The Mission Value Pyramid:
A Framework for Basic Research Supporting C2, with Examples

CONCEPT PAPER

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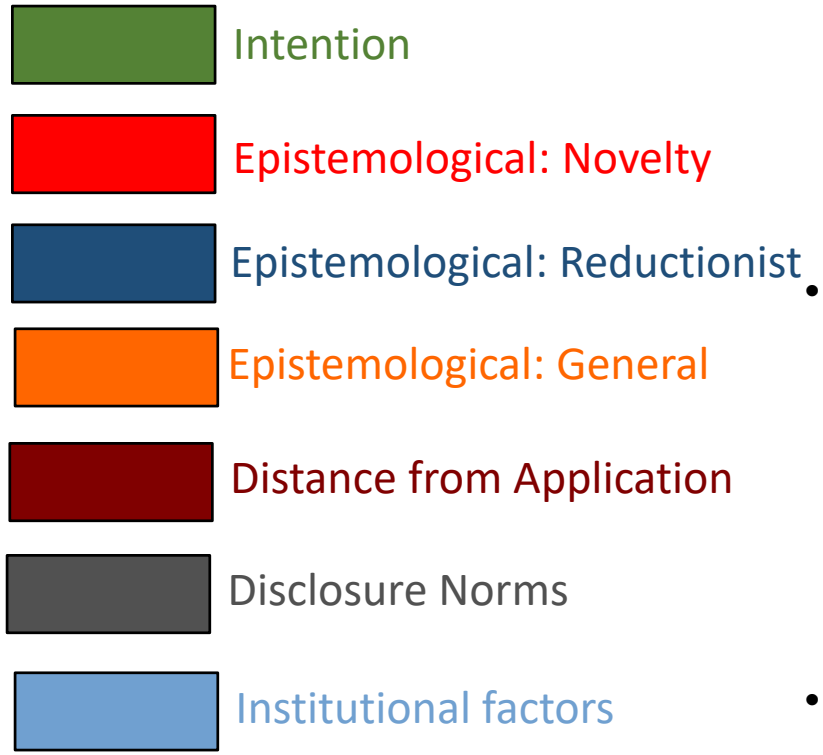
Context

- Study undertaken for Basic Science Office, (then) Office of ASD(R&E)
- Create a framework to motivate basic research that may be ultimately useful to C2, Communications

DoD Basic Research: Preliminaries

- Definition of basic research
- US DoD is a basic research player on a global scale

OECD Frascati Definitions of Basic Research



Basic research

- "is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view"
- "analyses properties, structures, and relationships with a view to formulating and testing hypotheses, theories or laws. The results of basic research are not generally sold but are usually published in scientific journals or circulated to interested colleagues. Occasionally, basic research may be 'classified' for security reasons.
- "is usually undertaken by scientists who may set their own goals and to a large extent organize their own work"

OECD (2002). *Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development*. Paris: Organization for Economic Cooperation and Development.

US DoD Definition of Basic Research

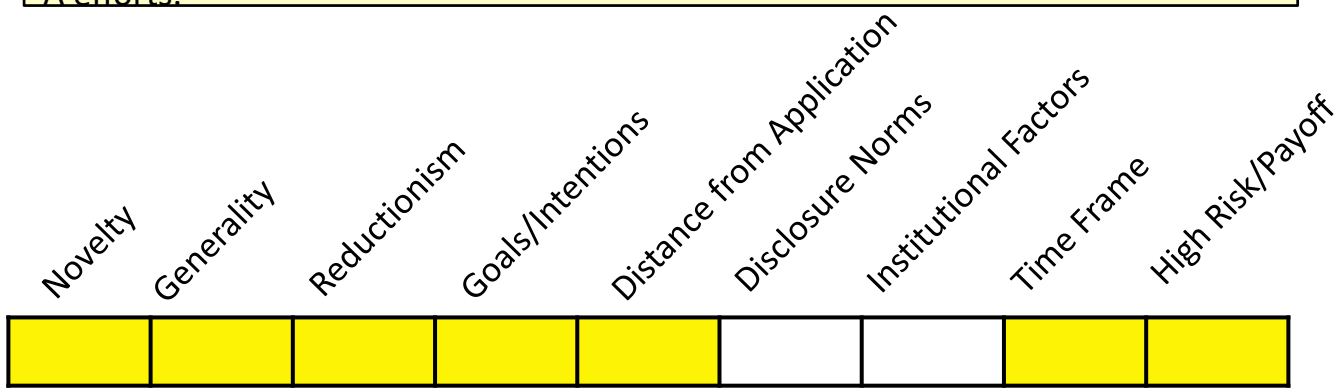
DOD Financial Management Regulation, DOD 7000.14-R, Vol. 2B, Ch. 5:

Budget Activity 1

Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research that provides the basis for technological progress. Basic research may lead to: (a) subsequent applied research and advanced technology developments in Defense-related technologies, and (b) new and improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, and personnel support. Program elements in this category involve pre-Milestone A efforts.

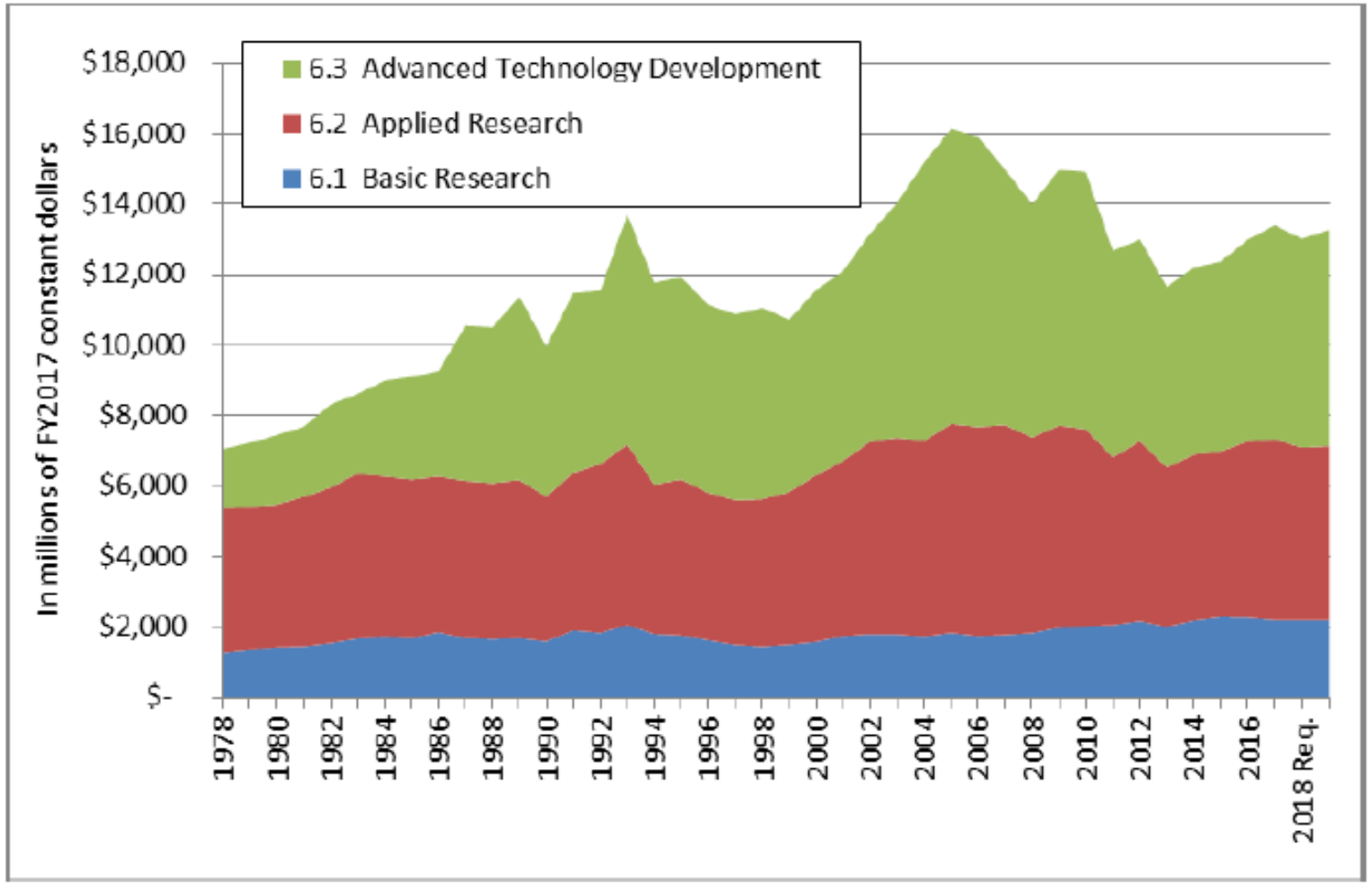
DoD definition

- Has elements similar to Frascati *Pure Basic Research*
- But adds clauses opening door for Frascati *Oriented Basic Research*

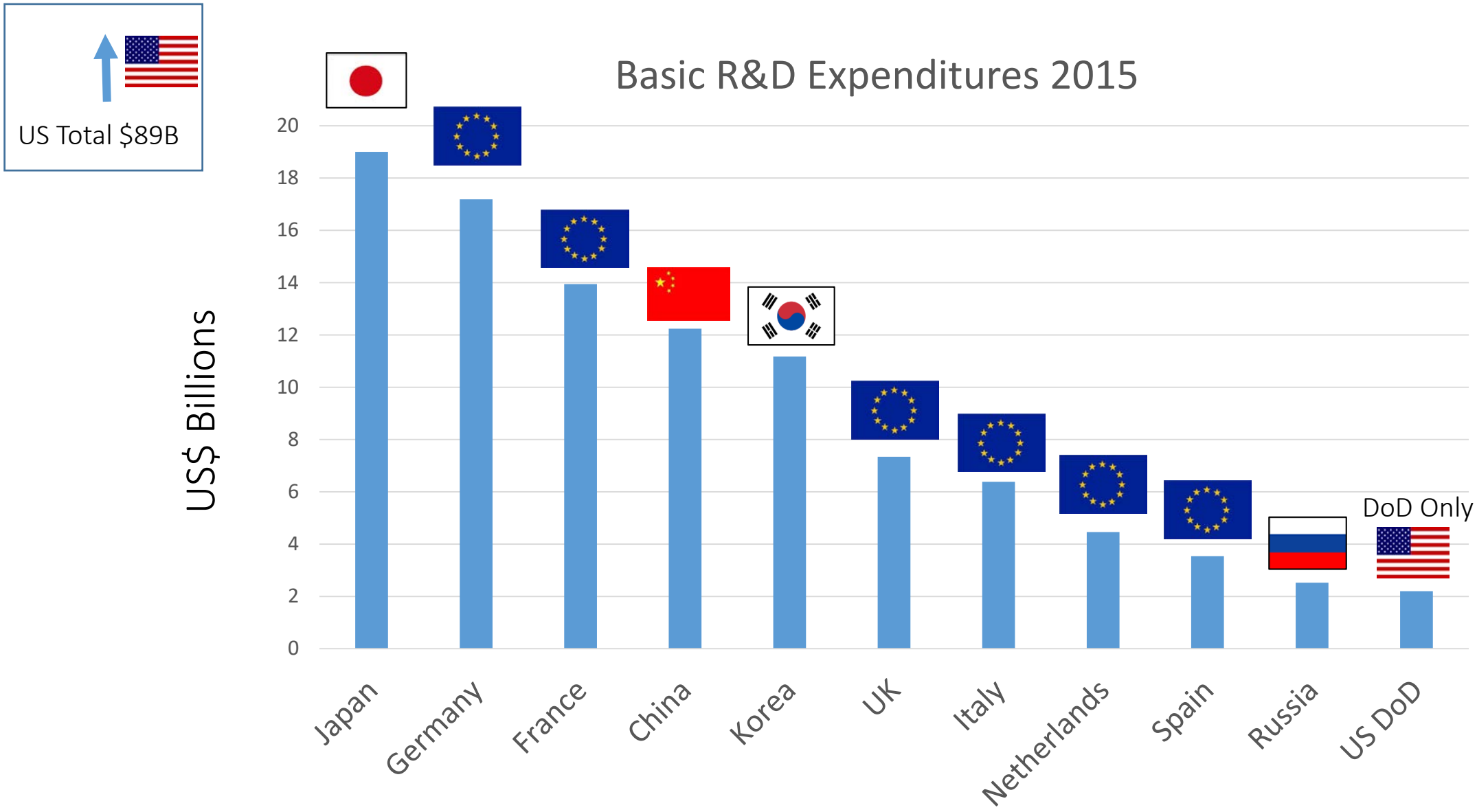


Defense S&T Funding, by Budget Activity, FY1978-FY2019

In millions of constant FY2017 dollars



Sargent, John F. (2018). Defense Science and Technology Funding. Washington, D.C.: Congressional Research Service. Report R45110.



Calculated from data in OECD Main Science and Technology Indicators (2018) and World Bank GDP statistics. Data for Germany are from German Federal Ministry of Education & Research and are for university research. Germany does not report "basic research" explicitly.

DoD Basic Research

- Based on an analysis conducted in 2011, US DoD basic research budget *alone* was
  - Nearly 13% the level of all defense-related R&D in the EU
  - Greater than all defense-related R&D in India
  - Greater than all defense-related R&D in Japan
  - Greater than 3 times the total defense R&D of Canada and Australia combined
  - Over 1/3 as large as all defense-related R&D in Russia

- If other countries/entities maintained the same percentage (~2%) of basic research in their defense-related R&D, DoD 6.1 would be nearly 4 times larger than the defense-funded basic research of the EU27, Japan, Korea, Russia, and India put together.

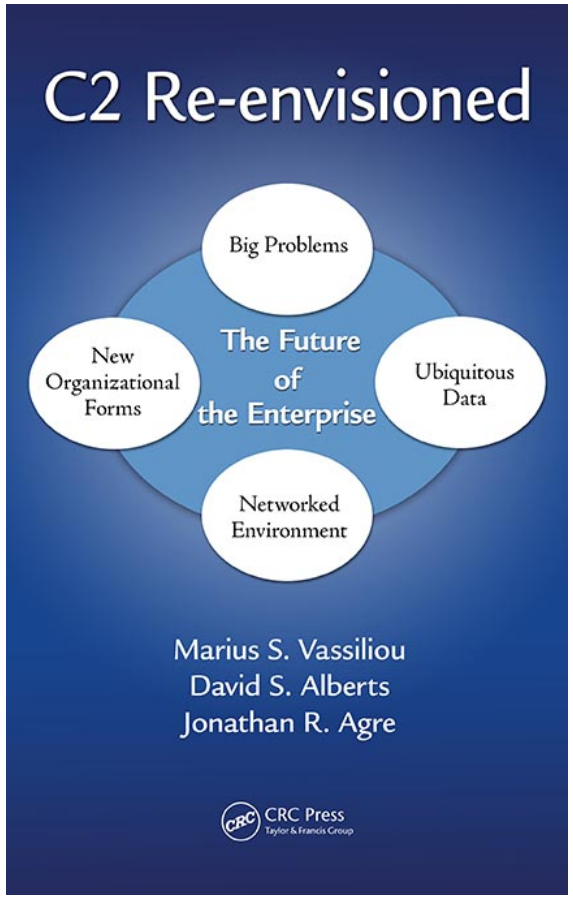
- Unless there are hidden basic R&D expenditures of which we are not aware, it appears that the US DoD has no peer among defense establishments in the funding of basic research.

Motivating Basic Research

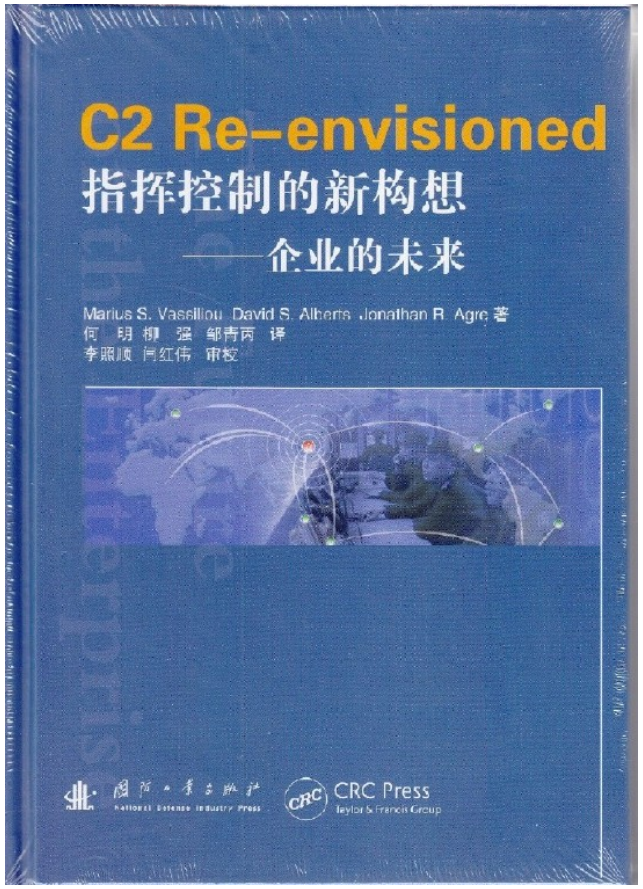
- Work backwards from broad goals
- i.e., try to make sure ladder is on the right wall!
- Create a framework
- Specific research directions are examples only!!!!

It helps if there is a wall!

Look at How C2 goes Wrong



Shameless plug



Chinese edition if you prefer

- Vassiliou et al. (2013, 2015)
  - Studied 20 operational cases of C2 failure since WW1
  - Military operations
  - Terrorist Attacks
  - Disaster & Emergency Response

C2/Enterprise Failures—Bottom Line

Somebody *couldn't* talk to somebody

or

Somebody *didn't* talk to somebody

"Talk" = Communicate, share, interact, speak, etc. etc.

Couldn’t or Didn’t

Couldn’t Talk

- *Because of circumstances*
  - Infrastructure/Equipment destruction, damage
  - Physical constraints
  - Denial by adversary
- *Because of system design or policy shortfalls*
  - Interoperability Problems
  - Equipment or bandwidth shortage
  - Security constraints

Exacerbates

Inappropriate Enterprise Approach/Organization Design

Didn’t Talk

- Behavioral failures
- Lack of will
- Lack of incentive
- Lack of Knowledge
- Lack of Trust (Individual)
- Lack of Trust (Institutional)
- Lack of Tools

Causes

Inappropriate Enterprise Approach/Organization Design

C2 Failure Characterization—Military Cases

Military Operations

			Inability to Communicate:					
			Because of system design or policy shortfalls			Because of circumstances		
Incident	**Inappropriate C2 Approach/Organization Design**	**Behavioral Failure to Communicate**	Lack of Interoperability	Equipment or Bandwidth Shortage	Security Constraints	Infrastructure/Equipment Destruction or Damage	Physical constraints	Denial by Adversary
Great Retreat of 1914, First World War	■	■		■			■	
German army in runup to 1st Battle of the Marne, First World War	■	■		■	■		■	■
1st Battle of Savo Island, Guadalcanal Campaign, Second World War	■	■						
Mayaguez Incident	■	■		■		■		
US Hostage Rescue Mission	■	■	■	■	■	■	■	
US Invasion of Grenada			■	■				
First Gulf War, Operation Desert Storm, FSCL	■							
Russia-Georgia War	■		■	■				

Iran Hostage Rescue (1): Couldn't Talk

Security

- C-130 transport airplane heading to landing site ("Desert One") encountered a large desert dust cloud (a *haboob*)
- *Haboob* not a major problem for the airplane but serious threat to 8 helicopters following far behind
- C-130 did not warn the helicopters because of strict dictate of radio silence
- Helicopters entered *haboob*
- Because of radio silence could not tell each other what they were doing or where they were going
- One helicopter had to abort because of a suspected blade failure Two others left *haboob* & landed
  - First: Group Leader
  - Second: Helicopter carrying spare parts
- Leader made secure call to U.S. command center in Egypt
  - Told to proceed to the rendezvous landing site ("Desert One")
  - But none of the other helicopters could hear the conversation
- Second made independent decision to return to aircraft carrier *Nimitz*
  - None of the helicopters could talk directly to Desert One and thereby learn that landing site was clear
  - Later he said he would have continued had he known
- Critical loss of needed helicopters and crucial spare parts at Desert One

Example of a *haboob* (Iraq, 2005)

http://upload.wikimedia.org/wikipedia/commons/7/75/Sandstorm.jpg

http://dmn.wpengine.netdna-cdn.com/wp-content/uploads/2012/07/RH-53-Sea-Stallions-Iran-Operation.jpg

Interoperability

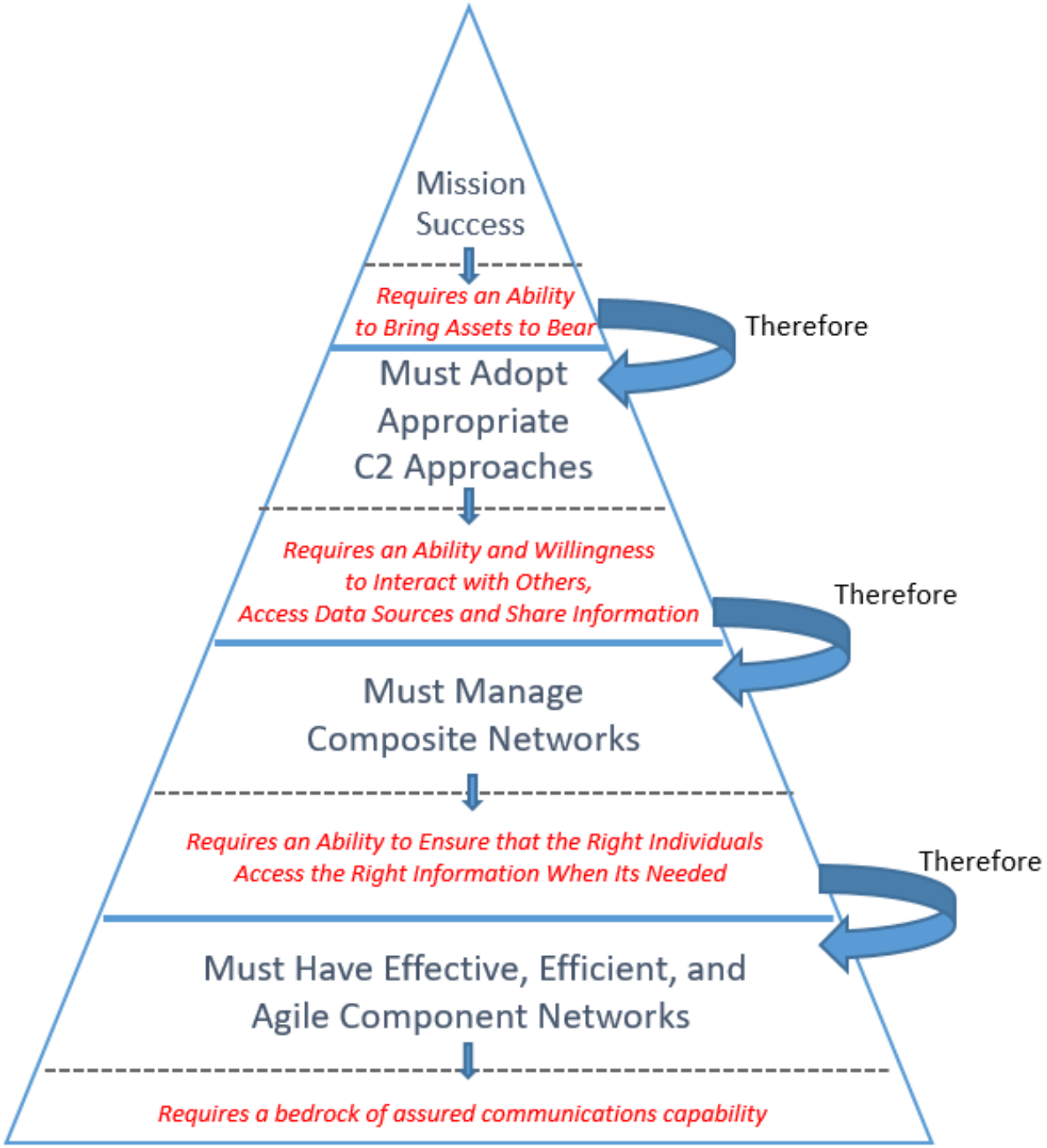
- Army Rangers guarding landing site in the Iranian desert used radios that could not communicate with Delta Force or Air Force personnel
- Rangers unable to inform ground commanders in a timely fashion when a bus full of Iranian civilians appeared, complicating the operation.
- Landing site could not talk to the helicopter fleet

Iran Hostage Rescue (2): Organizational

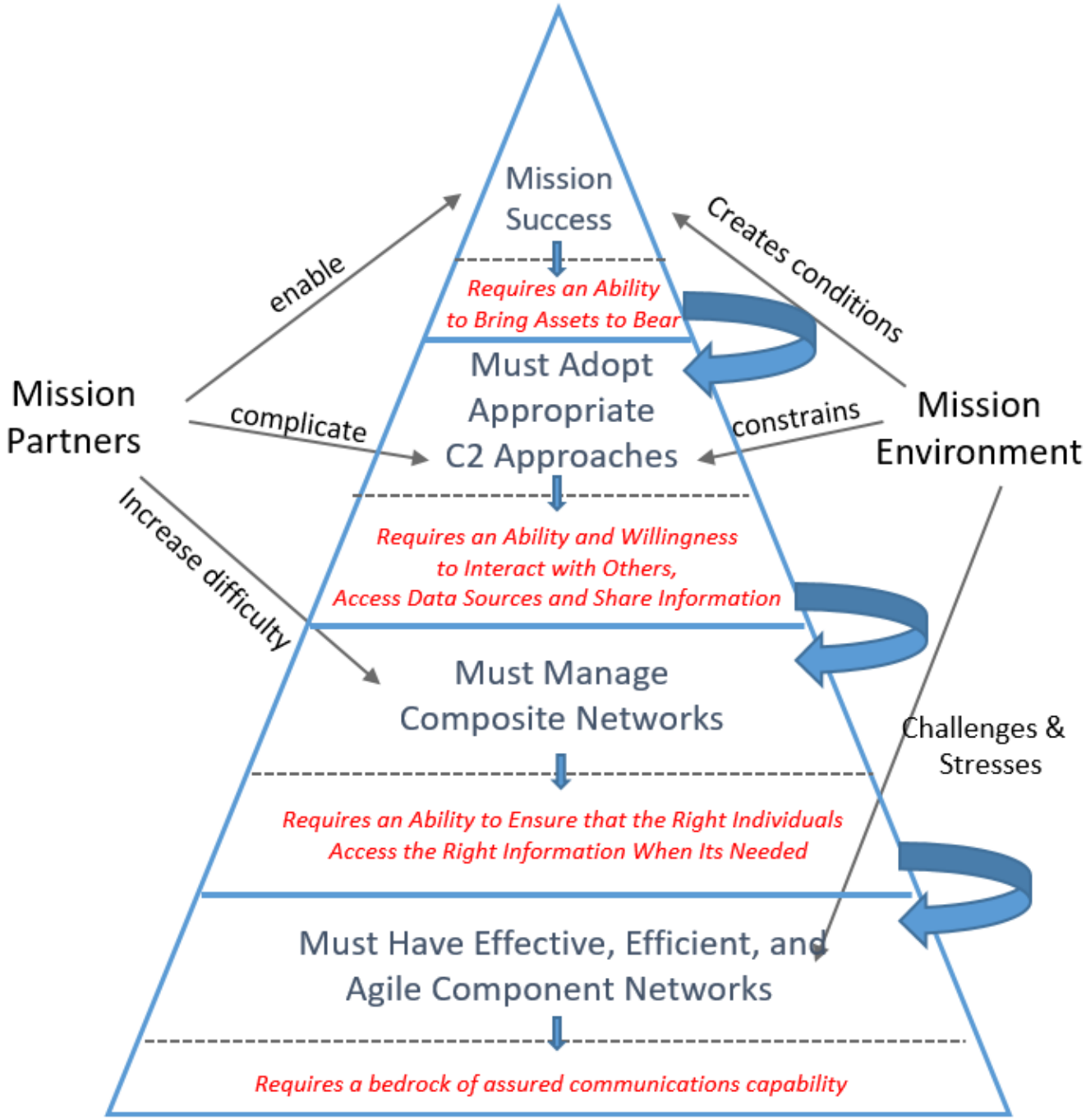
Not predisposed to effective communication

- Highly complex operation
- Several organizations
  - US Army Delta Force
  - US Army Rangers
  - US Air Force Pilots
  - US Navy Helicopter Pilots
- Compartmentalization & mutual mistrust
- Lack of unified command
  - No single component commander to unify AF airplanes and Navy helicopters
  - No single ground component commander to unify Delta Force & Rangers
- Put this together with communications interoperability problems, security constraints, and bad luck, and you get disaster

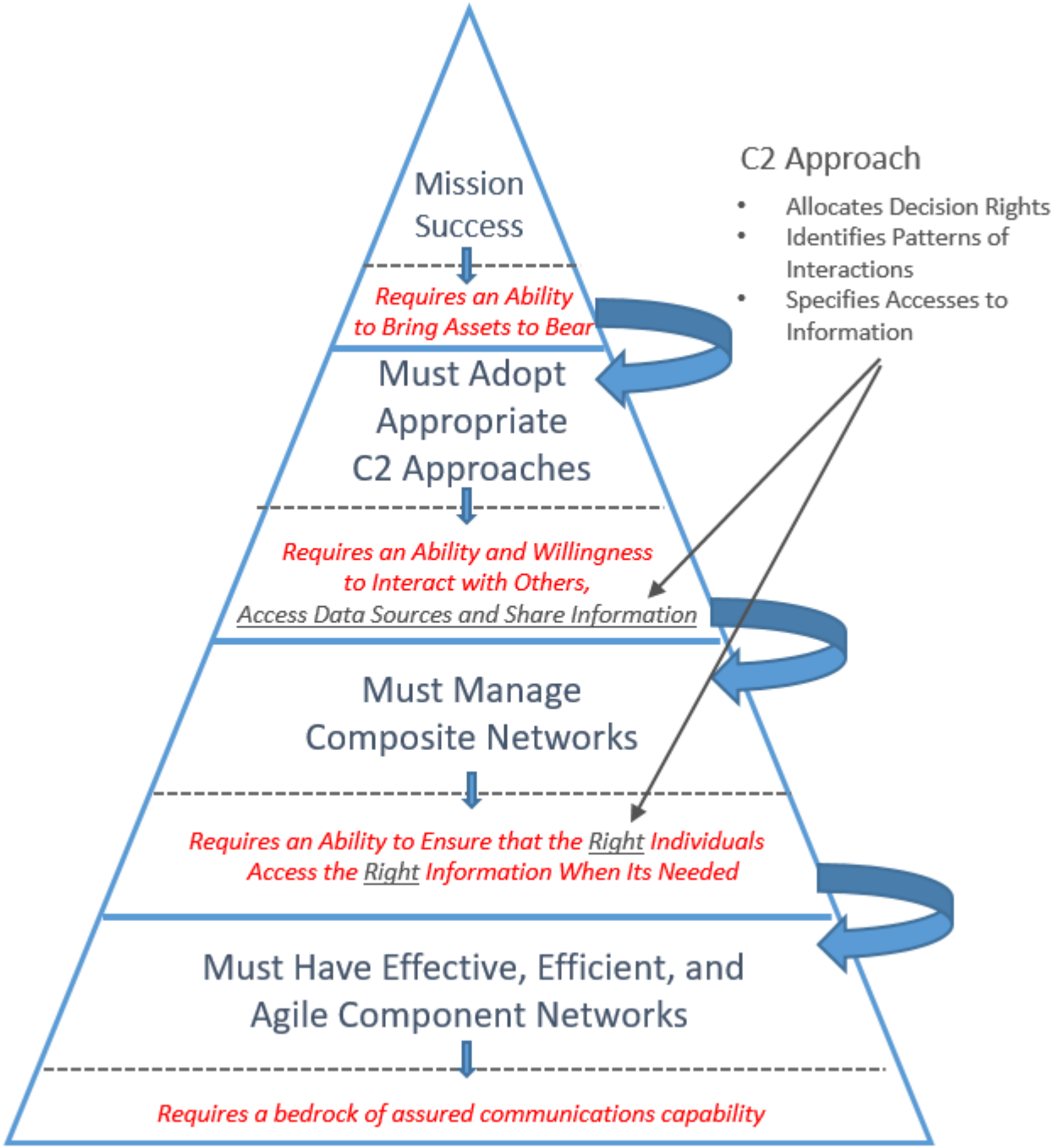
The Mission Value Pyramid



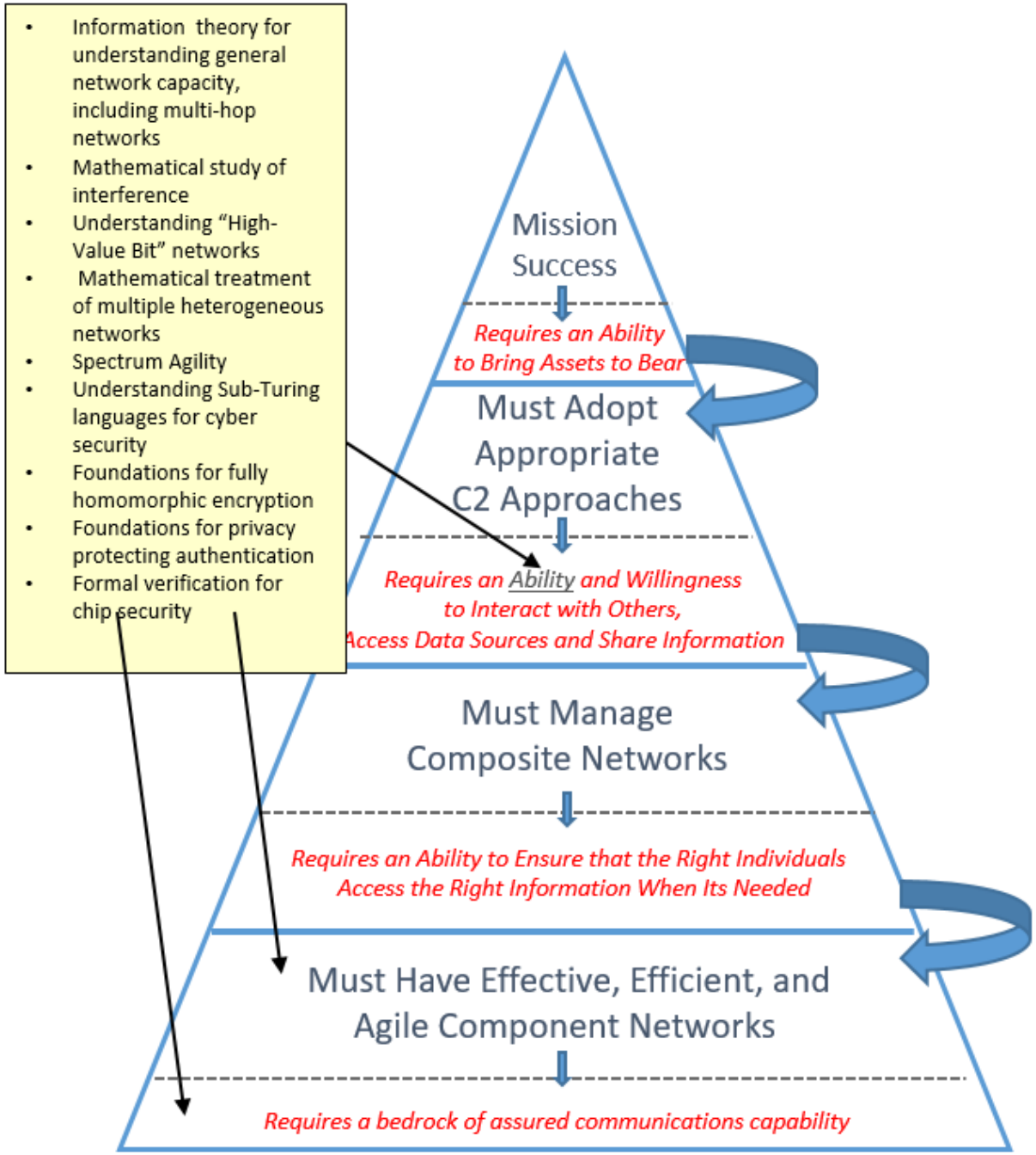
The Mission Value Pyramid with Conditions and Constraints

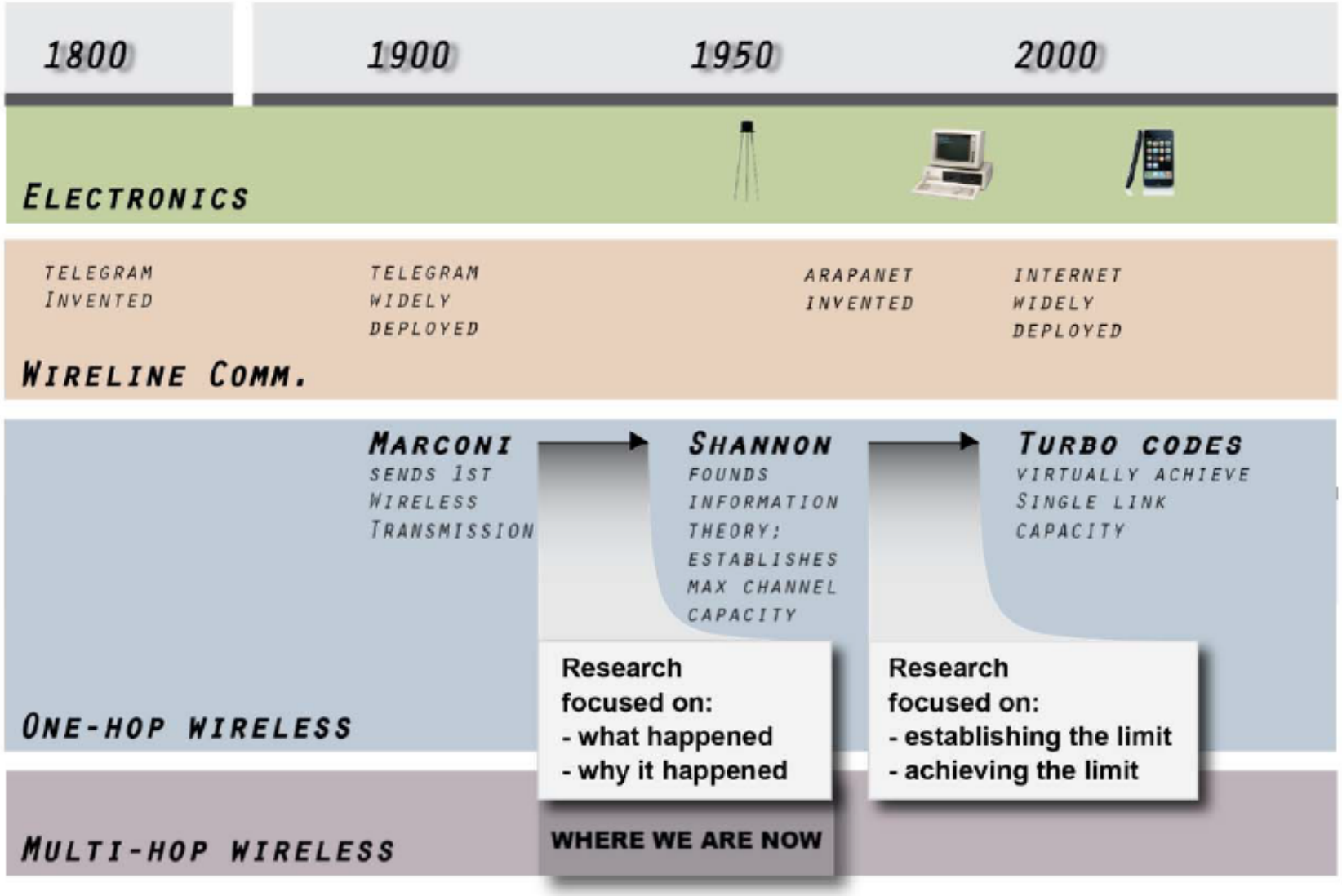


Impact of C2 Approach (Enterprise Approach) on Mission Value Pyramid

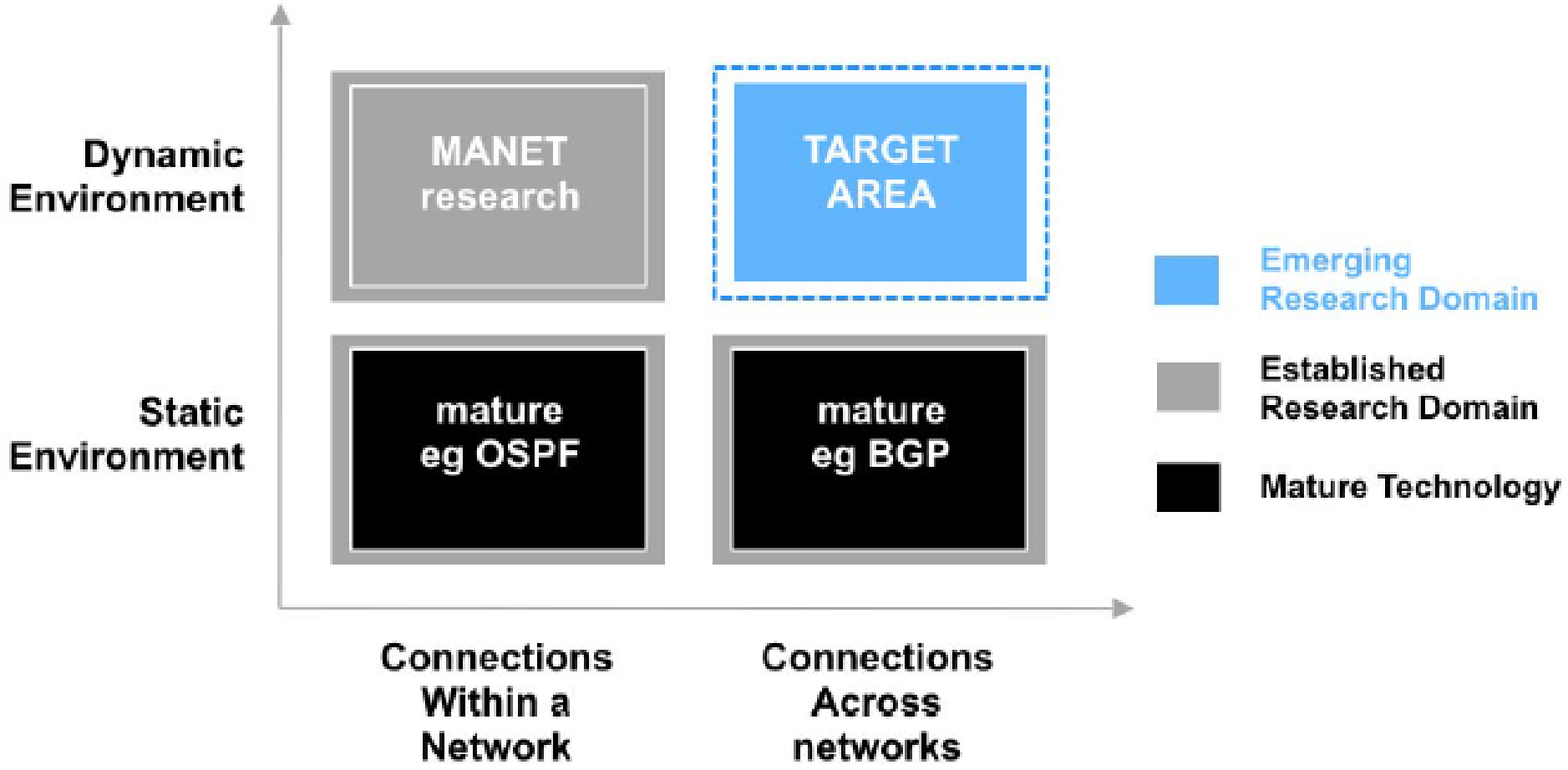


Examples of Basic Research Directions supporting lower levels of the pyramid: Assured Communications and Effective Component Networks



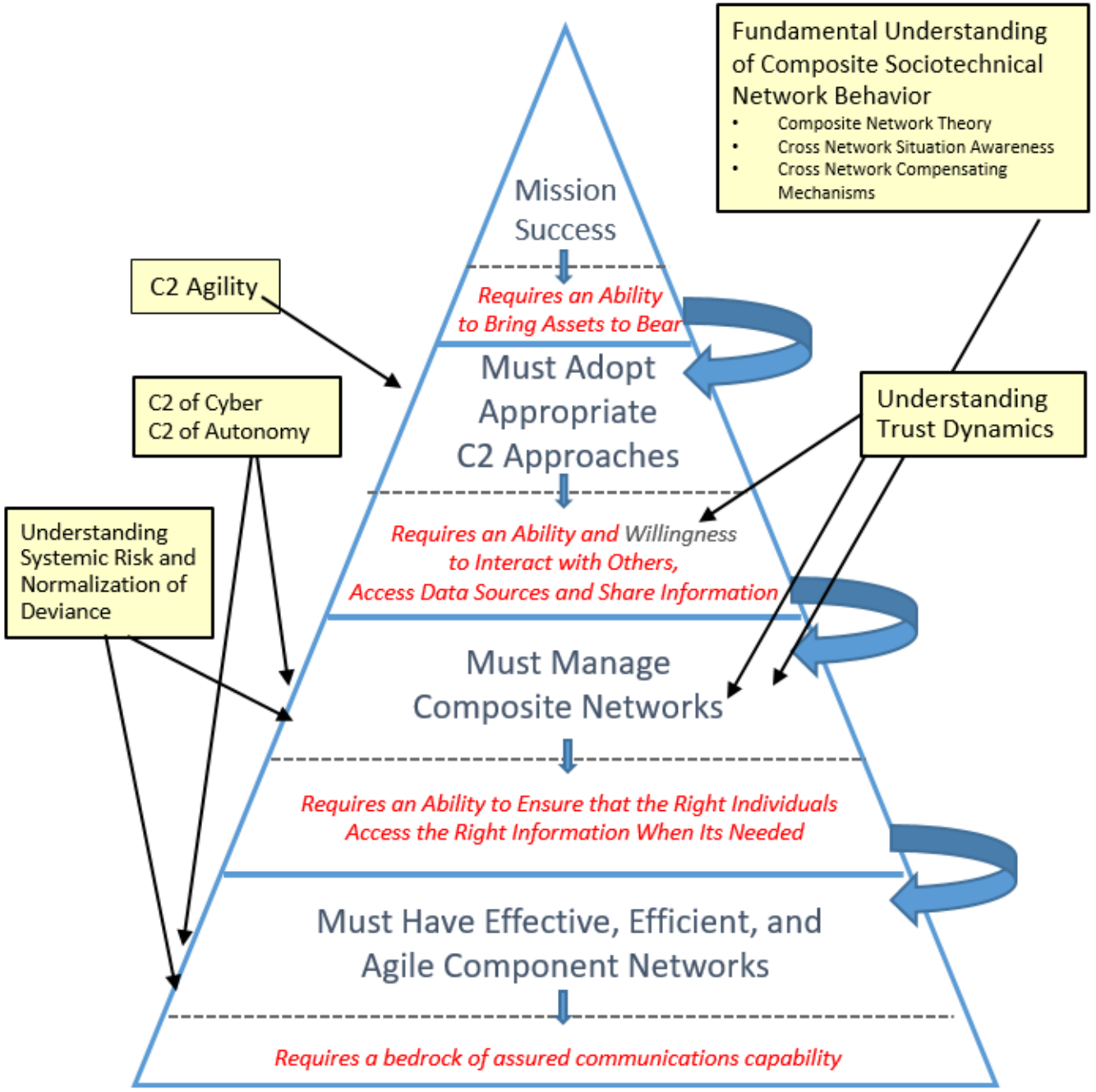


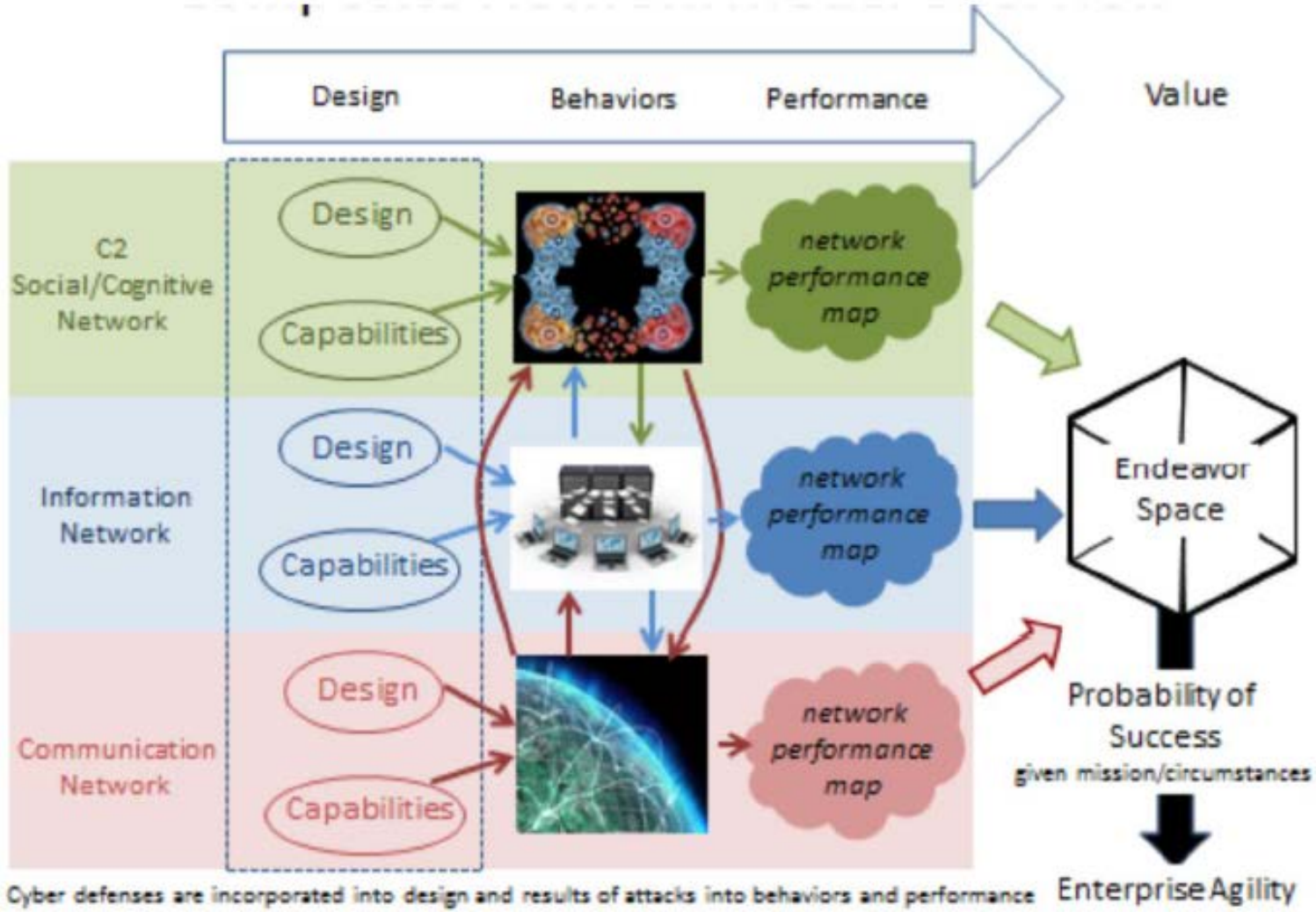
(From MacDonald et al., 2012) Wireless research timeline. For general multihop wireless networks, our level of theoretical development is roughly what it was for single-hop links in the 1940s.



(From MacDonald et al., 2012) Emerging research domain in internetwork connection.

Examples of Basic Research Directions supporting Higher levels of the pyramid: Composite Networks, Agility, and Systemic Issues





(From Alberts et al., 2015), A composite network, comprising several genres of networks. Each genre may be complex. The communications network, for example, may be composed of multiple heterogeneous networks.

Summary

- “Mission Value Pyramid”
  - Conceptual framework for the ingredients of success in complex missions
  - Use to motivate and suggest some example areas of fundamental research that have the potential to contribute ultimately to those ingredients.
  - Example topics in applied mathematics, information theory, computer science, and emerging disciplines such as sociotechnical network theory that may involve social sciences and psychology as well

- Lower levels of the Mission Value Pyramid,
  - Information theory for general, multi-hop, wireless mobile networks
  - mathematical treatment of multiple heterogeneous networks and their interconnection protocols
  - Sub-Turing languages for cyber security
  - New mathematics with applicability to encryption

- Higher levels of the Pyramid
  - Fundamental understanding of the behavior of composite networks, including trust dynamics.
  - Understanding of systemic risk, and phenomena such as the normalization of deviance

- Not an exhaustive set!
  - Many others are possible and desirable
  - E.g., Data science and data analytics.