teams" mandatory
- "Lean" concepts force closure of engineering (design) and manufacturing gaps
- Heavy emphases on Processes, Costs, "Value"

Engineering Curricula

- Retain strengths in math and physics fundamentals plus enhanced IT emphasis
- Emphasis on design and manufacturing
- New emphases on breadth, context and process issues:
  - Economics, business, project management
  - Environmental and societal issues
  - Teamwork and communication skills
  - Career-long learning

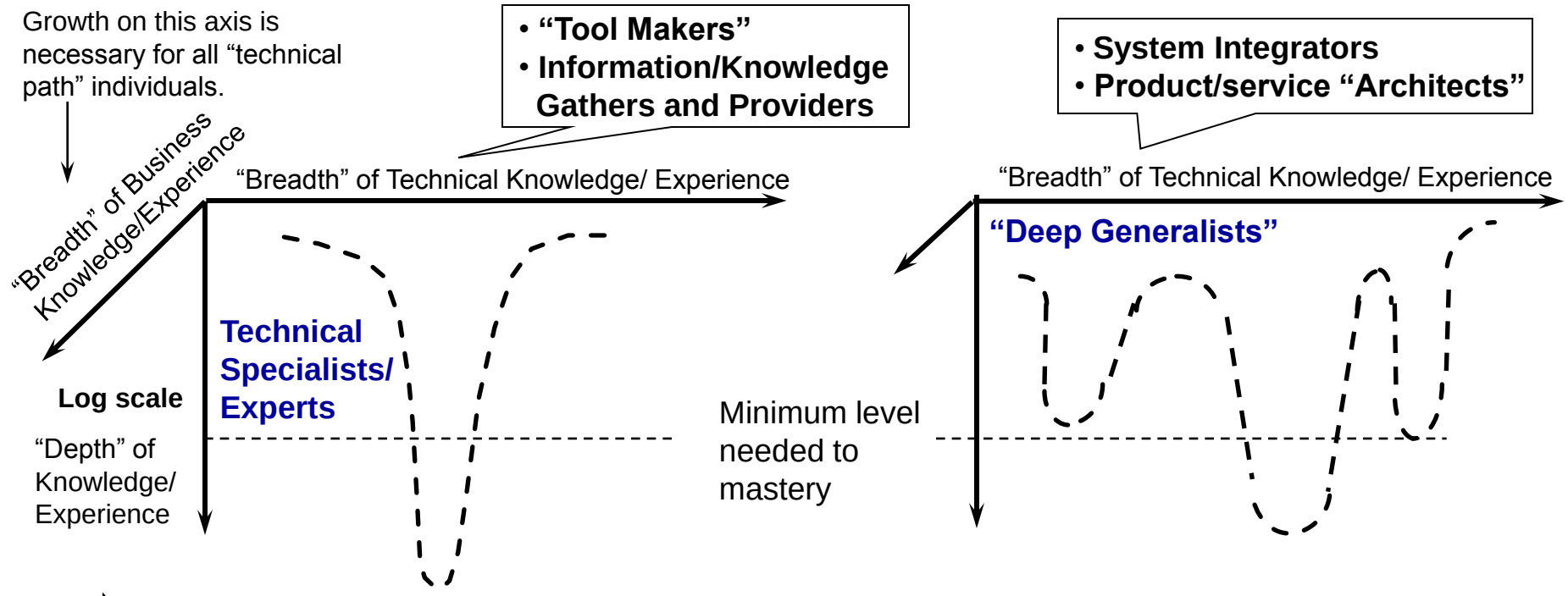




TECHNICAL EXCELLENCE BY DESIGN

Skilled and Motivated Workforce → Shareholder Value and Customer Satisfaction

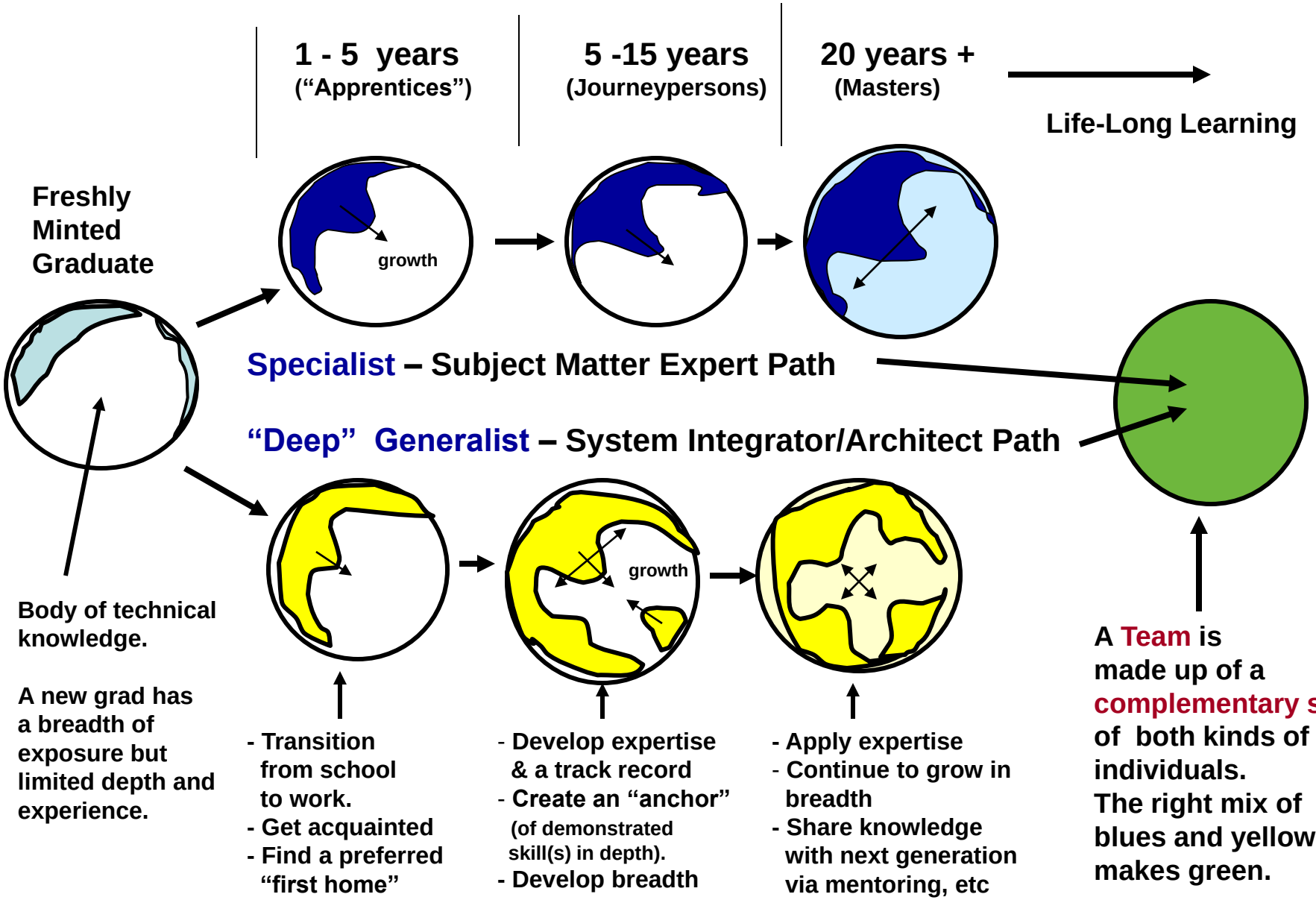
Which of these two archetypal technical employees is more valuable to the aerospace industry? They both are!



A proper balance is needed!

Boeing Technical Workforce	Currently	Future (5 -10 yrs +)
Technical Specialists	80-90 %	60- 70 % ?
"Deep Generalists"	10-20 %	30- 40 % ?

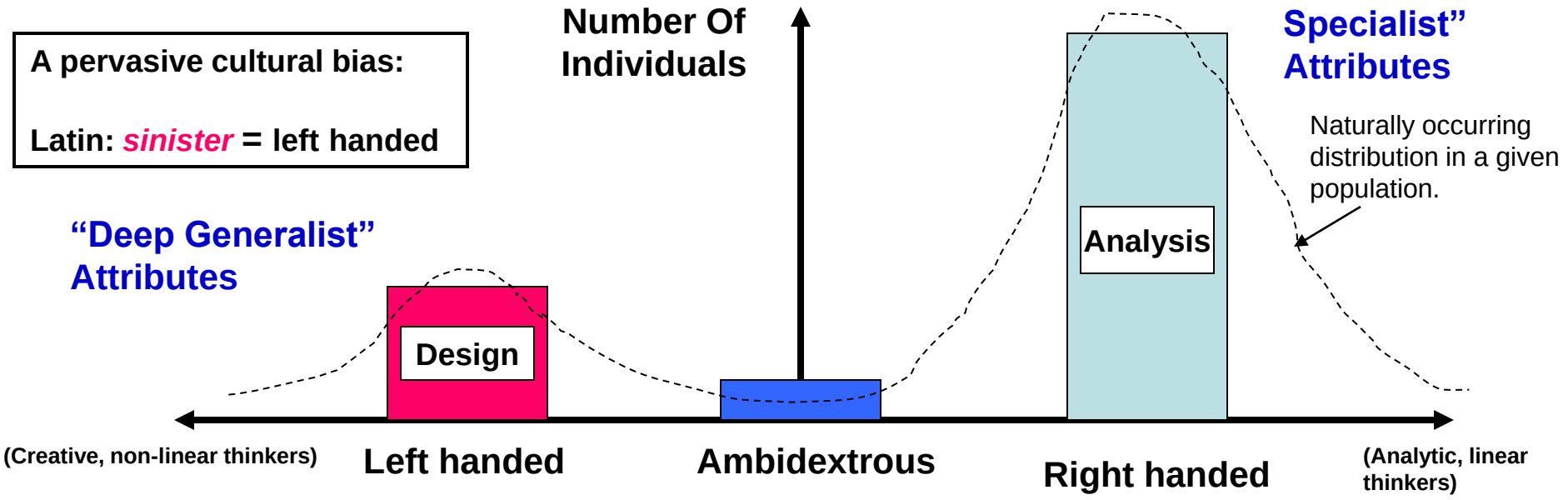
How People (Engineers) Grow and Develop



Observations on Bi-Modal, Non-Symmetric Population Distributions

A pervasive cultural bias:

Latin: *sinister* = left handed



By empirical observation, similar non-symmetric bi-modal distributions can be found in various professional populations of interest (c.f. Myer-Briggs data):

Biological taxonomy:	**"Lumpers"**	**and**	**"Splitters"**
Engineering:	**"Designers"**	**and**	**"Analysts"**
General:	**"Synthesists"**	**and**	**"Reductionists"**
	("System integrators")	**and**	**("System analysts")** **but [System architects ?]**

Note: These observations are not intended to place any value judgment on the importance of one archetype over another. Both are important, and the point is merely that the distribution isn't even in any natural population.

Myers-Briggs Type Indicator Dichotomies

E Extraversion ⟷ I Introversion

- Extrinsically motivated
- Focus on people and things

- Focus on thoughts and concepts
- Intrinsically motivated

S Sensing ⟷ N Intuitive

- Bottom up – specific to general
- Facts and data driven
- Detail and utility oriented
- Here and now orientation

- Top down – general to specific
- Concepts and meaning oriented
- Theory and speculation
- Future oriented

T Thinking ⟷ F Feeling

- Objective analysis of cause & effect
- Decisions based mainly on logic

- Subjective evaluations
- People centered
- Decisions based mainly on values

J Judging ⟷ P Perceiving

- Prefer planning and organization
- Prefer to have things settled

- Prefer flexibility and spontaneity
- Prefer to keep options open

Note: It is important to recognize that the Myers-Briggs construct places no value judgment on the importance of one personality type over another. People can (and frequently do) act outside a given type preference as need arises.

Myers-Briggs Type Indicator National Sample Data

Types predominantly attracted to engineering and science are:

ISTJ
INTJ
INTP
[ENTJ]

Sensing Types (**73.3%**) [M: 71.7%, F: 74.8 %]		**Intuitive Types** (**26.7%**) [M: 28.3%, F: 25.2 %]	
ISTJ **11.6%** [M: 16.4%, F: 6.9%]	**ISFJ** **13.8%** [M: 8.0%, F: 19.4%]	**INFJ** **1.5%** [M: 1.3%, F: 1.6%]	**INTJ** **2.1%** [M: 3.3%, F: 0.85%]
ISTP **5.4%** [M: 8.5%, F: 2.4%]	**ISFP** **8.8%** [M: 7.6%, F: 9.9%]	**INFP** **4.4%** [M: 4.1%, F: 4.6%]	**INTP** **3.3%** [M: 4.8%, F: 1.8%]
ESTP **4.3%**	**ESFP** **8.5%**	**ENFP** **8.1%**	**ENTP** **3.2%**
ESTJ **8.7%**	**ESFJ** **12.3%**	**ENFJ** **2.5%**	**ENTJ** **1.8%**

Introverts
(**50.7%**)
[M: 54.1%, F: 47.5%]

Extraverts
(**49.3%**)
[M: 45.9%, F: 52.5%]

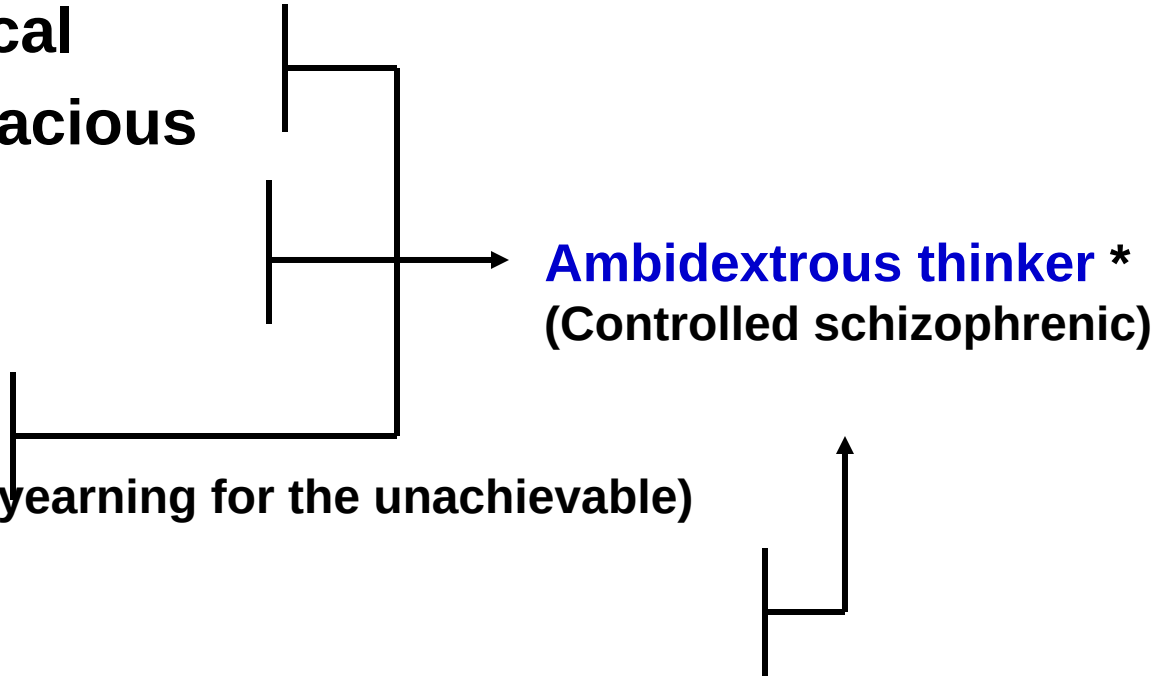
(National Sample, [**Male: N = 1,478; Female: N = 1,531**] combined male and female: N=3,009)

Attributes of a Good Designer

[Configurators → System Architects]

(adapted from a list by C.R. Chaplin, U.K. Fellowship of Engineering)

- **Visionary**
- **Creative, imaginative**
- **Objective, critical**
- **Stubbornly tenacious**
- **Flexible**
- **Cooperative**
- **Independent**
- **Nympholepsy (yearning for the unachievable)**
- **Pragmatic**



*** The pairs of attributes shown cannot be exhibited simultaneously without short circuiting the brain. One can (and must) learn to switch reflexively from one mode to the other as need may arise. This can be done, and one can learn how to do it.**

Growing "Engineering Generalists"
(System Integrators & Architects)

Using a strategic Performance Managements/PDP Process, we need:

- **An identification process of those individuals who have a reasonable probability of being "good at it" [e.g. based on Myers-Briggs].**
- **A strategically oriented job rotation program (well beyond a particular discipline or specific technical area)**
- **Targeted continuing education and training as needed to provide in-depth foundational rigor and exposure to fundamentals not provided in work assignments**
- **Targeted work assignments that provide a practicum for dealing with "system problems" of increasing complexity**
- **Mentoring (lots of mentoring !)**
- **Special assignments as opportunities arise that provide a non-traditional breadth of knowledge or perspective – or which simple stimulate "systems thinking"**
- **Exposure to important new technologies such as multi-disciplinary optimization (which can be more powerful as learning devices than as mere working tools) – operating like "video games".**

Possible Indicators of an INTP/INTJ Myers-Briggs Type Preference

Generic Traits:

- **Curiosity and eagerness to learn new things**
- **Breadth and well as Depth of Knowledge and Experience**
- **Interest in Concepts, Meaning and Context**
- **Flexibility**

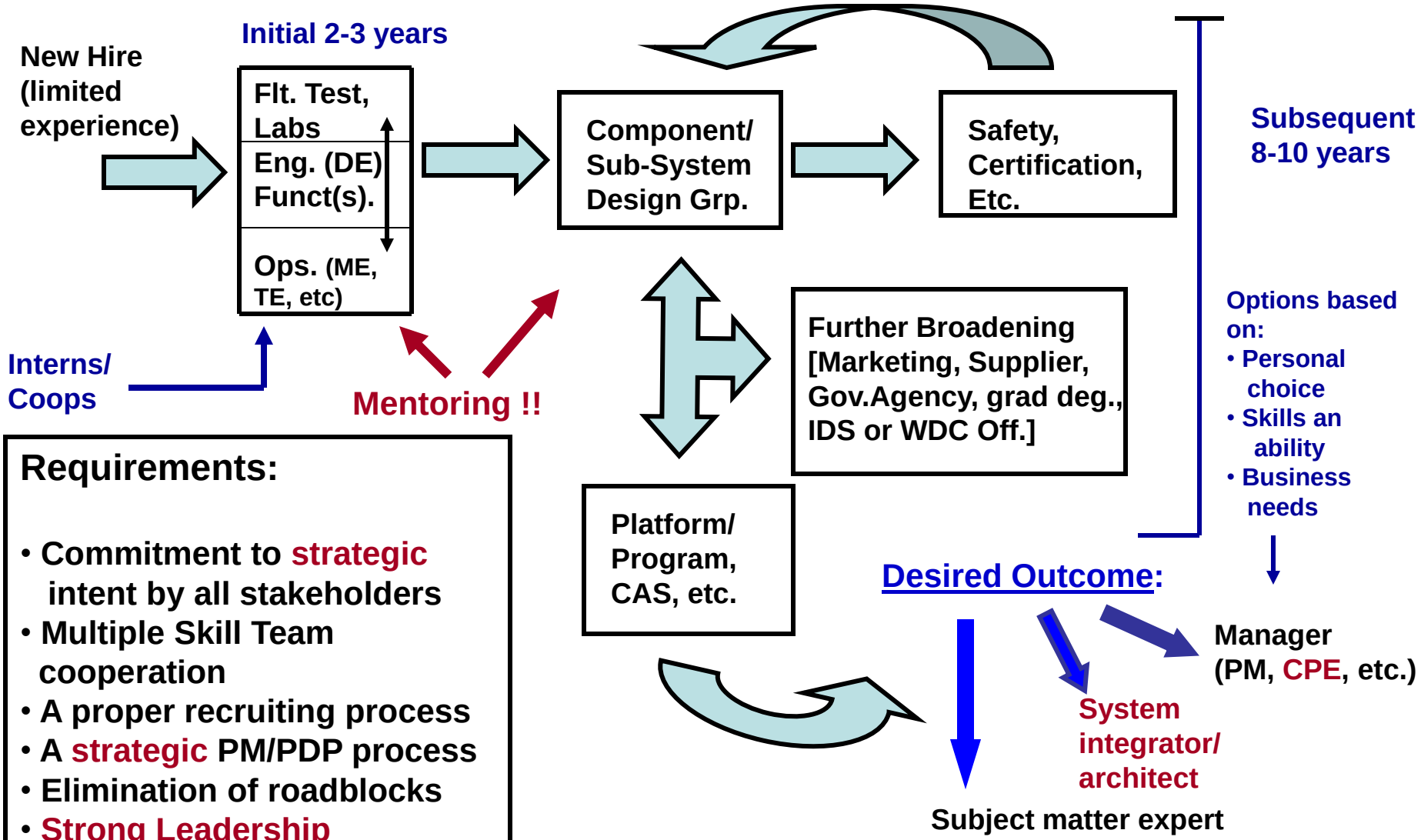
"What are your hobbies and interests outside of work and/or specific job assignments?"

"What is your work and job assignment history ?"

"Are you comfortable 'multi-tasking' or do you prefer to focus on one specific job or task at a time ?"

"What are your professional growth aspirations ? What you you like to be doing 5-10 years from now –professionally or other wise ?"

A Model Rotation Plan for an Engineering Graduate



Requirements:

- Commitment to strategic intent by all stakeholders
- Multiple Skill Team cooperation
- A proper recruiting process
- A strategic PM/PDP process
- Elimination of roadblocks
- Strong Leadership

And in grander, global terms……

“It is suicidal to create a society dependent on science and technology in which hardly anyone knows anything about science and technology.”

Carl Sagan

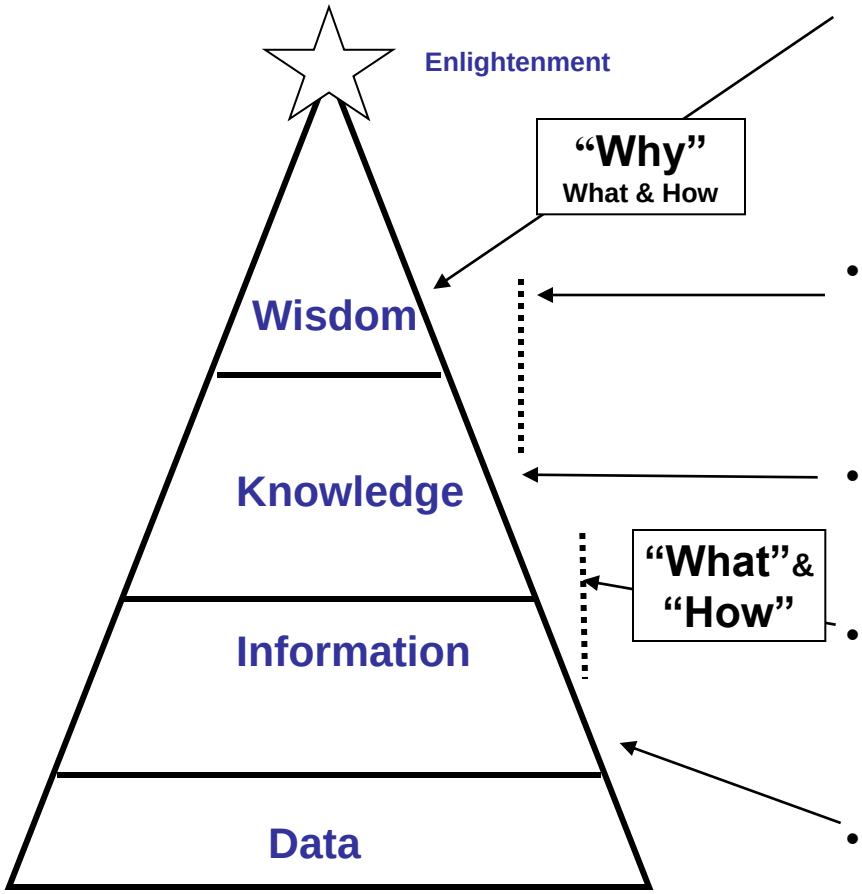
“The scientist discovers that which exists, the engineer creates that which never was.”

Theodore von Kármán

Knowledge Management

- KM identifies "knowledge" as a commodity with value that must be managed (effectively developed, distributed, retained, etc.)
- KM provides a useful taxonomy:
  - Data – individual bits and facts
  - Information - Processed (organized and interpreted) data
  - Knowledge - What the information really means (processed and interpreted information)
  - Wisdom - Knowledge plus judgment and experience (wise application of knowledge is "situational" – there are few "one size fits all, every time, everywhere" solutions to most problems)
- Includes the concept of "Communities of Practice" as a useful mechanism for the retention and sharing of knowledge among practitioners (wherever and whomever they may be). Mentoring is a powerful way to accomplish this aim.
- Can degenerate into a simple (and very expensive) exercise is the use of information technology [i.e. KM is fundamentally a "people issue" merely enabled by technology.]

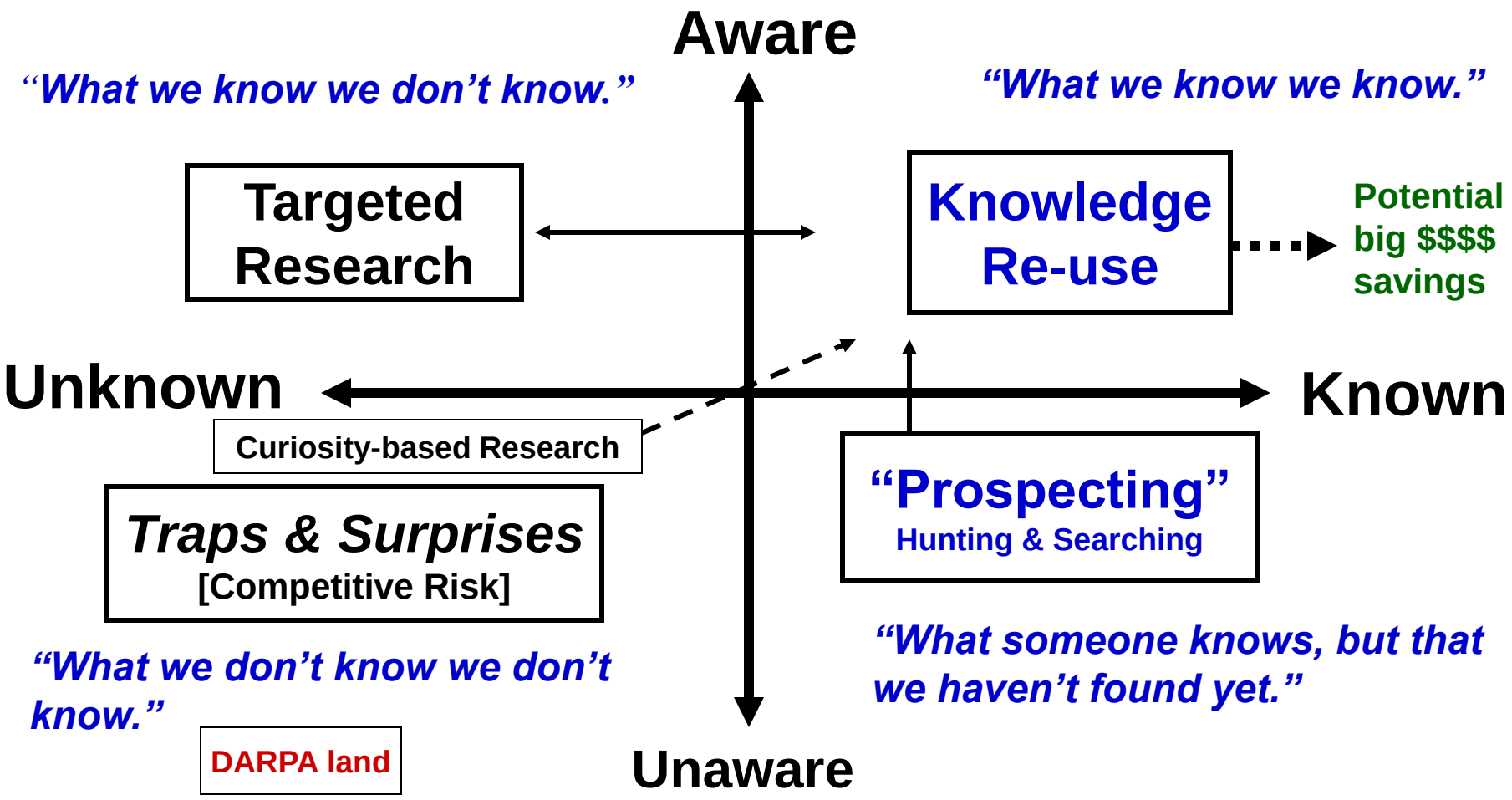
A Useful Knowledge Management Taxonomy



- Wise application of knowledge is "situational" - requiring judgment and experience. There are few "one size fits all, every time, everywhere" solutions to most problems.
- Mentorship is required to reach the higher levels of the KM value stream.
- Knowledge is processed [organized, interpreted] information.
- Lower-level knowledge and information is what we put in "textbooks"
- Information is processed data

Opportunities in the Knowledge Domain

A balanced approach is needed.



ENGINEERING – WHAT YOU DON'T NECESSARILY LEARN IN SCHOOL

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LEARN TO BE BUSINESS ORIENTED

1. ***Understand the "Cost of Doing Business".***
2. ***Realize that Today's Marketplace is Global.***
3. ***Understand the Relevance of Profit.***
4. ***Learn to Diagnose and Manage Marketplace Change.***
5. ***Beware of Your Competition.***
6. ***Learn the Color of Money.***

Investment	**Capital improvements (buildings, equipment, etc.)**
Expense	**General and administrative, (overhead) travel and living, developing something you don't sell, marketing, training**
IR&D	**Advance state of the art, advance technology**
Profit (DA)	**What's left after expenditures**
Contract	**What others outside give you to do work**

Dave Wisler (cont'd - 1)

EXPECT TOUGH MULTI-DISCIPLINARY PROBLEMS

1. ***Tough Problems Don't have single "Right answers" (found in the back of the textbook).***
2. ***Learn When to Stop.***
3. ***Learn from Discrepant Events.***

LEARN TO WORK AND NETWORK IN A NEW ENVIRONMENT

1. ***Work and Network in a New Time Scale.***
2. ***Work and Network as a Team Player***
3. ***Work and Network with Good Communication skills.***
4. ***Work and Network in the New Multi-Cultural and Multi-National Environment.***

Capture the Four "E's" (of effective colleagues).

Energy – They have high energy levels and enthusiasm for their work. They are dynamos who accomplish things.

Energize – They have the ability to energize others around common goals. Their enthusiasm is contagious.

Edge – They have discernable characteristics that separate them from others in measurable, favorable ways. They can make tough yes-and-no decisions.

Execute – They consistently deliver on their promises. It isn't that they don't ever make mistakes or take risks, but overwhelmingly they deliver.

Dave Wisler (cont'd - 2)

UNDERSTAND THE DIFFERENCES BETWEEN ACADEME AND INDUSTRY

Academe	Industry
1. More individual oriented	1. More team oriented
2. Is it original work?	2. Can we leverage existing work?
3. Does it contribute to science?	3. Does it contribute to the business?
4. Will it make archival publication?	4. Will it make it into production?
5. Is it interesting to do?	5. Is it worthwhile financially?
6. Develop the equations, analysis, etc. from first principles	6. Fit a curve through the data and/or anchor existing analysis
7. Is it original and complete from scientific (physics) perspective?	7. Is it institutionalized into the system from engineering perspective?
8. Graduate when thesis finished.	8. Meet schedule and budget
9. Publish, publish, publish	9. Customer, customer, **customer**
10. Sound scientific process templates	10. Design practices,
11. Non-profit institution	11. Profit institution
12. Solve roadblock issues as they occur	12. Identify and manage risks carefully up front with risk abatement plan and critical path scheduling
13. Professors (especially tenured) are independent	13. Formal management process up to shareholders

Dave Wisler (cont'd – 3)

UNDERSTAND THE VALUES, CODE OF CONDUCT AND CULTURE OF YOUR PARTICULAR COMPANY

BE OPEN TO IDEAS FROM EVERYWHERE

HAVE UNYIELDING INTEGRITY

MAKE YOUR MANAGER A SUCCESS

[John's Corollary: NEVER make an enemy of an Office Administrator.]

SUPPORT YOUR UNIVERSITY AND YOUR TECHNICAL SOCIETY

HAVE FUN (work and toil need not nor should not be the same thing)

NEVER Stop Learning!

Dave Wisler (cont'd -4)

MANAGE YOUR CAREER

(it's yours, no matter who you work for)

Face Today's Realities.

You'll Likely Need a Mentor and a Champion.

Diversify.

Get an Engineering License.

NEVER Stop Learning.

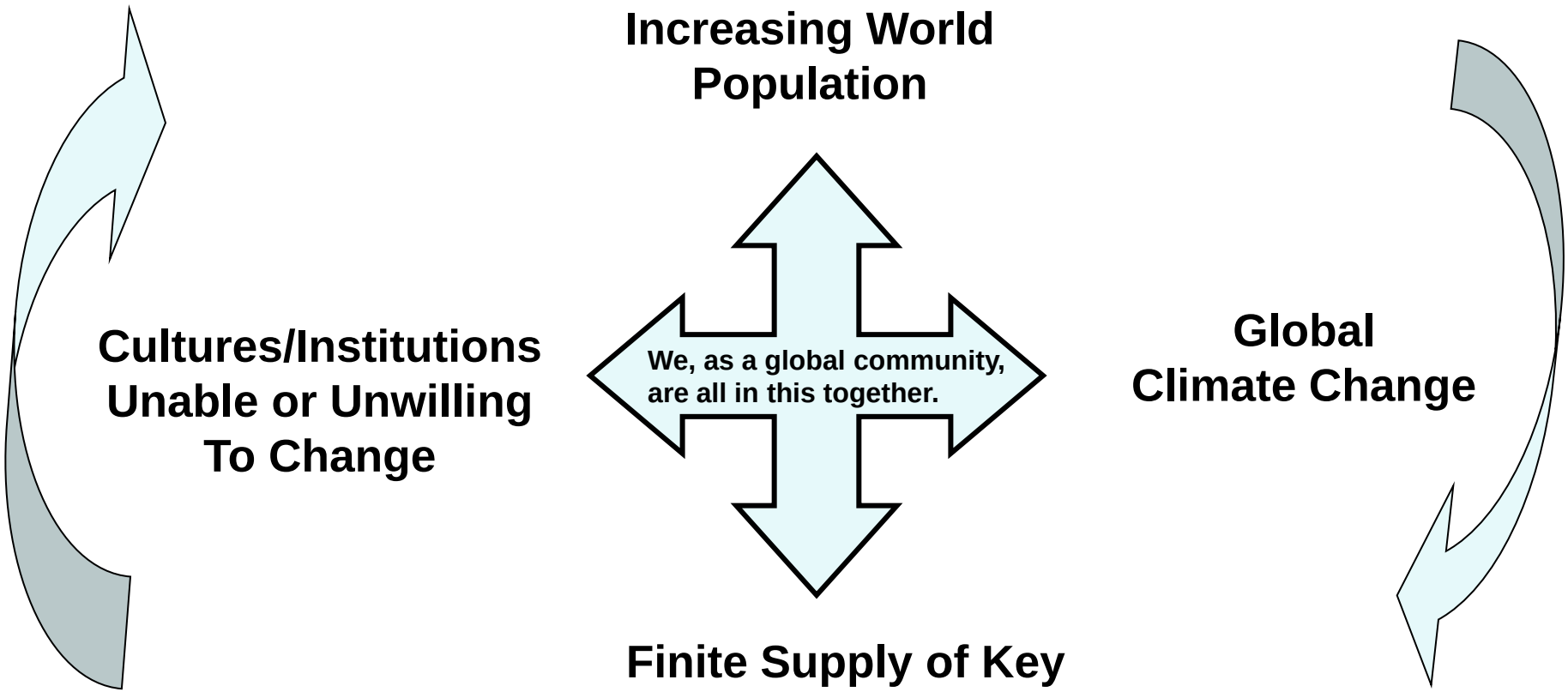
Early 21st Century Challenges for Aeronautics

To sustain an industry that continues to find a multi-billion dollar a year market for its products and services and contributes heavily to a favorable balance of trade, by:

- **Building an effective, efficient and safe global air transportation system**
- **Contributing to our national security in the face of an increasing number of non-traditional threats**
- **Providing an important component to the "affordable access to space"**

A Developing World-Wide "Perfect Storm" ?

(Some Global Challenges for the 21st Century)



Engineering is a fundamental part of any solutions or ameliorations!

Changing Times in Aerospace (cont'd)

Original Mantra (1903-1990):

Faster, farther, higher (and safer).

Post Cold War Mantra (1990-2000):

Quicker (to market), better, cheaper (and safer).

Emerging New Mantra (2001 - ?)

Safer, better, faster, higher, farther, cheaper, quicker, quieter, cleaner, etc..

Or: "Leaner, meaner, greener (and safer)" ?

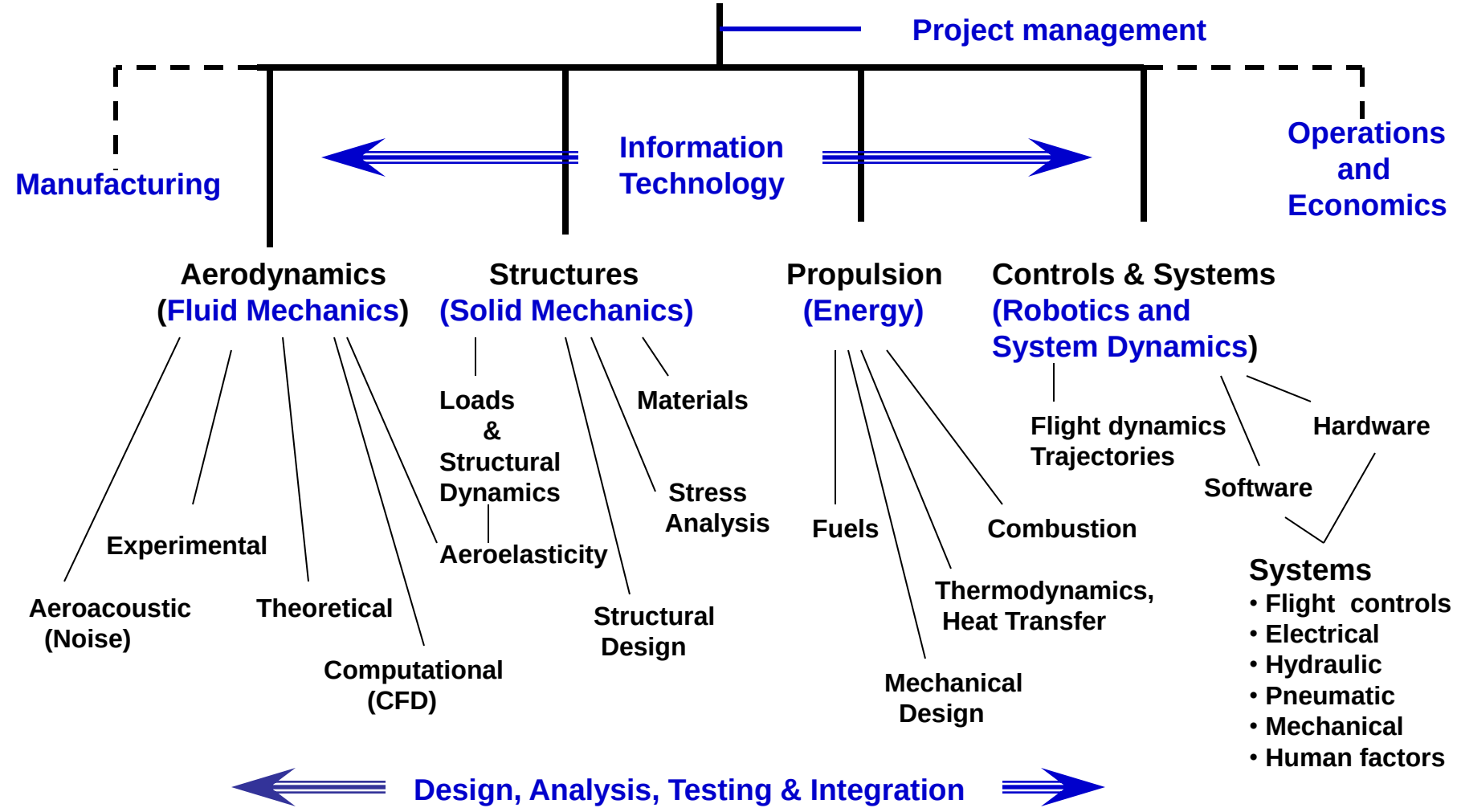
Some Conclusions

- **Aerospace is changing – For Better? Or Worse? Neither, it's just going to be different with many of the same basic element !**
- **Space (astronautics) has a brave future but is aeronautics ("airplanes") *passe* ? Not likely !**
  - **Air transportation is essential for global commerce (and national security)**
  - **Flight in hostile environments (from Chicago and Afghanistan to Mars and beyond) is an open field for further exploitation**
- **Aerospace engineering remains the single institutionalized "multi-disciplinary, large-scale systems oriented" program in our engineering education system. We need more, not less "aerospace engineering" graduates in our national future.**

AEROSPACE ENGINEERING

Aeronautical/Astronautical Engineering

(as a "Large-Scale, Multidisciplinary Systems Integration" Curriculum)

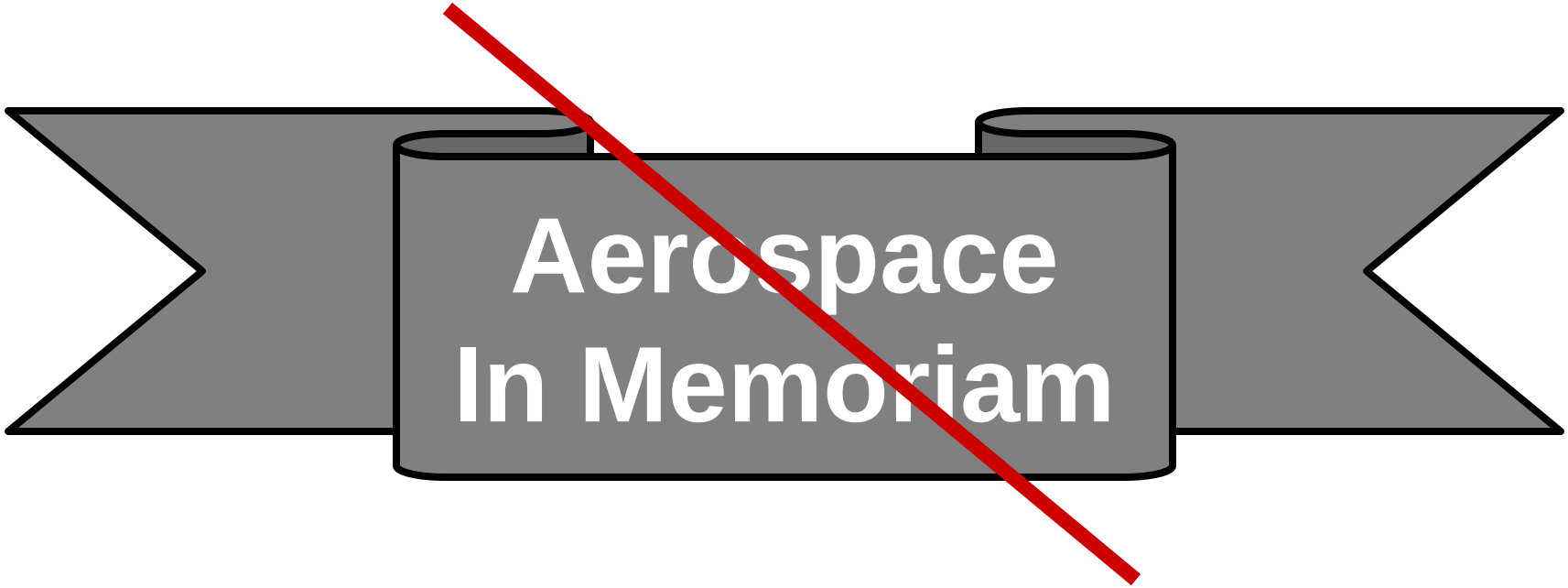


Despite some recent evidence to the contrary….

It is highly premature to write the history of the airplane business as an obituary !

Note: No beaver was actually injured in the creation of this image.

Despite some recent opinion to the contrary….



It is highly premature to write the history of the airplane business as an obituary !