A Few Words First

Courtesy – Please mute your phone (*6 toggle)

Sep 14, Rick Dove, Agile Systems & Processes 105: Operational Awareness – Alert to Threats and Opportunities

Oct 12, Phillip Helle, speaking from Germany at 9:00-10:15 am NM time, Testing of Autonomous Systems – Challenges and State of the Art

Oct 28-29 – Socorro Systems Summit – 2-Day Collaborative Workshop Produced by Enchantment Chapter and New Mexico Tech

- **Date: Friday/Saturday, October 28-29.**
- **Place: New Mexico Tech, Socorro, NM.**
- **Fee: $100, students free.**
- **Keynote: INCOSE President-Elect Garry Roedler.**
- **Collaborative workshops to explore issues of interest.**
- **See Q3 Newsletter pages 1, 5, and 8 (16 topic descriptions).**
- **See flyer on Chapter website, Library tab.**

Nine Top Topics on Interest Survey

- **SE cultural transformation**
- **SE: multidiscipline enabler/art/science**
- **High performance teaming**
- **Fail-fast rapid innovation**
- **SoS evolutionary integrity**
- **Agile security**
- **Agile HW development infrastructure**
- **Organizational project-pursuit teaming**
- **Critical infrastructure resilience**

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting

10 August 2016 – 4:45-6:00 pm:

How Ready Are We to Consider Natural Systems Concepts

Larry Pohlmann, Strategics pohlmann@incose.org

Abstract: The biomimicry community would have us believe that the 'genius of Nature' is ready source of inspiration for a wide range of our engineering, design, and sustainability problems. Should the SE community accept—and act on—this belief? This presentation starts with a brief overview of the objectives, activities, and findings-to-date of the INCOSE Natural Systems Working Group (NSWG). A major premise of the NSWG is that the SE community can, and should, more routinely con-sider natural systems data and solution concepts. This presentation proceeds to systematically ad-dress our ***readiness*** to do so from seven different, but interdependent, perspectives:

- Bio-inspired design (BID) process definition acceptance and consistency—Is there sufficiency?
- Technology readiness scales and assessments—Do TRS's apply in the BID context?
- Capability maturity models—What can we learn from the maturity model advocates?
- Process and product development precedence analyses—Are NS considerations especially applicable for unprecedented functions or systems?
- Change management concepts—Will it help to use these types of techniques to encourage BID?
- Corporate and customer culture and innovation climates—Is organizational culture ready for this?
- Application scale and complexity—Do NS inspirations help in the kinds of work we do?

The presentation concludes with a set of recommendations to increase our readiness. Selected references are provided.

Download slides today-only from GlobalMeetSeven file library or anytime from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio

Dr. Lawrence D. Pohlmann brings the perspective of working in academia, government, and small and large business industry settings. His experience includes serving in a variety of engineering and management positions in systems engineering, software engineering, ergonomics, and business development. His domain experience includes primarily aero-space, information technology, and military systems. Doing business as *Strategics*, he continues to provide consulting support for business development efforts for several clients. He has led or participated in process improvement in several contexts. He has published extensively.

Pohlmann is a founding member of INCOSE (membership #9) and has served in several elected and appointed positions. He was the appointed one-person 'technical director and board' from 1991 to 1993 and helped to initiate and direct efforts for the first 10 working groups. He wrote the Council's first Strategic Plan in 1996.

Since January, 2013, he has focused the majority of his INCOSE efforts on participation with the Natural Systems Working Group.

Natural Systems Working Group

INCOSE International Council on Systems Engineering

How Ready Are We to Routinely Consider Natural Systems Data and Solution Concepts?

— Seven Interdependent Perspectives —

Presentation to the INCOSE Enchantment Chapter
August 10, 2016

Lawrence D. Pohlmann, Ph.D.
Owner, *Strategics*

Member/Advisor: Natural Systems Working Group (NSWG)
https://sites.google.com/site/incosenswg/

Abstract

The biomimicry community would have us believe that the 'genius of Nature' is readily applicable to a wide range of engineering, design, and sustainability problems.

The premise of the NSWG is that the SE community can, and should, more routinely consider natural systems data and solution concepts.

This presentation: first introduces the NSWG, and then addresses our *readiness* to consider natural systems data and solution concepts during the SE life cycle—from seven different, but interdependent, perspectives:

- **Process definition acceptance and consistency**
- **Technology readiness scales and assessments**
- **Capability maturity models**
- **Process and product development precedence analyses**
- **Change management concepts**
- **Corporate and customer culture and innovation climates**
- **Application scale and complexity**

The presentation concludes with a set of recommendations to increase our readiness. Selected references are provided.

Biography

Natural Systems Working Group

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Agenda

- What Are Natural Systems (NS)?
- Why Should SEs Care About NS?
- What Is The Natural Systems Working Group (NSWG)?
- Why Perspectives?
- What Perspectives?
- S-o-o-o?
- Where Can I Learn More?

‘Natural Systems’

Natural Systems Working Group

INCOSE International Council on Systems Engineering

Anything not human-made

- **All living things: flora and fauna everywhere**
- **All non-living things**
- **Terrestrial and cosmic events**

And the interactions among these—

According to the laws of nature

Natural Systems are the results/successes of evolutionary experimentation

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Bio-inspired Design (BID)
Consciously? Or By Coincidence?

Natural Systems Working Group

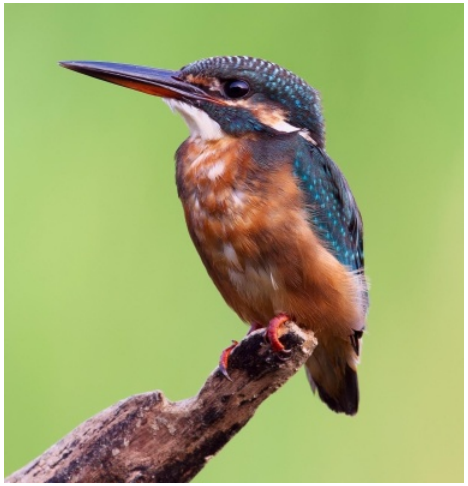
INCOSE International Council on Systems Engineering

COMMERCIAL AVAIATION
- Continuing bio-inspiration from birds for over 100+ years
- More than basic wing shape
- Above: level flight with 'landing gear stowed'

- Can you think of other bird-inspired aircraft structure and operations characteristics?

VELCRO® INDUSTRY
- Burrs sticking to clothes inspired new type of fastener
- Conceived in 1941
- Patented in 1950's
- World-wide, multi-million dollar industry

- Can you think of somewhere where Velcro did <u>not</u> work and was phased out?



BULLET TRAIN FIX
- The kingfisher bird: Inspiration for solving the 'tunnel boom' problem
- Significant engineering efforts required

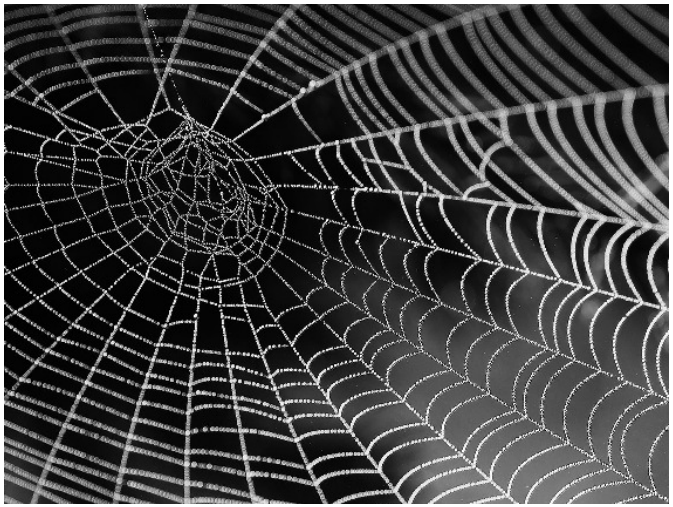
- Can you identify the analogy—and why it worked?

Bio-inspired Design (BID)—2
Consciously? Or By Coincidence? **

Natural Systems Working Group

INCOSE International Council on Systems Engineering

- Things four-legged ??? [Most of our furniture]
- Things four-wheeled ??? [Most of our vehicles]
- Fork lift ???
- Fans ???
- Fire and garden hoses ???
- Siphons ???



- Fishing nets ???
- Screens ???
- Cloth ???
- Architectural concepts ???
- Suspension bridges ???
- Very high strength materials ???

- Armor ???
- Armored vehicles ???
- Military tactics ??? [E.g., Roman 'testudo' formation]
- Riot squad tactics ???

***** Sometimes it is hard to tell which***

Nature's 'Genius'
— Nature is Very Good at a Lot of Things —

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- An integrated, no waste system
- Operation in a wide range of environments
- High strength, low volume, low weight materials
- Locomotion in creative ways across a wide range of environments
- Diverse, extremely capable sensing
- Materials creation/recycling at low pressures, temperatures, and toxicity levels
- Energy conversion and utilization
- Real time adaptation
- Reproduction and growth
- Evolution to survive and succeed

Aren't these desirable traits for our engineered systems?

BID Successes (Examples)

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- **Have gone far beyond airplanes, Velcro, bullet trains**
- **Are numerous and diverse and increasing**
  - **Interface Carpet—large scale sustainability, camouflage, Lotusan—self cleaning paint, ChromaFlair—color changing paint, WhalePower turbine blades, beetle-inspired water collection, the "termite building," Sharklet Technologies—bacteria transfer avoidance, bendable glass, Fibonacci spiral inspired pump and fan blades, Evocative—mushroom inspired, custom grown, bio-degradable packaging materials**
- **Are easily located online**
  - **Search on 'biomimicry successes'**

Doesn't the number and diversity of BID successes provide a foundation for routine NS consideration?

Predictions by Brilliant People

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"We're going to see in surprisingly short order that biological inspiration and biological processes will become central to engineering real systems. It's going to lead to a new era in engineering."

Charles M. Vest (1941-2013), former President of MIT (2009)

"I think the biggest innovation of the twenty-first century will be the intersection of biology and technology. A new era is beginning, just like the digital one . . . "

Steve Jobs (1955-2011), former Apple CEO (2011)

Is routine consideration of NS inevitable?

Agenda

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Natural Systems Working Group

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<u>NSWG Goal</u>: Influence SE processes to routinely and appropriately consider natural systems solution concepts and data throughout the SE life cycle. Help SE teams learn how to ask:

"What would nature do?"

<u>Recent/Current Special Initiatives</u>:

1. **INSIGHT Special Feature on Natural Systems (April 2016)**
2. **SEBoK article on 'good/best' practices for considering NS as part of SE processes**
3. **Article on Reference Architectures related to NS**

https://sites.google.com/site/incosenswg/

nswg-info@incose.org

Come and Join Us ! !

Started January 2013
—The Time Was Right!—

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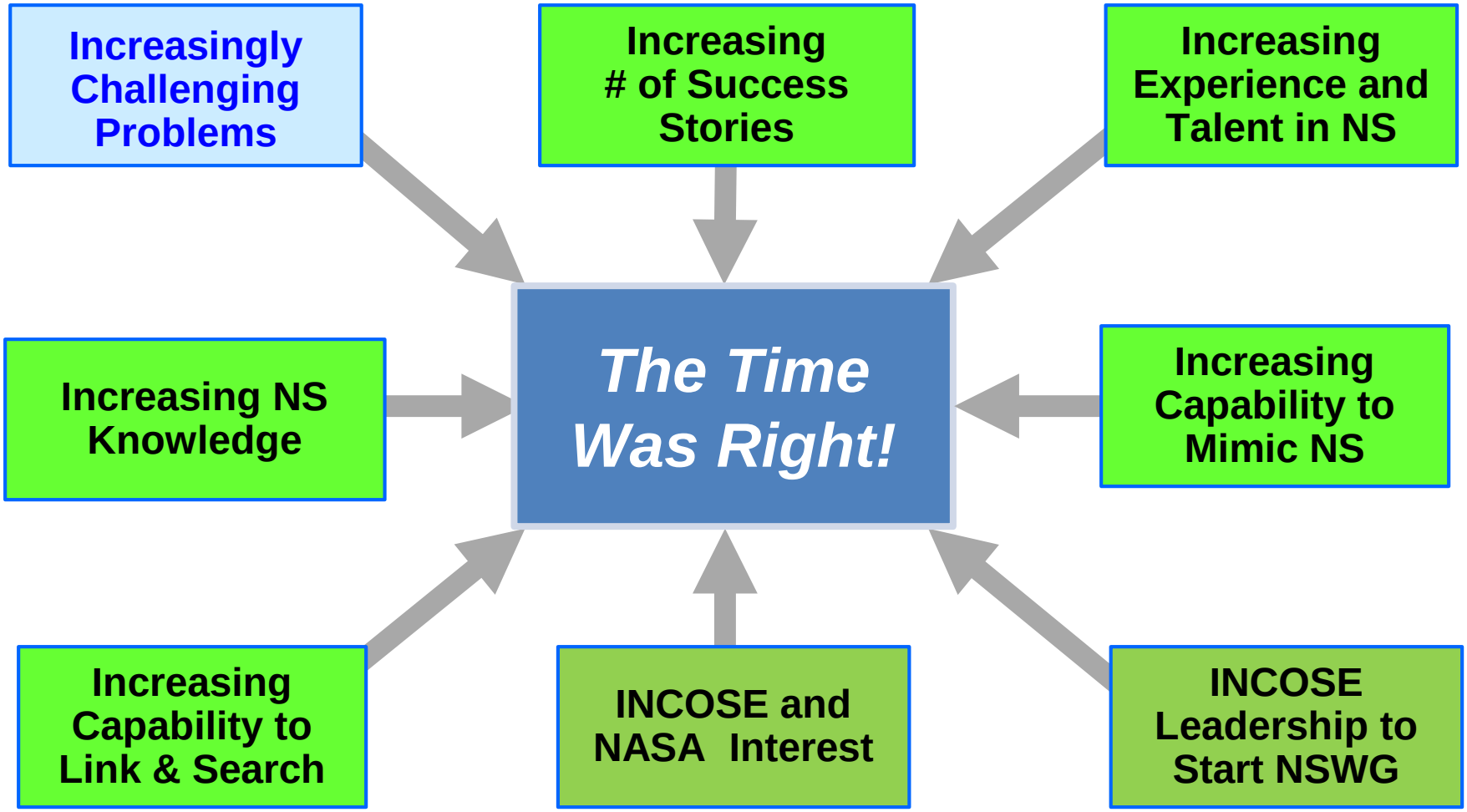

NSWG Activities: Webinars (Sample Below), Weekly Meetings, Initiatives

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- "Systematic Design of Biologically Inspired Engineering Solutions." Jacquelyn K.S. Nagel. James Madison University—Webinar 2015-3. A process examination example.
- "Jellyfish Node and Colonies: Modeling Biological Structure and Behavior, System Architecture Design and Implementation." Shashank Priya et al. Virginia Polytechnic Institute and State University—Webinar 2014-4. A robotics research example.
- "Gecko-grippers for space – from the animal to Zero-g Flight Test." Aaron Parness. NASA Jet Propulsion Laboratory—Webinar 2014-7. A NASA research project example.
- "WYSS Institute for Biologically Inspired Engineering." Mary Tolikas, Harvard University—Webinar 2013-4. A BID business incubator example.

- "The AskNature Website and The Biomimicry Taxonomy." Ethan Smith, The Biomimicry Institute—Webinar 2015-8. A tools example.
- "Compound Eyes—They Might Not Do What You Think." Jerome B. Franck. US Army Night Vision & Electronic Sensors Directorate—Webinar 2015-1. A sensor study and modeling example.
- "Natural Inspiration for Unnatural Characters in Creative Cinema." Phil Tippet. Tippett Studio—Webinar 2015-6. An entertainment industry use of BID example.
- "Georgia Tech's Center for Biologically Inspired Design." Jeannette Yen. Georgia Tech University—Presentation at International Workshop 2015. A BID interdisciplinary training and research program example.

The NSWG has sponsored a wide range of NS-related webinars. See the NSWG site for list, slides, recordings

INSIGHT April 2016
Special Feature on Natural Systems

Natural Systems Working Group

INCOSE International Council on Systems Engineering

- **13 articles on SE/NS-related topics**
- **Available via Connect**
- **Articles also available on the NSWG public site**

Recommended reading !

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Using Multiple Perspectives—Can Help Us Understand Reality

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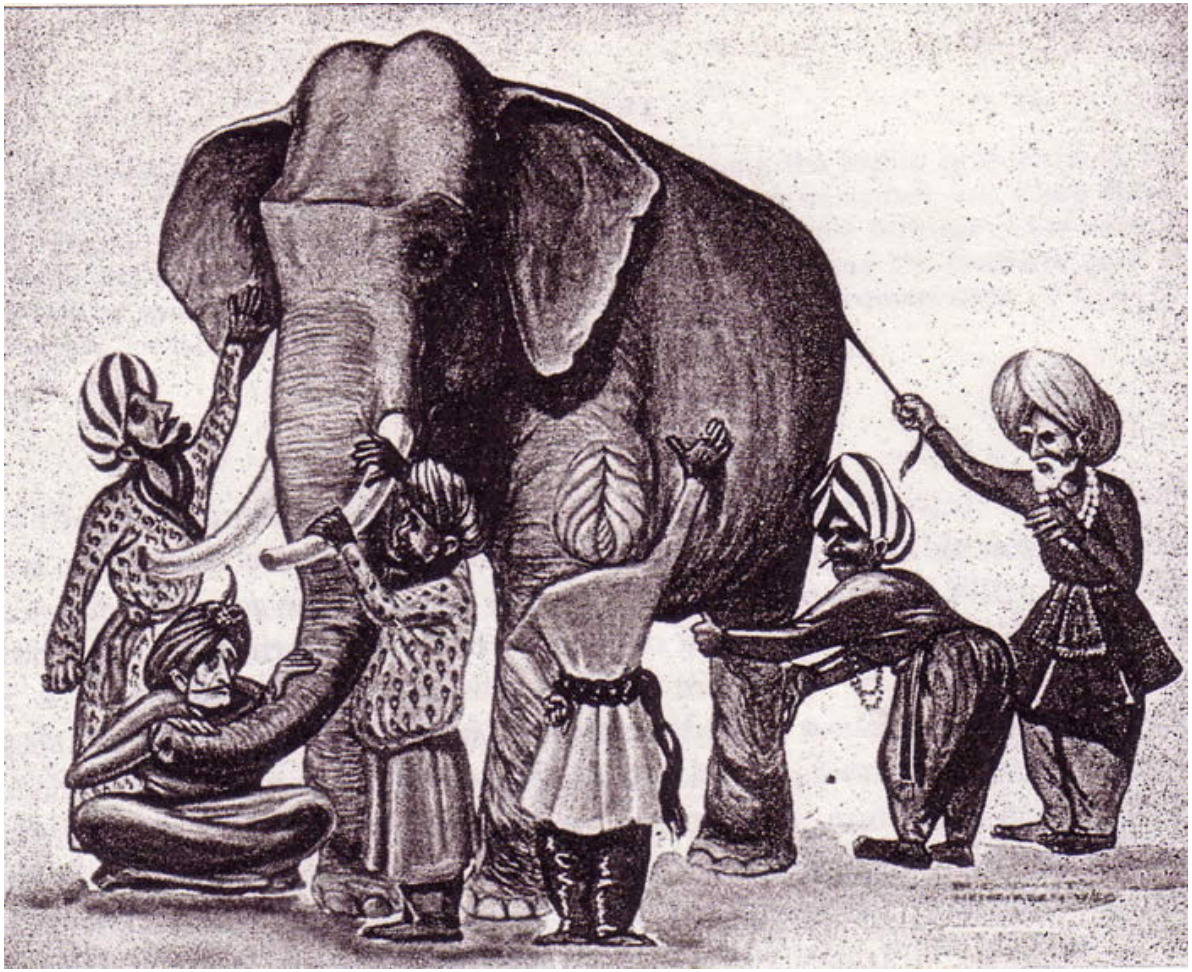

Examination from multiple perspectives has been around a long time

Multiple Perspectives— Are Widely Used in Engineering

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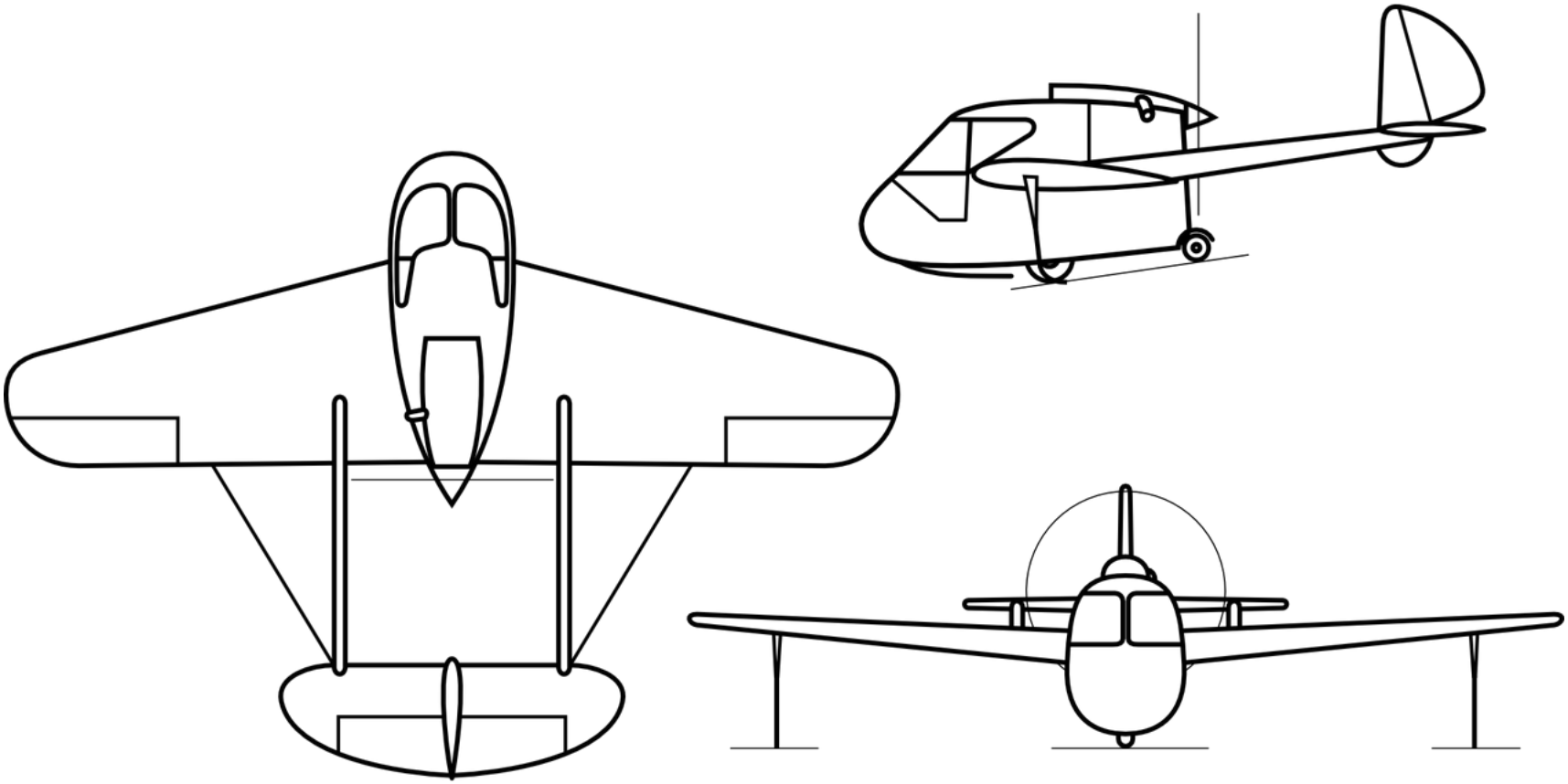

Remember the basics?

Top/Plan View + Side View + Front/Elevation View

Understanding Enterprise Architecture —The Zachman Framework

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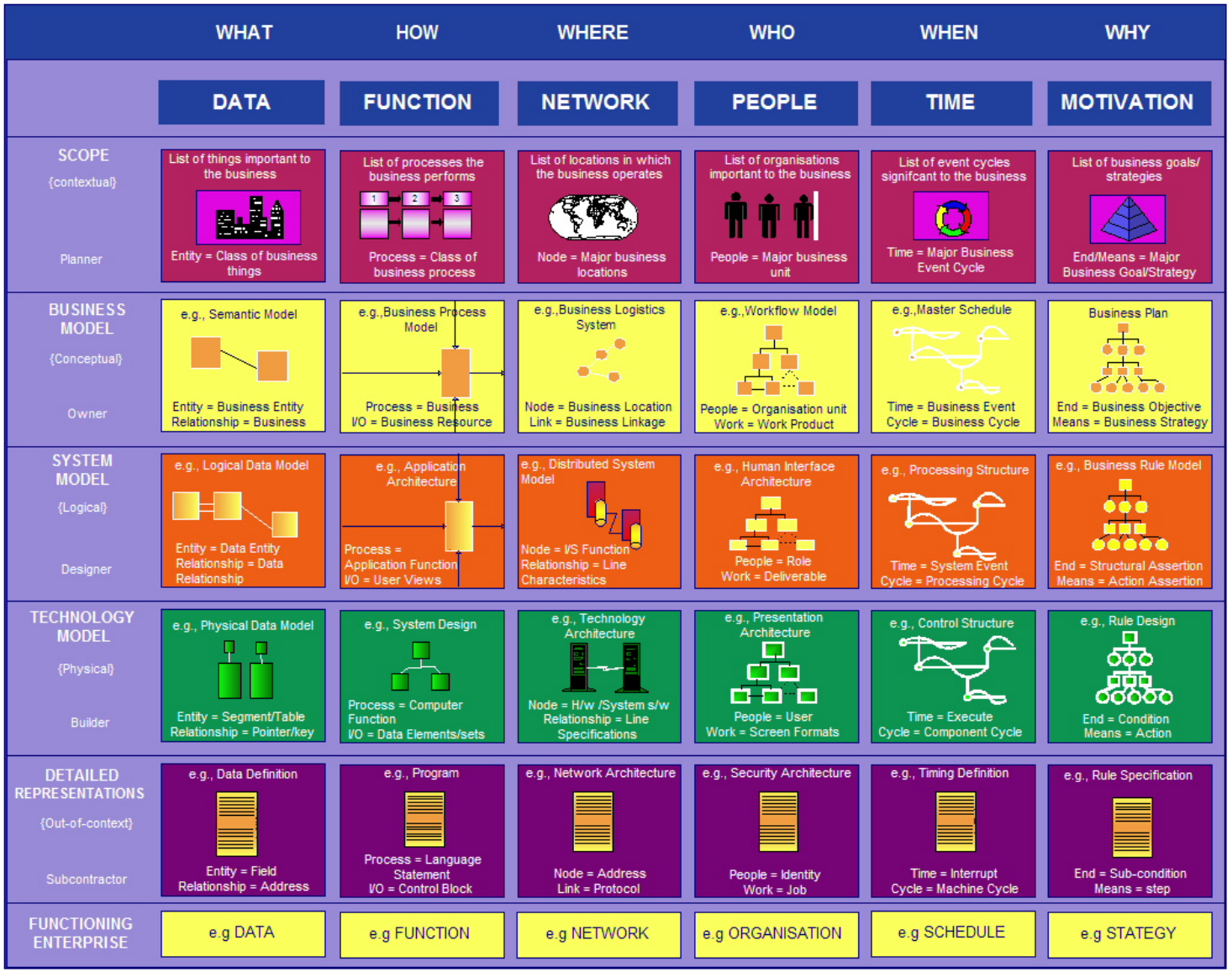

Another famous multiple perspec-tives ex-ample

Is there an SE/NS equivalent?

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Interdependent Perspectives—
To Help Assess NS Consideration Readiness

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1. **Process definition acceptance and consistency**
2. **Technology readiness scales and assessments**
3. **Capability maturity models**
4. **Process and product development precedence analyses**
5. **Change management concepts**
6. **Corporate and customer culture and innovation climates**
7. **Application scale and complexity**

These seven perspectives can help us examine the 'reality' of our readiness for routine NS consideration

1. Process Definition Acceptance and Consistency

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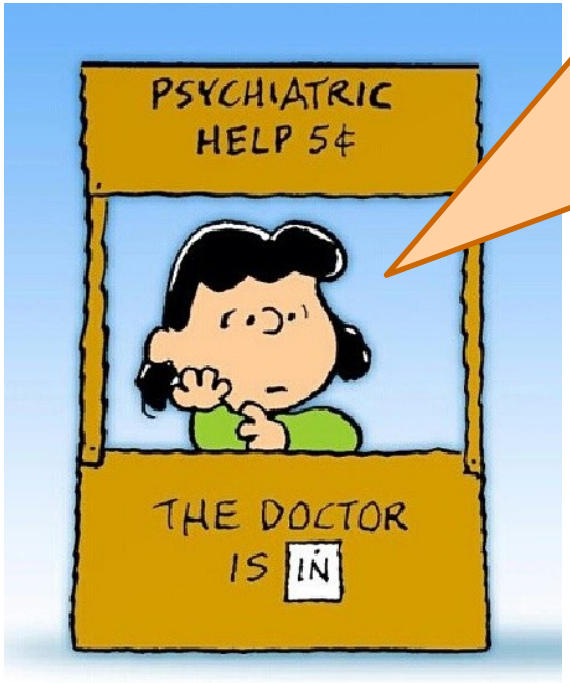
- What is the BID process?
- How much agreement is there on this?



*"Let me get this straight. You want to build a new discipline of biologically inspired design (BID) — but your terminology and processes are inconsistent, and there are few experts, and few communities of practice, and little theory or methodology, and no scientific discipline! And you want me to help you??***

Good Grief!!!"

**Adapted from Goel, NSWG webinar, December 2013

There is terminology and process definition work to do!
It will take a while!!
Five years? 10? More?
How much consistency do we need?

2. Technology Readiness Level Scales and Assessments

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US Department of Energy Technology Readiness Levels***

- TRL9—Actual system operated over the full range of expected mission conditions
- TRL8—Actual system completed and qualified through test and demonstration
- TRL7—Full-scale, similar (prototypical) system demonstrated in relevant environment
- TRL6—Engineering/pilot-scale (prototypical) system validation in relevant environment
- TRL5—Laboratory scale, similar system validation in relevant environment
- TRL4—Component and/or system validation in laboratory environment
- TRL3—Analytical and experimental critical function and/or characteristic proof of concept
- TRL2—Technology concept and/or application formulated
- TRL1—Basic principles observed and reported

***Publication DOE G 413.3-4A

Wikipedia discusses multiple Technology Readiness Level (TRL) scales—i.e., NASA, DoD, DOE, the European Space Agency, and the Oil and Gas industry

https://en.wikipedia.org/wiki/Technology_readiness_level

- Powered flight experiments
- Self driving car experiments

Discussing BID approaches using TRL terminology may make them more credible with the SE community

3. Capability Maturity Models

[https://en.wikipedia.org/wiki/Capability_Maturity_Model#CMMI]

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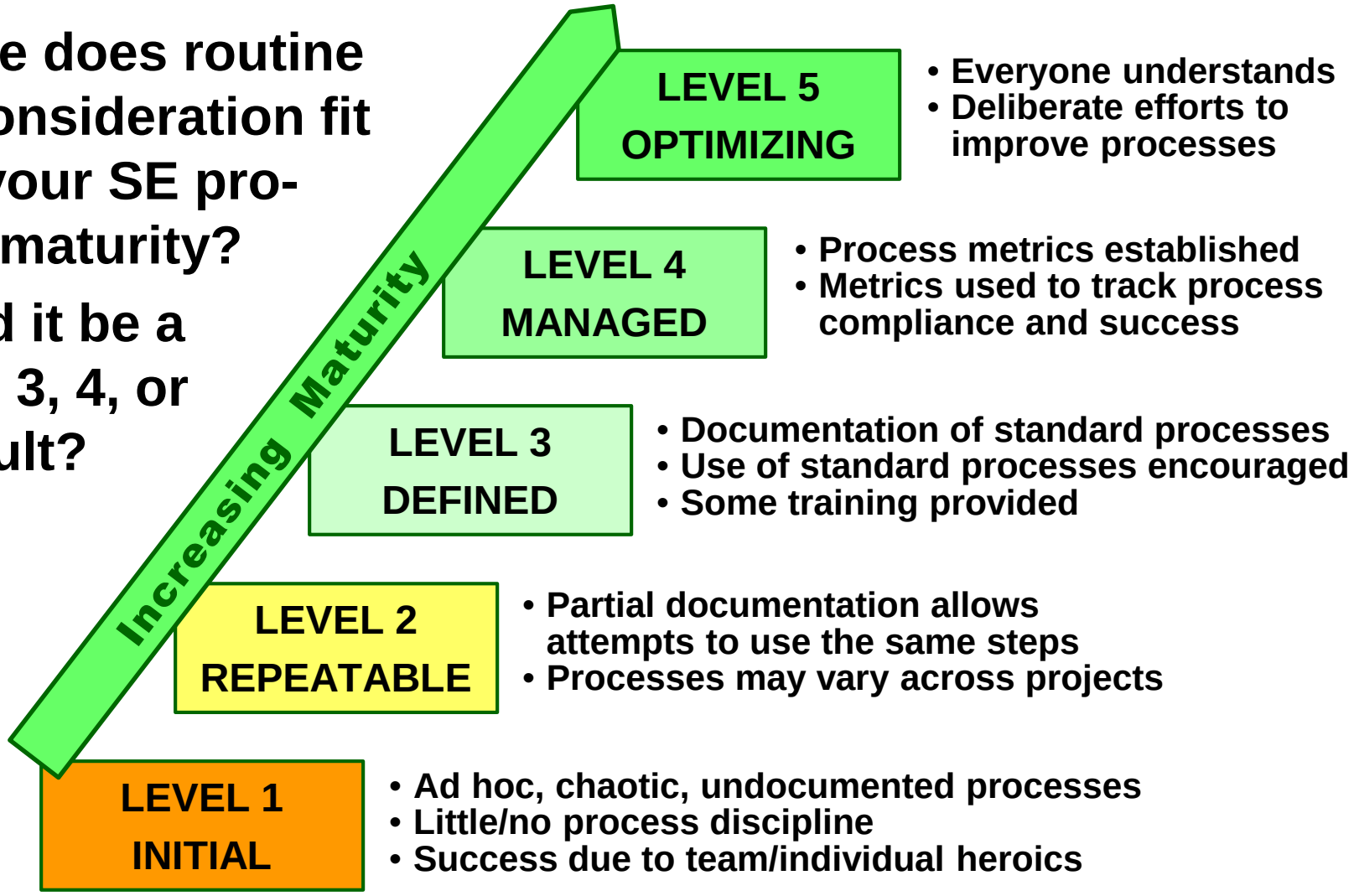
- **Where does routine NS consideration fit into your SE process maturity?**
- **Could it be a Level 3, 4, or 5 result?**



4. Process and Product Development Precedence Analyses

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Precedence = the fact of preceding in time, antedating

- **Has anyone done this before?**
- **Has our company done this before?**
- **Has our project team done this before?**
- **Which concepts/systems/subsystems are new?**
- **Is there expertise that we can access?**
- **Has our customer specified/acquired/used these types of products/systems before?**

"Precedence" may apply to domain, tools, process— as well as system, application, or design

Precedents reduce 'cognitive distance' to a goal

5. Change Management Concepts

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Moving to routine consideration of NS is a *change* — and can/should be handled with change management methods: e.g., via Kotter's eight stage process**

- Establishing a Sense of Urgency
- Creating the Guiding Coalition
- Developing a Vision and Strategy
- **Communicating the Change Vision**
- Empowering Employees for Broad-Based Action
- Generating Short-Term Wins
- Consolidating Gains and Producing More Change
- Anchoring New Approaches in the Culture

Key!
Needs lots of time and effort!!

****Kotter, *Leading Change,* Harvard Business School Press, 1996**
See also Prosci.com (for free stuff), or 'Change Management' in Wikipedia

6. Corporate and Customer Culture and Innovation Climates

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Some characteristics facilitate moving toward routine NS consideration—while others tend to be barriers

7. Application Scale and Complexity

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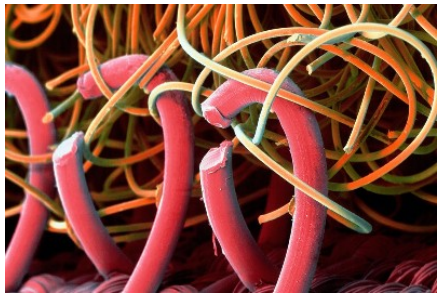
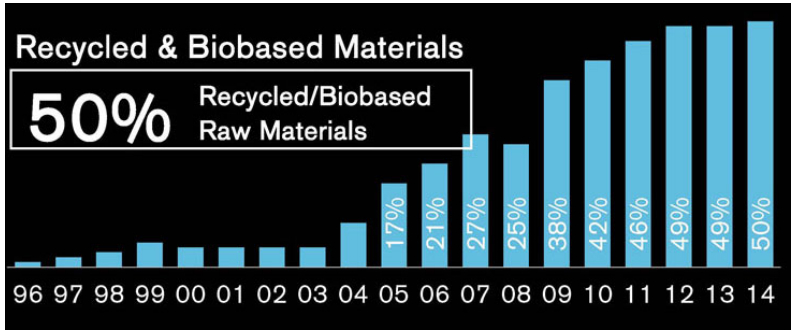


Velcro (Curiosity → Quick inspiration)
- Opportunity driven: Why do burrs stick to my clothes?
- Small scale, narrow focus (Common to many BID successes)
- Nearly immediate solution vision
- Long, complex materials engineering problem ~10 years
- 50+ years old, has now achieved diverse, world-wide usage

Shinkansen (Japanese bullet train) (An excellent example!)
- Requirement driven: tunnel boom and vibration problems
- Larger scale problem with multiple situation dimensions
- Extended search for solution, multiple trade studies
- Recognized as situation of dealing with pressure change
- Simulated solution concepts in laboratory



Interface Carpet (High Complexity)
- Vision driven: total sustainability
- Very large and complex *challenge*
- Long term, incremental goals (25+ yrs)
- World-wide company participation
- Wide range of bio-inspirations
- Entire company is NS sensitive

There is wide spectrum of scale and complexity — and spectrum position drives NS consideration approaches

Interface Carpet's Mission Ø —
Zero Impact, Total Sustainability by 2020

[www.interfaceglobal.com/sustainability/interface-story.aspx]

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- ***Front 1 – Eliminate Waste*:**
  - **Eliminate all forms of waste in every area of business.**
- ***Front 2 – Allow Only Benign Emissions:***
  - **Eliminate toxic substances from products, vehicles, and facilities.**
- ***Front 3 – Renewable Energy:***
  - **Operate facilities with 100% renewable energy.**
- ***Front 4 – Close The Loop:***
  - **Redesign processes and products to close the technical loop using recovered and bio-based materials.**
- ***Front 5 – Use Resource Efficient Transportation:***
  - **Transport people and products efficiently to eliminate waste and emissions.**
- ***Front 6 – Sensitize Stakeholders:***
  - **Create a culture that uses sustainability principles to improve the lives and livelihoods of all of our stakeholders.**
- ***Front 7 – Redesign Commerce:***
  - **Create a new business model that demonstrates and supports the value of sustainability-based commerce.**

Interface Carpet is a good example of a visionary, coordinated, long-term, multiple front, corporate-wide BID effort

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So: Are We Ready?
— Point and Counterpoint —

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Yes, We Are!

- ✓ There are numerous, diverse BID successes
- ✓ SEs are capable of working across disciplines
- ✓ SEs are capable of integrating in new technologies
- ✓ SE community is willing, able to adapt, improve processes
- ✓ BID acceptance is spreading
- ✓ NS/BID data, advocacy, R&D, and training are expanding
- ✓ Advances in computational capability, miniaturization, and materials science make real considerations feasible

No, Not Yet!

- ✖ BID successes tend to be small—and mostly irrelevant to the SE community
- ✖ BID is still largely an academic vs. practical discipline
- ✖ BID as a process remains too ill-defined for routine use
- ✖ BID is in the hype phase, it is not clear that it will succeed on 'SE scale' problems
- ✖ Most large companies have too much inertia and not enough $$$ to seriously and routinely consider embracing BID at this time

All of these statements are 'defendable'

Pohlmann's SE/NS Manifesto

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- We have complex, hard problems to solve
- Nature has a wide range of elegant solutions
- Some of natures solutions ***may*** be applicable
- There are BID success stories we can learn from
- SE processes ***can*** grow to appropriately and routinely consider concepts/data from nature
- Increasing computational, materials sciences, and miniaturization capabilities are enablers

It starts with the appropriate and timely interdisciplinary communications

Recommendations

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- ***Accept as inevitable that routine consideration of NS will grow over time***
- ***So Go For It! Use the perspectives to shape your adoption approach and priorities***
- ***Sell the vision! But be cautious of the dangers of 'irrational exuberance'***
- ***Pohlmann's position: Build expertise, then begin routine consideration—judiciously!***

By system/product, select one of three options—

  - ***NS not relevant → look no further at this time***
  - ***NS may be relevant → do more trade studies***
  - ***NS is relevant → dig deep, shape, use wisely***

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Interesting and Informative Free Stuff

Natural Systems Working Group

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- **Benyus. J. M. "Biomimicry Primer." Downloadable from: http://biomimicry.net/about/ biomimicry/a-biomimicry-primer/**
- ***Zygote Quarterly*. http://zqjournal.org/**
  - **A free on-line journal**
  - **Goes beyond titillating headlines**
- ***INSIGHT* 19:1 April 2016**
  - **Special Feature on Natural Systems**

Two Really Good Books — Not Free

Natural Systems Working Group

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- **Benyus, J. M. 1997, 2002. *Biomimicry – Innovation Inspired by Nature*. New York, US-NY: William Morrow. [Hardback 1997, Paperback 2002] $**
  - **Informative, interesting and entertaining**
  - **Review submitted to INSIGHT**
  - **The review is also on the NSWG site**
- **Bar-Cohen, Y., Ed. 2011. *Biomimetics: Nature-Based Innovation*. Boca Raton, US-FL: CRC Press. $$$**
  - **A review of this book is in INSIGHT Volume 17, Issue 2, July 2014, 64-65**
  - **The review is also on the NSWG site**

A Few Good URLs and Some Candidate Search Terms

Natural Systems Working Group

INCOSE International Council on Systems Engineering

- **Biomimicry 3.8. http://biomimicry.net/**
- **Biomimicry Institute. http://biomimicry.org/**
- **Ask Nature. http://asknature.org**
- **Interface Carpet—Mission Ø.**

  www.interfaceglobal.com/sustainability/interface-story.aspx

- **Candidate search terms**
  - **Benyus + talks, videos**
  - **Biomimicry or bioinspired design + successes, challenges, failures, hype, education, engineering, cool stuff, research, startups, examples, videos, books, products, or processes**

There is a lot out there. Follow your interests!

BID and SE:
Three Good Examples of Working Together

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- **Overview of the Wright brothers invention process**
  - http://wright.nasa.gov/overview.htm
- **Bullet train 'tunnel boom' problem**
  - https://www.greenbiz.com/blog/2012/10/19/how-one-engineers-birdwatching-made-japans-bullet-train-better
  - See also the NSWG site Success Story
- **Eastgate Centre (the 'termite building')**
  - https://www.foe.co.uk/news/eastgate_centre_harare_termite_mound_41325

Look for case studies that talk to complexity and engineering issues

? ? ? Questions ? ? ?

Natural Systems Working Group

INCOSE International Council on Systems Engineering

THANK YOU!!

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See the INCOSE INSIGHT Special Issue on Natural Systems
Volume 19, Issue 1 April 2016

Come join the NSWG, and learn to ask: *What would nature do?*

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Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/enchant_08_10_2016

www.surveymonkey.com/r/enchant_08_10_2016

Look in GlobalMeet chat box for cut & paste link.

Slide presentation can be downloaded now/anytime from:

The library page at: www.incose.org/enchantment

Recording will be in the library tomorrow.