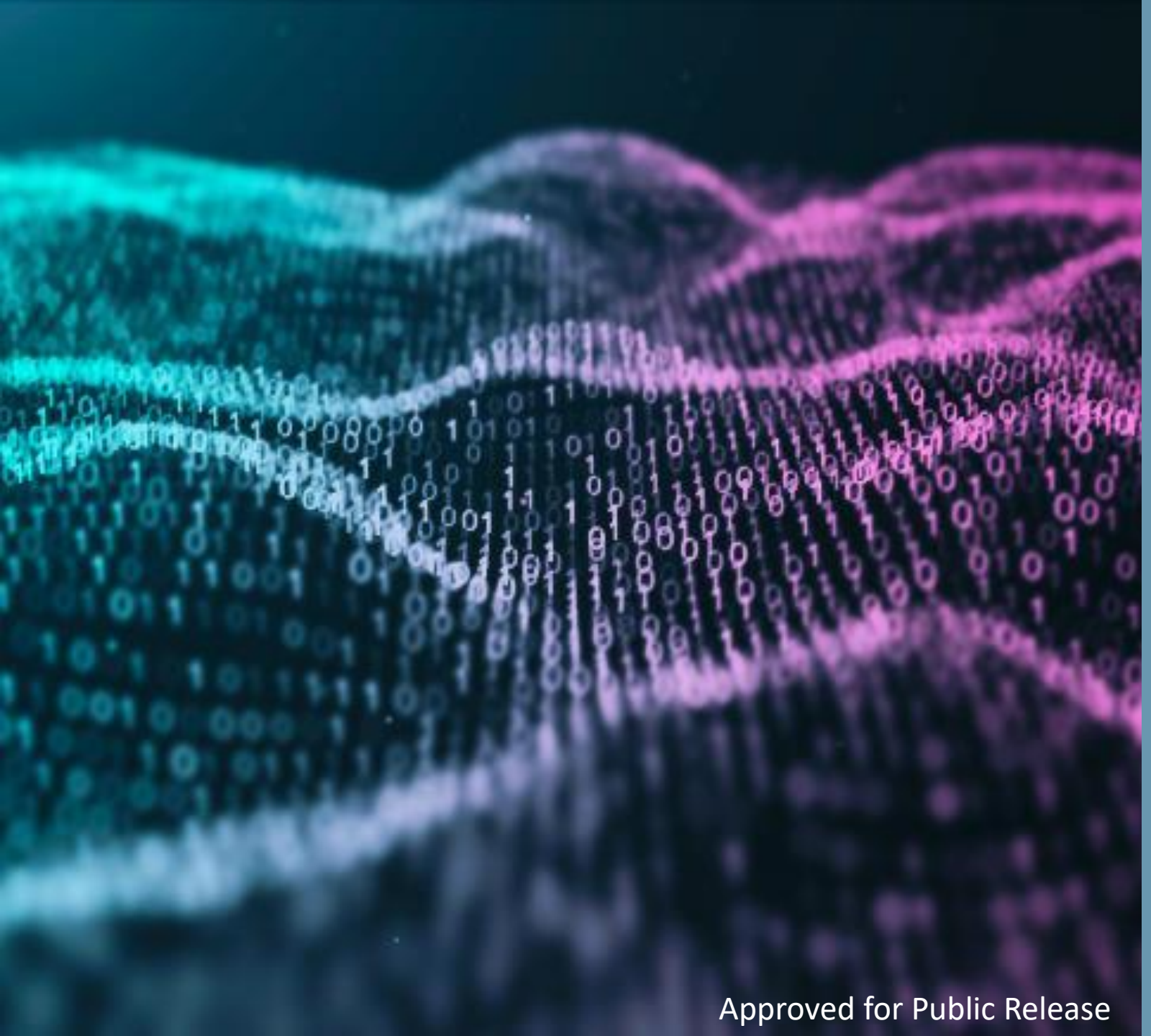


Mission Engineering and Complexity

DAVE CHESEBROUGH

Agenda

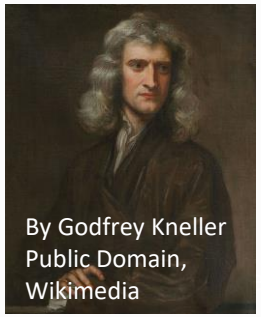
- Complexity Theory – Background and Applications
- Mission Engineering Context
- Relationship to Systems Engineering
- A Look Ahead
- Conclusion

Complexity Sciences

Driven by computational science

Branched into five distinct lines of research

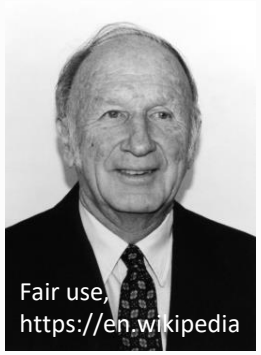
17th Century **Science of Dynamics**



Isaac Newton

Ability to predict motion based on Newtonian mechanics

20th Century **Chaos**



Edward Lorenz, MIT

Computer Weather Modeling

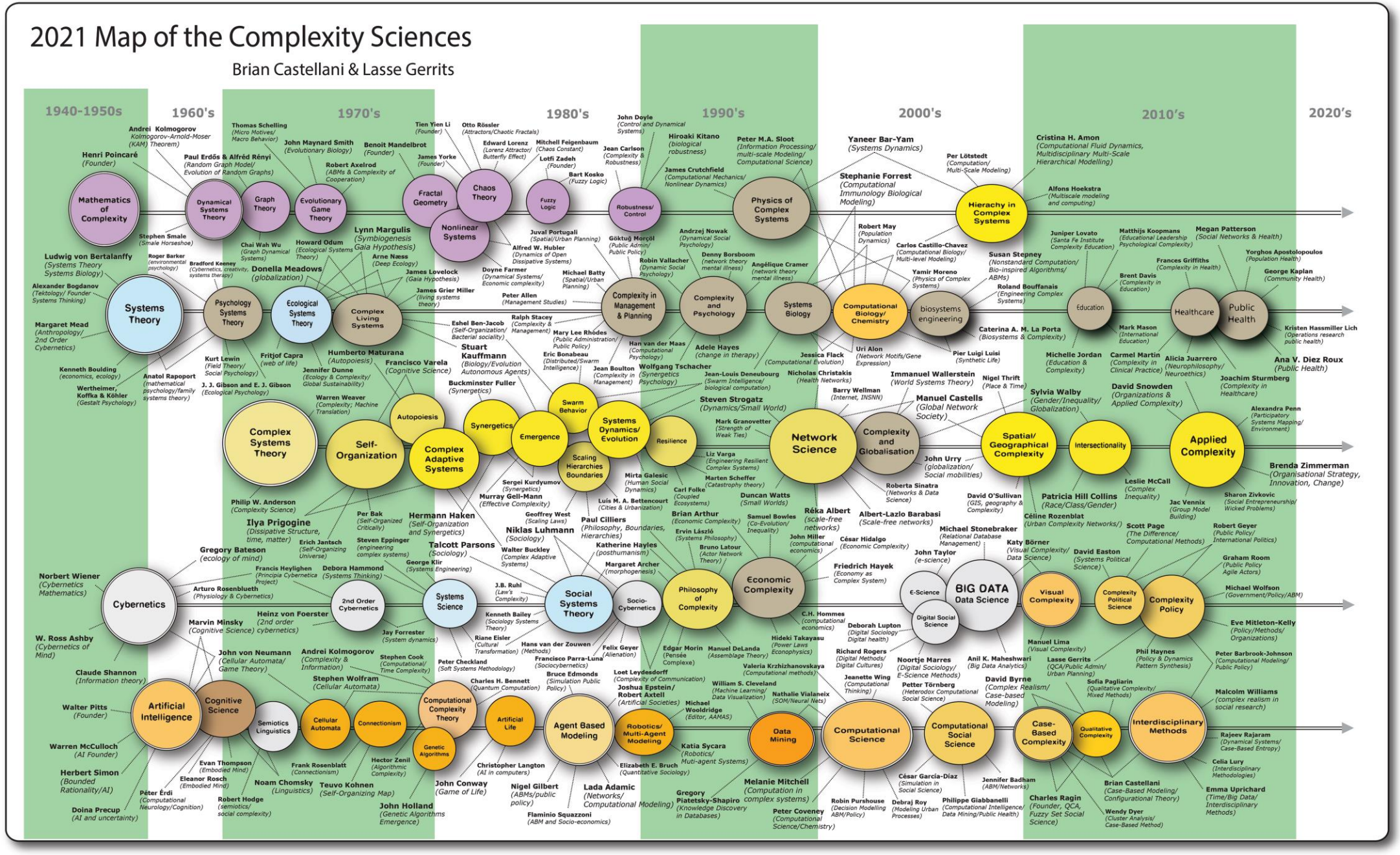
- deterministic nonlinear systems
- Butterfly effect
- deterministic nature of these systems does not make them predictable

Complexity

Theoretical Computer Science and Information Theory

- Nonlinear
- Emergent, non-predictable behavior
- Transitions between order and disorder

Chaos and Complexity both feature non-linearity



Castellani, B. (2018) Map of the Complexity Sciences. Art & Science Factory. https://www.art-sciencefactory.com/complexity-map_feb09.html

Complicated Systems

- Engineered and Deterministic
- Many interacting components
- Dependencies
- Predictable, known, planned and linear behavior

THESE

must function within

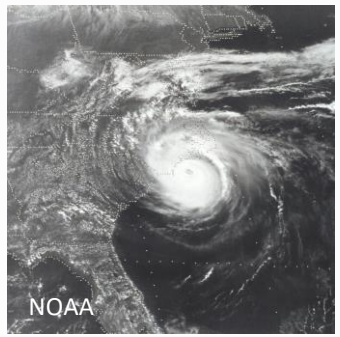
Complex Systems

- Unordered and Stochastic
- Many interacting components
- Dependencies, competitions, relationships
- Exhibit nonlinearity, emergence, self-organization, adaptation

THESE

Photo by Ralph Chang

Photo by Michał Ludwiczak



NOAA

Systems Thinking

Focus on structure, relationships, interdependence

Thinking systematically about the properties of the whole being different from the parts

Define the end-state and work to fill the gaps

Complexity Theory

- the study of complex dynamic, non-linear, self-organizing, open, emergent, sometimes chaotic and adaptive systems (Larsen-Freeman, 1997)
- There are limits to what can be anticipated given current knowledge
- We don't know what we don't know (COVID-19 results if chip shortage)

The search for simple – if not simpleminded – solutions to complex problems is a consequence of the inability to deal with complexity

- Russell L. Ackoff, Wharton School

“There are known knowns — there are things we know we know. We also know there are known unknowns — that is to say, we know there are some things we do not know. But there are also unknown unknowns, the ones we don’t know we don’t know.”

- Donald Rumsfled, Secretary of Defense, February 2002

“The absence of evidence is not evidence of absence”

Complexity Theory – Current

Santa Fe Institute

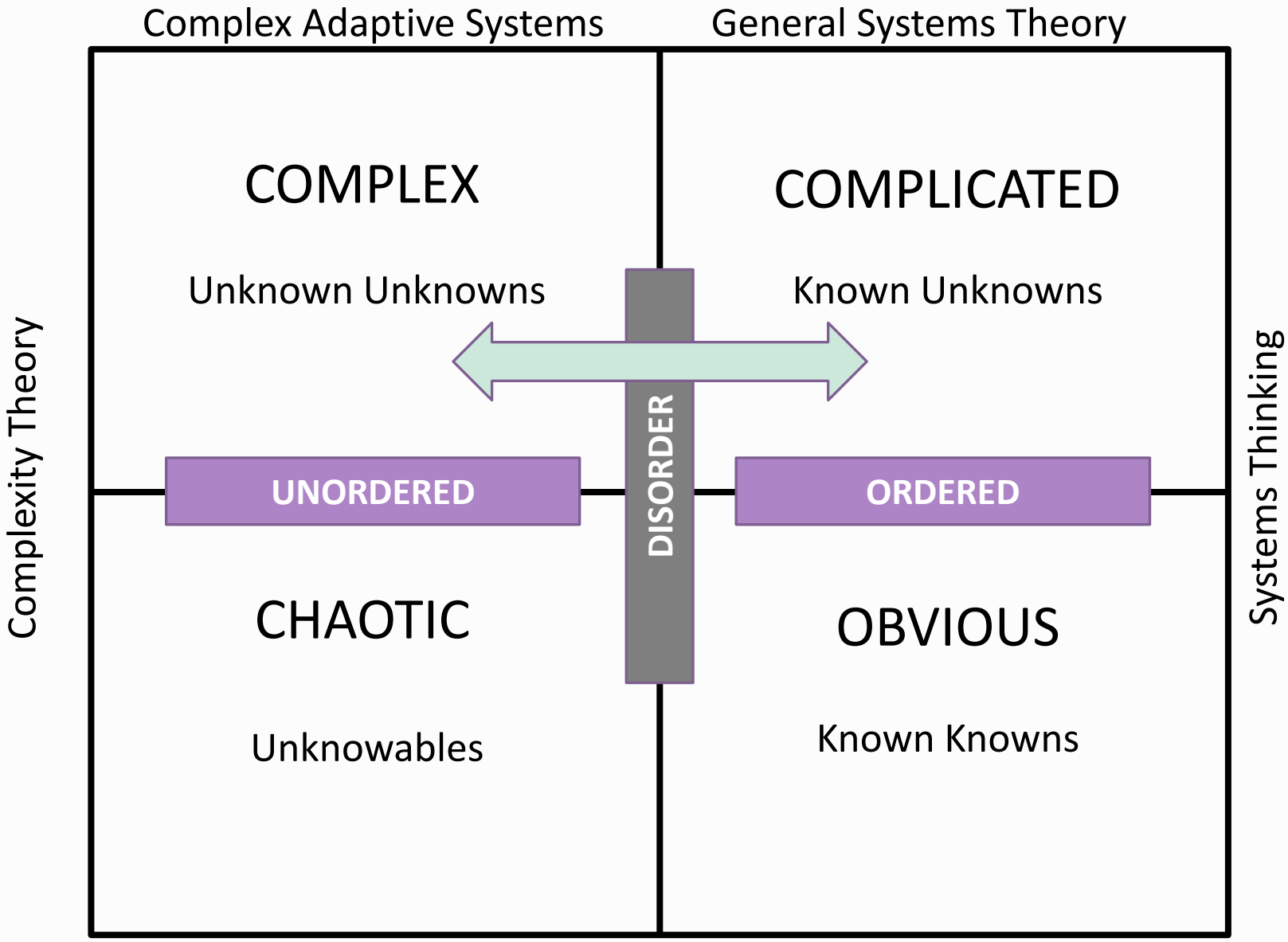
- Founded 1984
- First research institute dedicated to the study of complex adaptive systems
- Focus on complex physical, biological, social, cultural, technological areas

Cynefin Framework

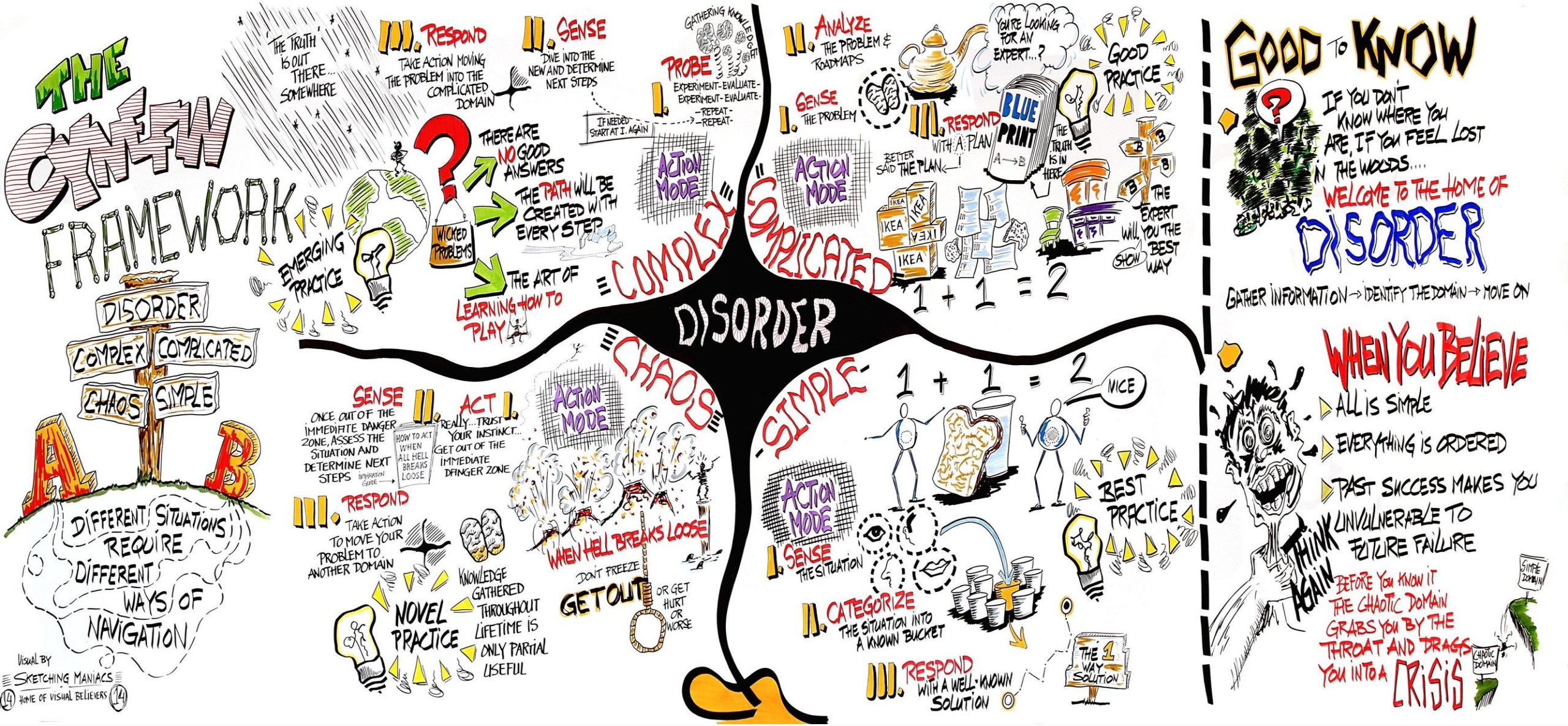
- Developed in 1999 by Dave Snowden, IBM Global Services
- Draws on research into systems theory, complexity theory, network theory and learning theories
- Conceptual framework to aid in decision-making

Cynefin Framework

- Started in Knowledge Management
- Framework for contextualization
- Used to frame multiple perspectives around a specific event
- Scenario planning and wargaming



Kurtz and Snowden, IBM, **2003**



By Edwin Stoop (User:Marillion!!62) - [1], CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=53810658

Mission

a duty assigned to an individual or unit

Mission Integration Management

the synchronization, management, and coordination of concepts, activities, technologies, requirements, programs, and budget plans to guide key decisions focused on the end-to-end mission.

MISSION ENGINEERING CONSUMERS

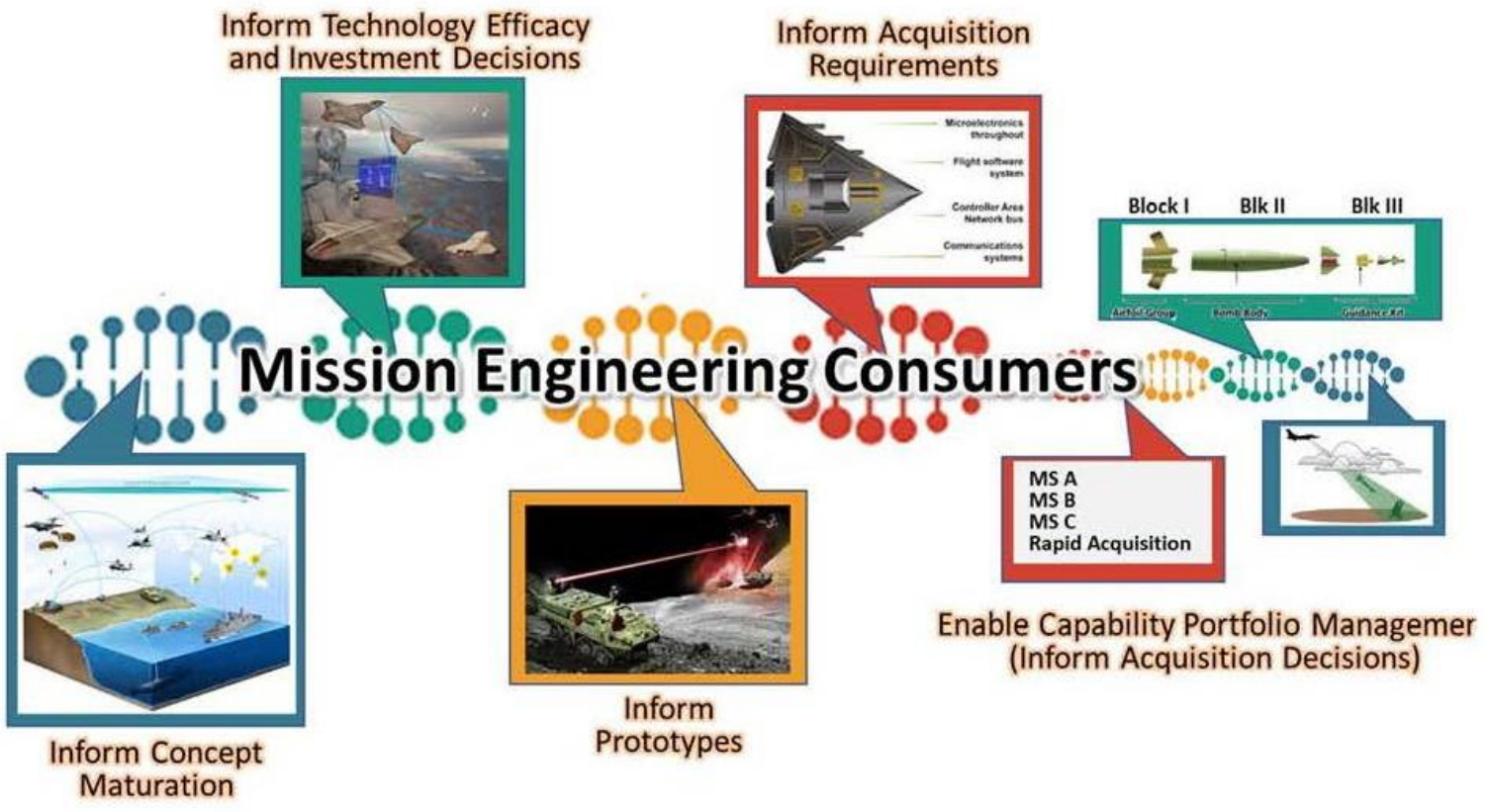


Figure 1-1. Consumers of Mission Engineering Outputs



Mission Engineering

the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects

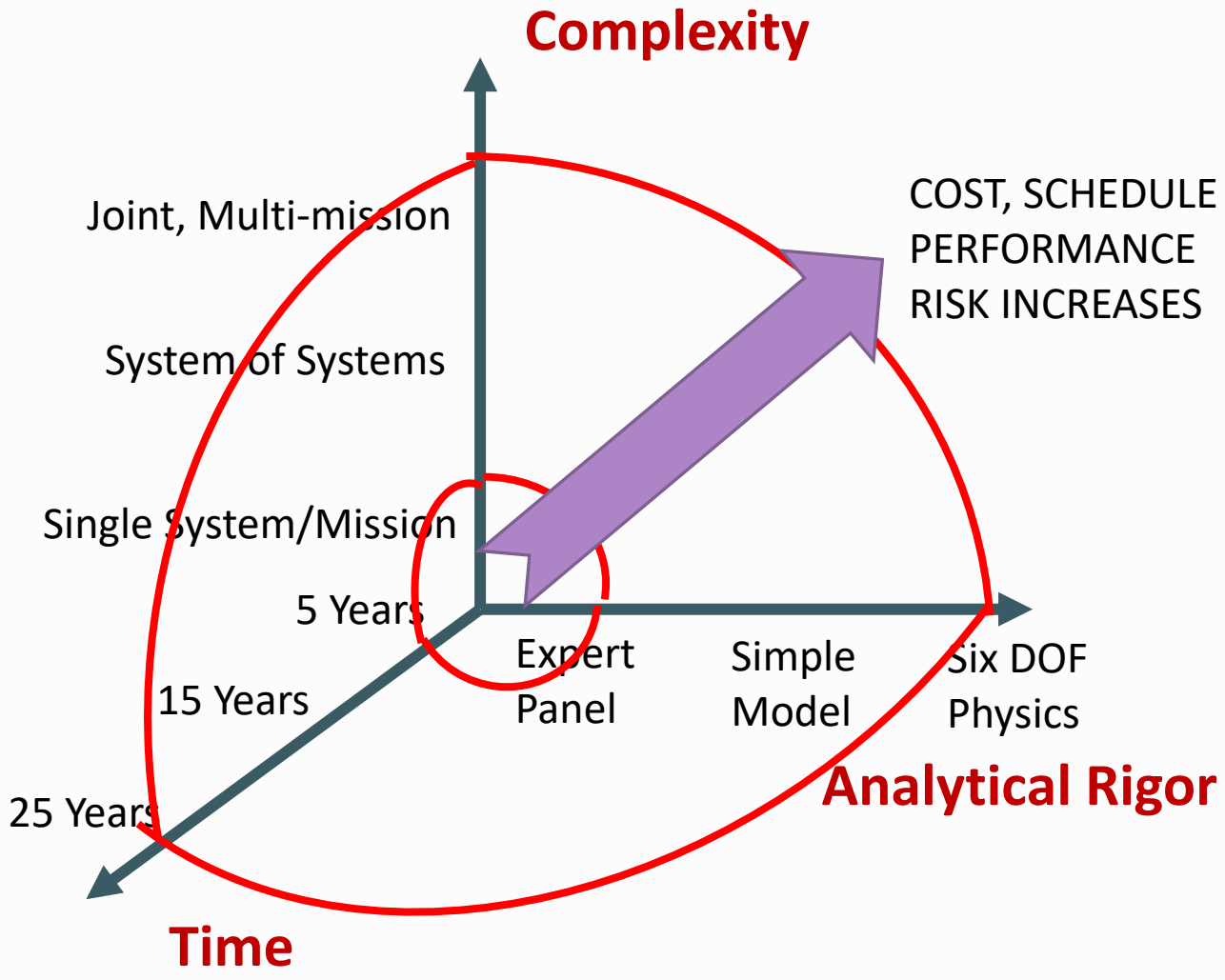
The right thing, at the right place, at the right time

Mission Engineering Balance

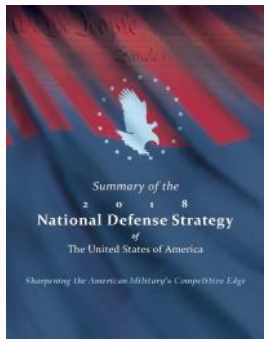
Overreach on any axis will impact

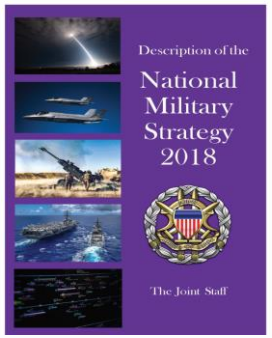
- Confidence in ME products
- Validity of analysis
- Availability of data

Three Axes of Mission Engineering

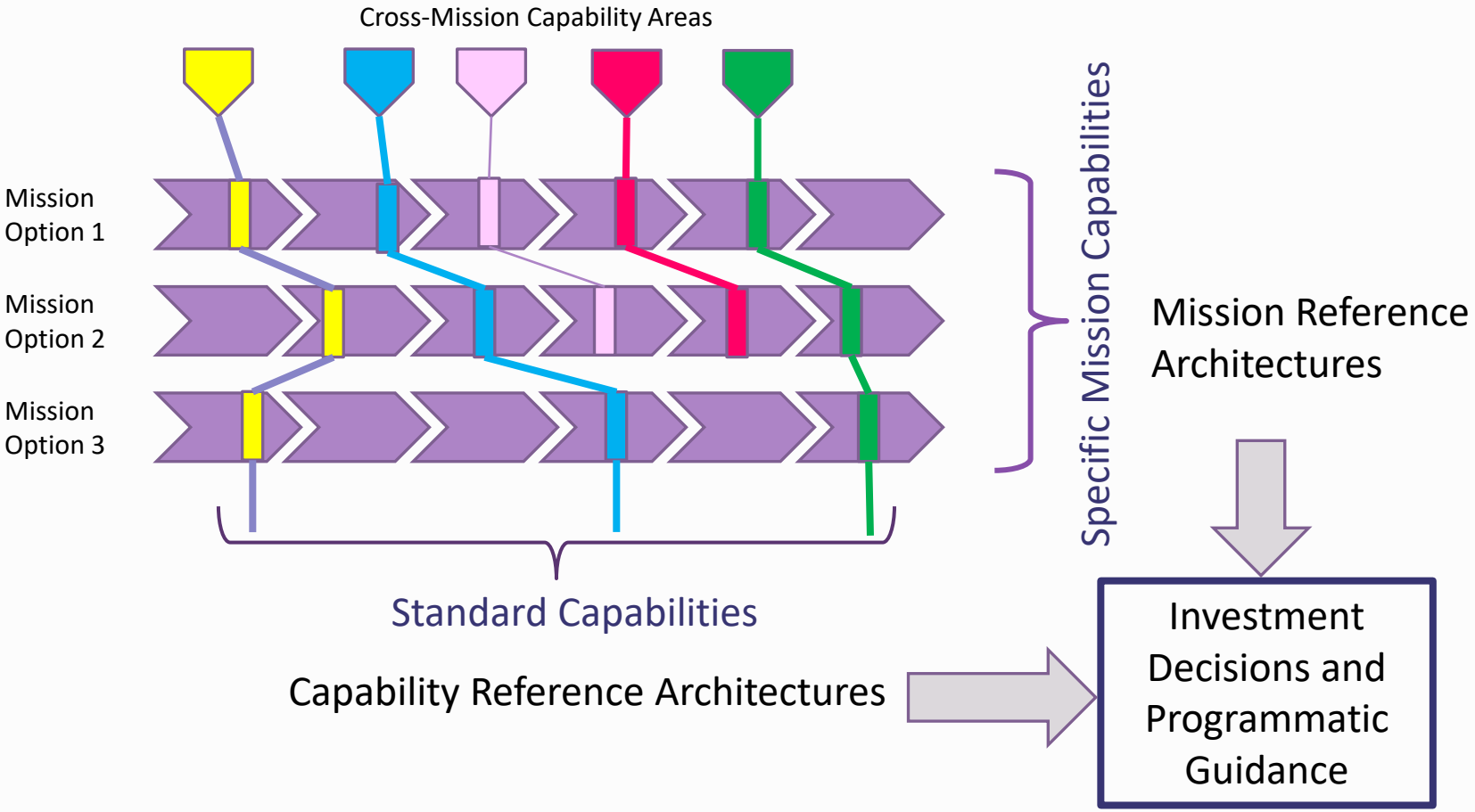


Strategy & Guidance





Mission Engineering Analysis



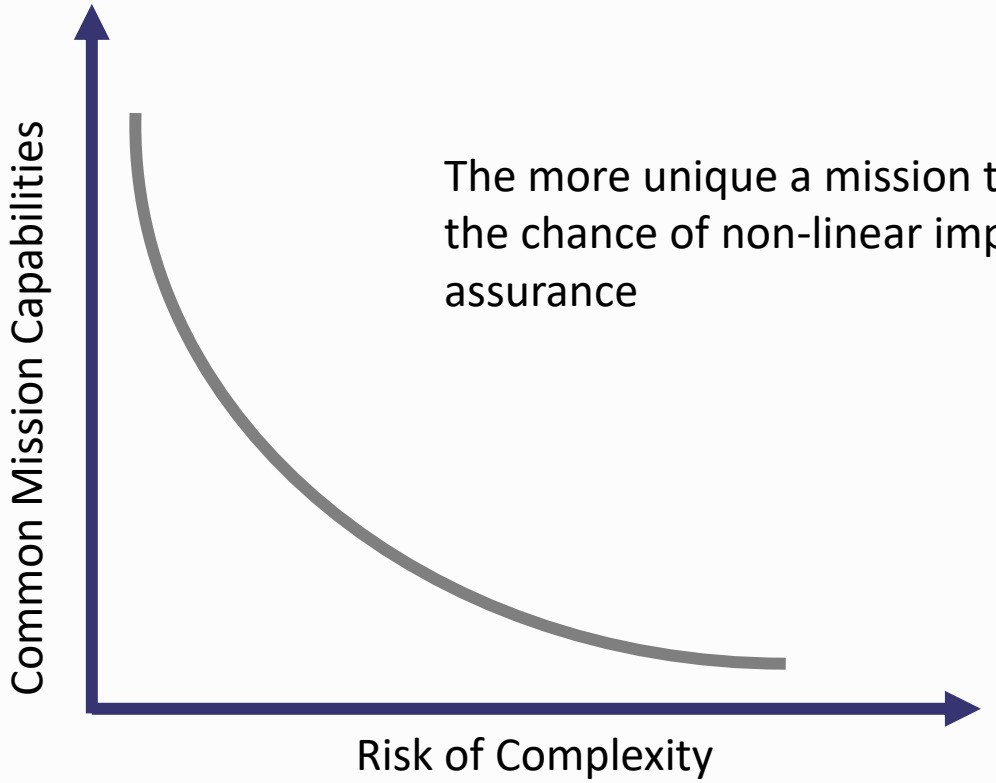
Trade studies between mission effectiveness and common capabilities

The Non-linearity Effect

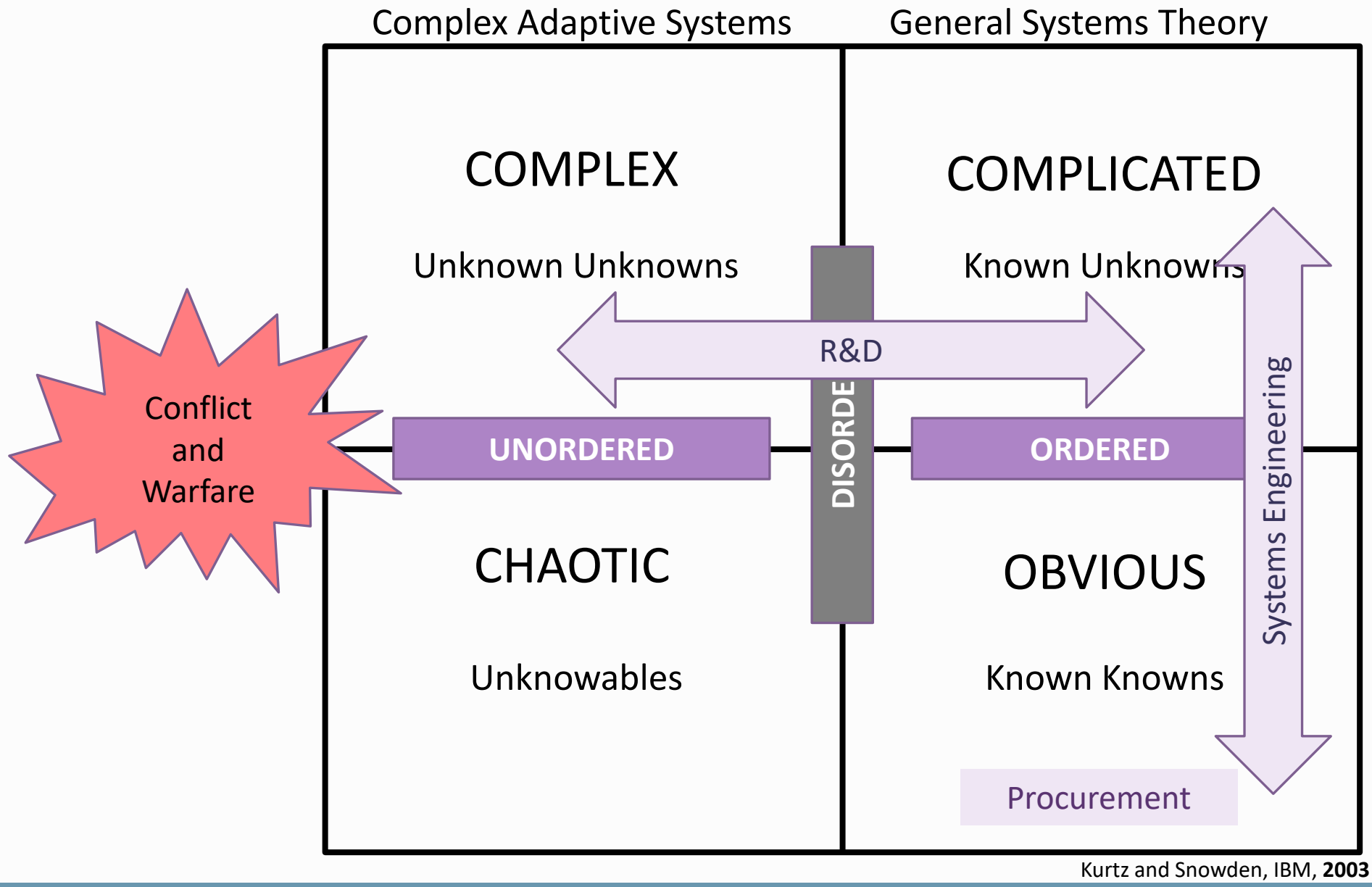
For want of a nail the shoe was lost. For want of a shoe the horse was lost. For want of a horse the rider was lost. For want of a rider the battle was lost. For want of a battle the kingdom was lost.

- A Proverb

- Something minor has a disproportionate effect on outcomes
- Complexity increases the possibility of having non-linear interdependencies
- Standardization of capabilities across missions provides a measure of assurance



The more unique a mission thread is the greater the chance of non-linear impacts on mission assurance



Kurtz and Snowden, IBM, **2003**

What Do We Know?

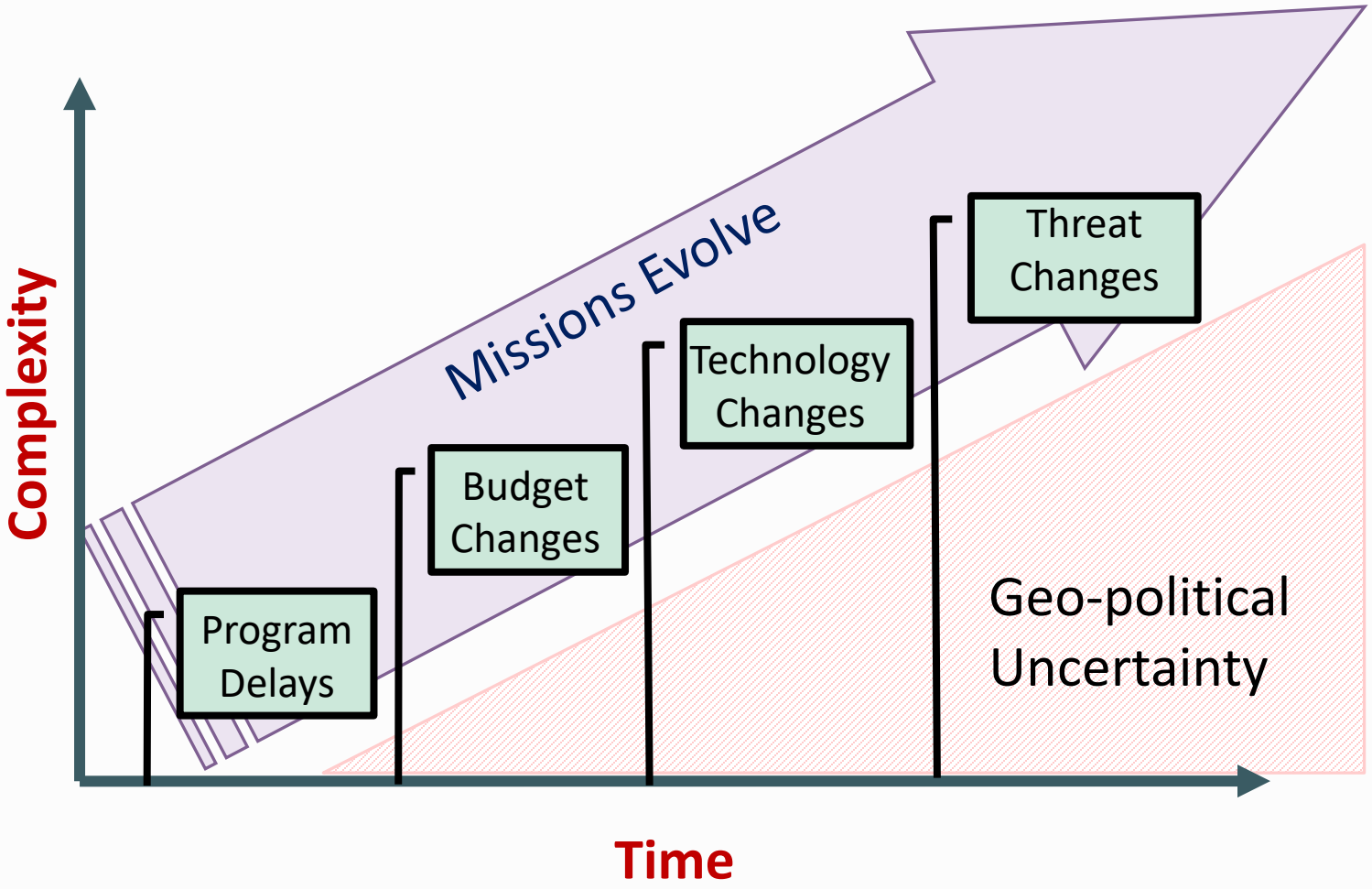
Change is constant and unpredictable

Systems must adapt

Real-world complexity always creeps in

Present imperative is to move faster, innovate quicker

Three Axes of Mission Engineering



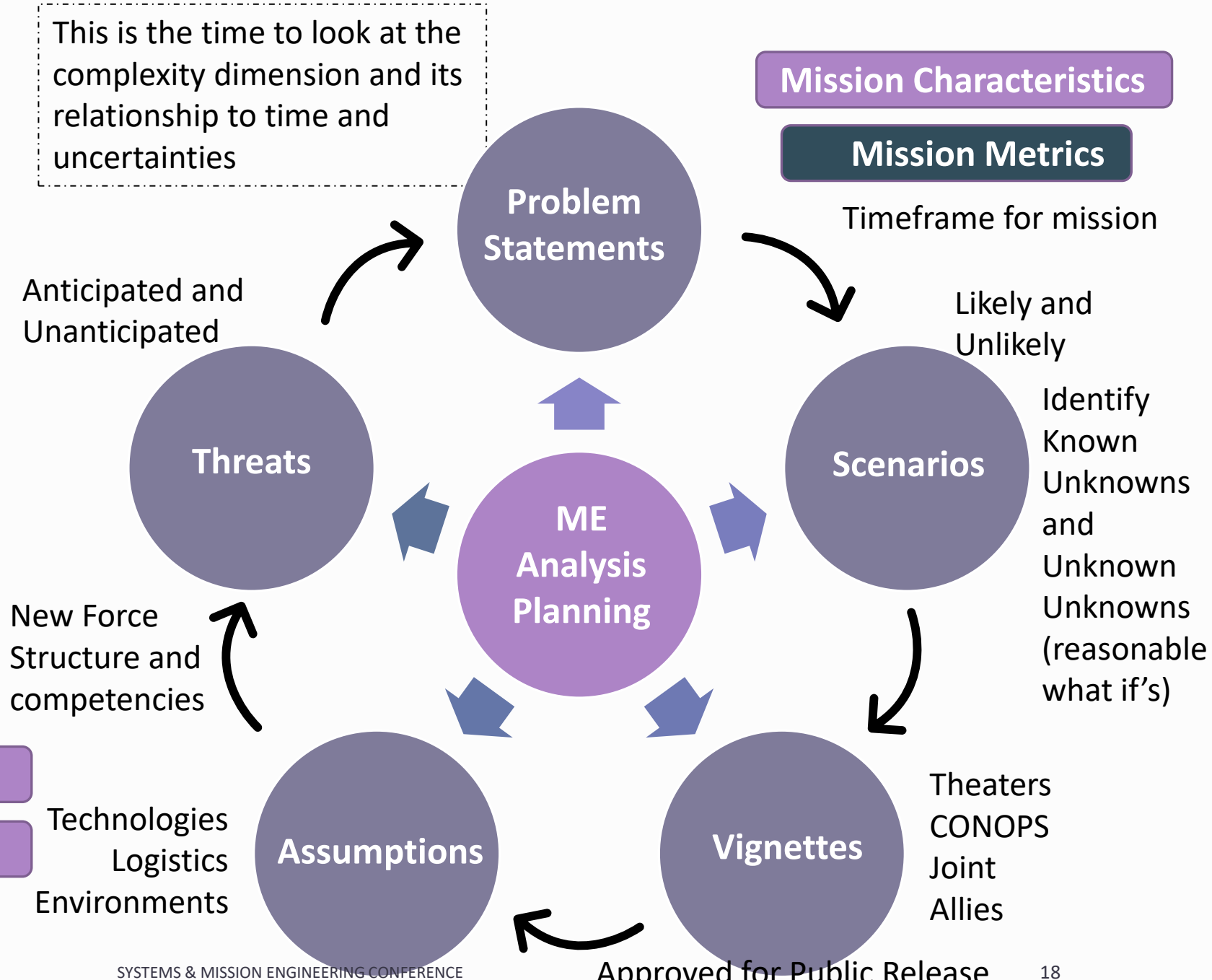
How does ME Deal with Complexity

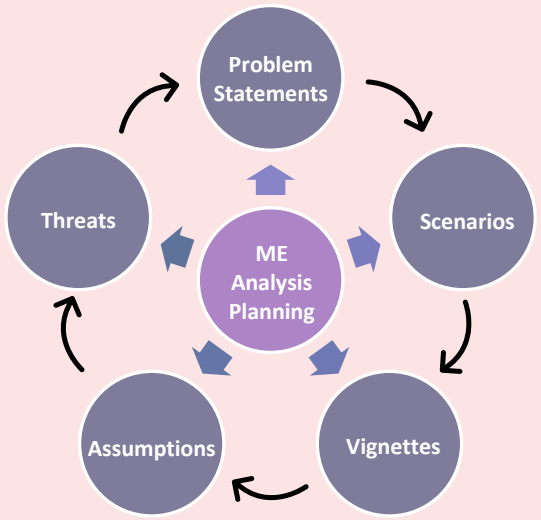
By addressing questions that impact mission architectures while planning the analysis

- What are we trying to do?
- Who should be doing it?
- What is the context?
- What is the timeframe?

Relationships

Dependencies



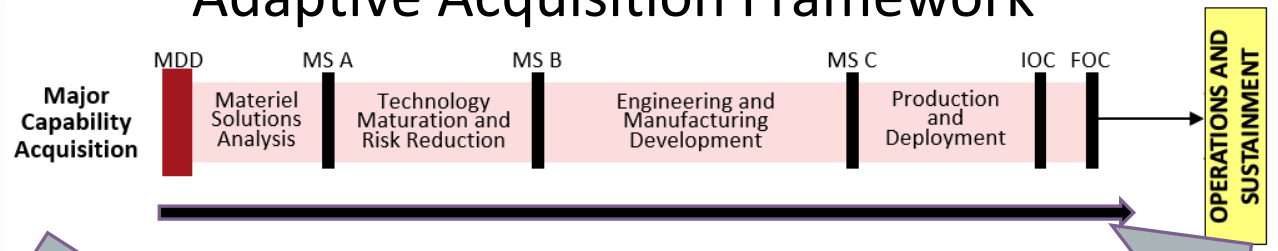


GMRA/GCRA

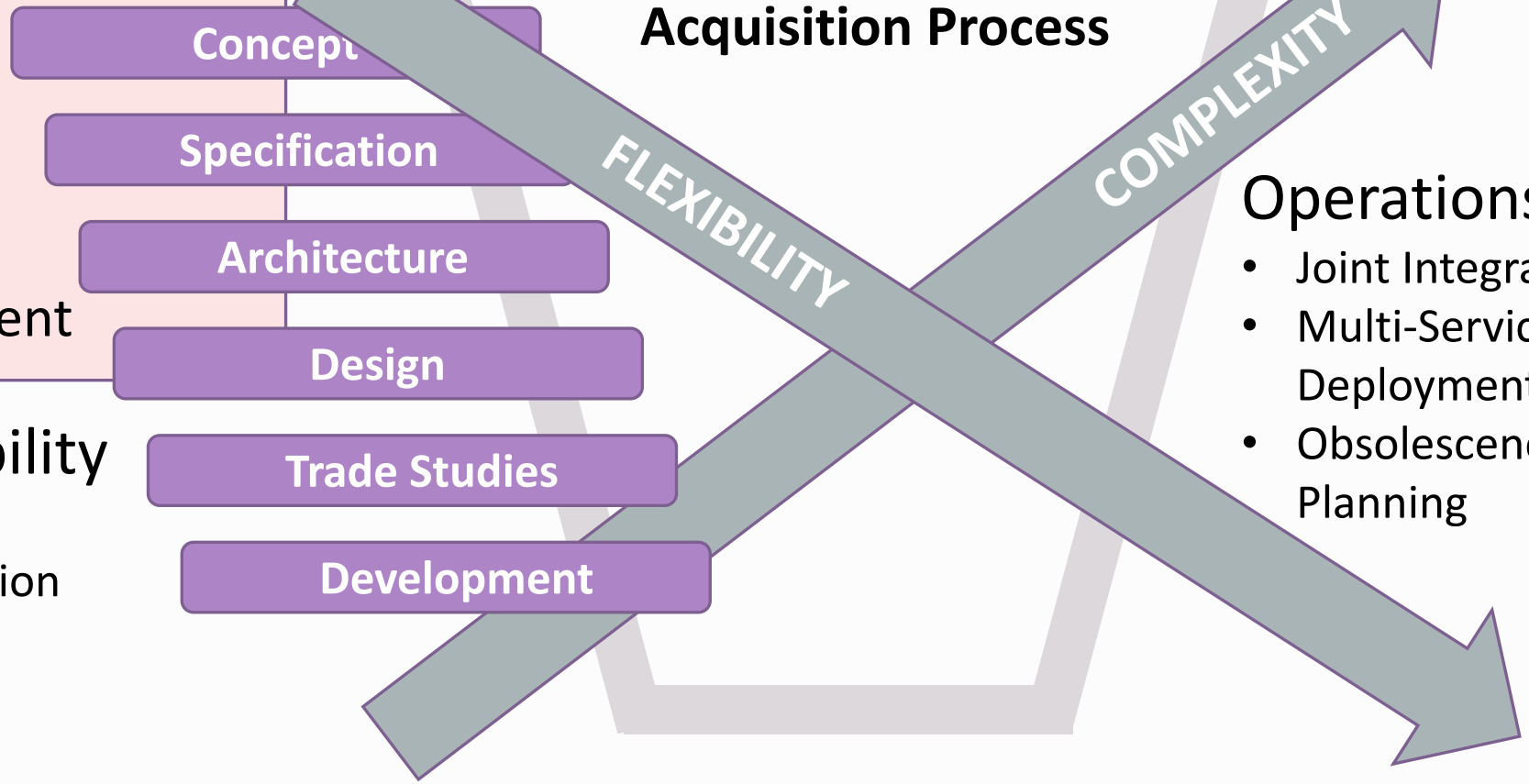
Mission Engineering

Capability Assessment

Adaptive Acquisition Framework



Acquisition Process



Design for Flexibility

- Digital Engineering
- Modeling & Simulation
- MOSA
- SOS Interoperability

Operations

- Joint Integrated Ops
- Multi-Service Force Deployment
- Obsolescence Planning

Summary

- Mission Engineering addresses complexity
  - Problem Statements, Scenarios, Assumptions
- Systems Engineering Provides Flexibilities
  - Modeling and simulation
  - MOSA
  - SOS Interoperability
- Over time the ability to deal with complexity shifts from design to operations – plan on it!

Thank You

Dave Chesebrough

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