SAASS 660
TECHNOLOGY AND MILITARY INNOVATION

TECHNOLOGICAL EVOLUTION FROM THE STONE AGE TO AI

AY 2018-2019

"Evolution is an algorithm*; it is an all-purpose formula for innovation, a formula that, through its special brand of trial and error, creates new designs and solves difficult problems… Because evolution is a form of information processing, it can do its order-creating work in realms ranging from computer software to the mind, to human culture, and to the economy."*

-- E. Beinhocker, *The Origin of Wealth*

"*Historians now aim to see weapons not as the results of inevitable, incremental progress, but as components of social and institutional, as well as technical spheres. Military enterprises, in this view, are not simply passive users of technology but are sources of patronage, management techniques, and intellectual traditions that shape the course of invention."*

-- D. Mindell, *War, Technology, and Experience aboard the* USS *Monitor*

"Systems are evolving cultural artifacts rather than isolated technologies. As cultural artifacts, they reflect the past as well as the present. Attempting to reform technology without systematically taking into account the shaping context and the intricacies of internal dynamics may well be futile."

-- T. P. Hughes, *Networks of Power*

Course Director: Lt Col Mark Jacobsen

Syllabus Approved: _____

SHAWN T. COCHRAN, PhD, Col, USAF
Commandant and Dean

Date:

COURSE DESCRIPTION AND OBJECTIVES:

This course is subtitled "Technological Evolution from the Stone Age to AI", which embodies its core theme: *the evolution of both technology and strategy is guided by an algorithm. It is the same algorithm whether we are talking about Neanderthals building stone tools, the Founding Fathers designing new political institutions, or AIs learning to more effectively classify images or develop strategies.*

Innovation is a constant process of (1) introducing novel technologies, strategies, organizational models, etc. (variation) (2) evaluating these novelties using some measure of fitness and embracing the most promising (selection) and (3) promulgating the most successful innovations (replication). This approach—which draws on complexity theory, computation, and biological evolution—gives us powerful, rigorous, and scientifically-grounded tools to study how innovation has unfolded throughout human history. By framing even ancient military innovation as an algorithmic process, you will be well-equipped to understand the basic principles of machine learning and AI. You will see how these technologies are a continuation of human history, not a decisive break.

This course emphasizes the intensely *human* dimension of innovation. We live in a world of organizations, polities, and individual human beings who constantly formulate new strategies to achieve their goals, but their strategies depend on the strategies of every other agent. The human arena in which innovation occurs is a "complex adaptive system," and human beings play crucial roles at every step of the innovation algorithm. It is humans who conceive of new technologies, strategies, and ideas; humans who peer into the future and forecast what innovations look most promising; humans who engage in an intensely political process of determining what innovations to explore, resource, and promulgate; and humans who wield innovations against adaptive adversaries in the constant pursuit of strategic advantage.

The course also explores how the emergence of machine learning and other forms of AI could affect this innovation process. What are the implications when machines can innovate thousands of times faster than a human being? To what degree should humans try to guide this process? What level of trust should humans place in their machines?

Ultimately, the course will help you build and lead innovative military organizations in the future. In addition to theoretical readings, the course contains numerous historical case studies, which cover a wide variety of innovation models—including state-led R&D efforts to develop radar networks and computers, wartime innovation in World War II and Vietnam,

DARPA's turbulent efforts to usher in a disruptive future, and the Silicon Valley startup scene. Even the theoretical readings are intended to provoke deep thought about leading innovative organizations. What does it mean to build an innovative organization? How should it be structured? What personnel systems does it require? How much should a commander resource proven technologies, and how much should she resource risky experiments? Why do some militaries successfully innovate, while others fail?

CLASS PARTICIPATION (40%):

Your professor will evaluate your class participation on your ability to present and analyze arguments, and the dynamic of the seminar environment should help you develop the skills necessary to decompose, compose, and express points of view logically and effectively. The quality, quantity, and appropriateness of your inputs are all aspects of your participation grade, which will be 40% of your total grade.

ESSAY (60%):

Answer One (1) of the following:

A. Technologies pressure strategists to innovate, yet organizations, particularly military ones, tend to resist change. How do strategic innovators resolve this paradox?

B. Strategists manipulate context for strategic advantage. However, by definition, complex systems cannot be controlled; outcomes result from the interaction of many different actors. To what extent can military strategists manipulate complex systems to gain strategic advantage, and how?

Your essay of 2500 words, or so, should answer one of the questions and reflect the wisdom you have distilled from this course and the others you have taken at SAASS to this point in the curriculum. Your work should be your own. Please write your narrative in Times New Roman, 12-point font, double-spaced, with one-inch margins. Your grade for the final paper will be 60% of your total grade. Please see your professor if you have questions.

Papers are due no later than 1630 on Friday, February 15th.

COURSE FACULTY:

Lt. Col. Mark Jacobsen (Course Director)

Dr. Rich Muller

Lt. Col. Nate Huston

REQUIRED READINGS:

Arthur, Brian W. "Complexity Economics: A Different Framework for Economic Thought." *Complexity and the Economy.* New York: Oxford University Press, 2015.

Axelrod, Robert and Michael D. Cohen. *Harnessing Complexity: Organizational Implications of a Scientific Frontier*. New York: Basic Books, 2000.

Beinhocker, Eric D. *The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics.* Boston: Harvard Business School Press, 2006.

Bijker, Wiebe E.; Thomas P. Hughes; and Trevor Pinch. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology.* Cambridge: MIT Press, 1994.

Cote, Owen R. Jr., *The Politics of Innovative Military Doctrine: The U.S. Navy and Fleet Ballistic Missiles*, Dissertation: Massachusetts Institute of Technology, September 1995.

Hughes, Thomas. *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World*. New York: Vintage Books, 2000.

Jacobsen, Mark. "Fitness Function." Center for International Maritime Security. Oct 31, 2016. Retrieved from: http://cimsec.org/fitness-function/29130

Kissinger, Henry A. "How the Enlightenment Ends." *The Atlantic*. June 2018. Retrieved from: https://www.theatlantic.com/magazine/archive/2018/06/henry-kissinger-ai-could-mean-the-end-of-human-history/559124/

Lee, Kai-Fu. *AI Superpowers: China, Silicon Valley, and the New World Order*. New York, NY: Houghton Mifflin Harcourt, 2018.

McNeill, William H. *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000.* Chicago: The University of Chicago Press, 1982.

Posen, Barry R. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars.* Ithaca NY: Cornell University Press, 1984.

Ries, Eric. *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses.* New York, NY: Crown Publishing, 2011.

Rosen, Stephen P. *Winning the Next War: Innovation in the Modern Military*. Ithaca, NY: Cornell University Press, 1991.

Schmidt, Eric. "Statement of Dr. Eric Schmidt to House Armed Services Committee." April 17, 2018. Retrieved from https://docs.house.gov/meetings/AS/AS00/20180417/108132/HHRG-115-AS00-Wstate-SchmidtE-20180417.pdf

Schultz, Timothy. *The Problem with Pilots: How Physicians, Engineers, and Airpower Enthusiasts Redefined Flight.* Baltimore, MD: Johns Hopkins University Press, 2018.

Smith, Merritt Roe and Leo Marx, eds. *Does Technology Drive History? The Dilemma of Technological Determinism.* Cambridge: MIT Press, 1994.

Vance, Ashlee. *Elon Musk*. New York, NY: Ecco Press, 2015.

Wallace, Mark. "How the U.S. Air Force learned to code—and saved the Pentagon millions." *Fast Company.* July 5, 2018. Retrieved from https://www.fastcompany.com/40588729/the-air-force-learned-to-code-and-saved-the-pentagon-millions

Weinberger, Sharon. *The Imagineers of War: The Untold Story of DARPA, the Pentagon Agency that Changed the World.* New York: Alfred A. Knopf, 2017.

COURSE SCHEDULE AND READINGS

Lesson 1: The algorithm of innovation (Mon, Jan 28)

Readings:

- Axelrod and Cohen. *Harnessing Complexity.*
- Miles. "Hill Climbing Algorithm and Artificial Intelligence." https://www.youtube.com/watch?v=oSdPmxRCWws
- Arthur. "Complexity Economics" (PDF).

Optional but helpful:

- "Economic Fitness Landscape." https://www.youtube.com/watch?v=rM23GF0YL9k (may be a helpful introduction if the concept is still confusing)

This lesson introduces the theoretical framing for the course: complexity economics. Axelrod models the economy as a complex adaptive system in which numerous agents continuously experiment with new technologies and strategies in pursuit of advantage. The book provides a gentle introduction to complexity, with a focus on implications for policymaking. The Robert Miles video covers a critical concept called *fitness landscapes* for visualizing how agents

optimize their behavior. The idea might seem abstract but is extremely useful, especially once we discuss AI. The Arthur reading is challenging but contains rich insights into how complexity economics can help us understand real-world phenomena.

How do military forces introduce variation? How do they evaluate the fitness of innovations and promote the most useful? Are there better ways to organize military forces to capitalize on useful innovations? What does hill-climbing mean in the context of military strategy and what are its pitfalls?

Lesson 2: Human civilization as a complex adaptive system (Tues, Jan 29)

Readings:

- McNeill. *The Pursuit of Power*. Chapters 1-7, pp. vii-261; skim remainder.

This is a magisterial overview of military innovation from the dawn of man until World War I. McNeill presumably did not have access to the tools of complexity economics, but his preface introduces a metaphor of genetic mutation that should be familiar from lesson 1. The book provides abundant empirical material for considering the different types of agents that shape innovation, their different goals and optimization strategies, and the relationship between technology and political-social institutions.

Who are the agents in this history and what are their interactions like? What are different kinds of agents optimizing? How do innovations arise? What is the relationship between the evolution of technology and institutions?

Lesson 3: The social construction of technology (Th, Jan 31)

Readings:

- Smith, Marx, and Roe. *Does Technology Drive History?* pp. i-35, 53-78, 101-113
- Bijker, Hughes, and Pinch. *The Social Construction of Technological Systems.* pp. vii-127

This lesson provides an overview of Social Construction of Technology (SCOT), a theory associated with MIT that emphasizes the role of human action in shaping technology. The Smith, Marx, and Roe anthology contains various essays evaluating the idea of technological determinism. The Bijker, Hughes, and Pinch anthology introduces rich ideas about the networks of actors and technologies that surround any new innovation.

To what degree does technology drive history and to what degree do humans have agency? Are we destined for arms races with dangerous new technologies? What are the implications of SCOT for leading innovation? What skills does a successful innovator need? How much can strategists anticipate the future?

Lesson 4: "Selection" in military history – exogenous influences (Fri, Feb 1)

Readings:

- Posen. *The Sources of Military Doctrine.*

With a theoretical foundation in place, the course turns to empirical studies of military innovation in historical context. The books by Posen (this lesson) and Rosen (Lesson 5) are classics in the military innovation literature. Both ask about the conditions under which innovation in military doctrine occurs. Posen focuses on external pressures that force military organizations to innovate.

How convincing is Posen's argument? If militaries are so resistant to change, can they be made more adaptive? How? Given how dynamic and interconnected today's world is, can militaries ever adapt fast enough? What is the proper role of visionary and innovative officers within such a system?

Lesson 5: "Selection" in military history – endogenous influences (Mon, Feb 4)

Readings:

- Rosen. *Winning the Next War.*
- Cote. "The Politics of Innovative Military Doctrine" (PDF). Dissertation conclusion; pp. 331-395.

Like Posen, Rosen asks what leads military forces to successfully innovate. He differs from Posen in focusing on internal explanations for change and has a lot to say about the role of personnel management and promotion systems. Cote carries the argument forward and considers the role of interservice conflict in driving innovation.

How well does Rosen's theoretical framework align with the complexity model from the first lesson? Where do promotion systems fit? What role do intraservice or interservice rivalries play in driving innovation? What role, if any, do mavericks have?

Lesson 6: State-led innovation (Tu, Feb 5)

Readings:

- Hughes. *Rescuing Prometheus.*

From World War II until roughly the 1980s, government was the major catalyst for private sector innovation. Government-led research and development efforts gave the world jet aircraft, space travel, radar, computers, and the Internet, among other technologies. Hughes presents four different case studies of state-led innovation, using a Social Construction of Technology framework to analyze the interplay of technology and social forces.

What is the proper division of labor between government, academia, and the private sector? What sorts of problems arise in executing a complex government-led project? What skills does a government innovator need to guide a project to successful completion?

Lesson 7: Agile approaches to innovation (Th, Feb 7)

Readings:

- Ries. *The Lean Startup*
- Wallace. "How the U.S. Air Force learned to code" (PDF).
- Schmidt. Testimony to House Armed Services Committee (PDF).

This business classic introduces agile private sector models of innovation, which are quite different from the government-led models in the previous reading. This lesson should feel like a radical departure from the previous readings, because it is.

Are old models obsolete or are they complementary? How well do these new business models work in a government context? Are the rules for software innovation different than hardware innovation? Is DoD capable of utilizing these new models? Should it? What should DoD mimic from the private sector, and what traps should it avoid?

Lesson 8: Case study – Disrupting space (Fri, Feb 8)

Readings:

- Vance. *Elon Musk.*

Elon Musk is the quintessential disruptive innovator, and Space X is a prime example of the changing relationship between government and the private sector. This biography tells the story of Musk's quest to remake the automotive, energy, and space industries. It should provoke thought about how to lead large-scale change but should also tie together much of the material in the course thus far: the role of agency in shaping technology, heterogeneous engineering, and the relationship between technology and institutions.

How should government relate to disruptive companies like Tesla and Space X? What are the opportunities and what are the risks? What about Elon Musk has made him such a successful entrepreneur? To what degree can we or should we cultivate these characteristics within uniformed military members?

Lesson 9: Case study - the challenge of practice at DARPA (Mon, Feb 11)

Readings:

- Weinberger. *The Imagineers of War.*

This book depicts DARPA as something of a chaotic, blundering organization that has never been quite sure of its identity. The organization has struck some home runs but also had some disastrous failures. Weinberger shows just how hard it can be to put innovation into

practice; in fact, the algorithmic view of innovation predicts a high degree of Darwinian churn—or what Schumpeter famously called "gales of creative destruction." The book also raises hard questions about how to lead an agile, innovative organization in government.

Under what conditions can government innovate? How do leaders strike a balance between organizational discipline and the freedom to experiment? What accountability mechanisms should be in place? How much failure should government organizations tolerate?

Lesson 10: Computation, evolution, and strategy (Tu, Feb 12)

Readings:

- Beinhocker. *The Origin of Wealth*. pp. xi-20, 187-380, 451-454.
- Jacobsen. "Fitness Function" (PDF).

This lesson returns to theory with a much deeper dive into complexity economics, computation, and evolution. The book is dense and challenging but the concepts are critical to understanding artificial intelligence and recognizing how AI extends computational processes that have always been at work in human history. The book is paired with a short story Lt. Col. Jacobsen wrote that brings many of these abstract ideas to life in a military context and shows why they matter.

Is DoD ready for a world of autonomy and AI? If not, what reforms are necessary to prepare for that world? How much technical education do military leaders need to successfully lead in a world of AI? What implications does this lesson have for organizational design?

Lesson 11: Autonomy and human-machine teaming (Th, Feb 14)

Readings:

- Schultz. *The Problem with Pilots.*

This new book grapples with the proper relationship between man and machine. It argues that as aviation developed between World War I and World War II, pilots were often the weak link in the system. Pilots, engineers, and flight surgeons had to work together to build cybernetic systems around human frailties. Pilots evolved from stick-and-rudder servomechanisms to

managers of complex information systems. A key theme in the book is that technological innovation eliminates some roles for humans, alters others, and creates entirely different roles.

Can men and women ever trust their machines? How do we handle cases where machines outperform humans? What are the comparative strengths and weaknesses of humans and machines? What new roles might emerge for human beings in a more autonomous future?

Lesson 12: Artificial intelligence (Fri, Feb 15)

Readings:

- Lee. *AI Superpowers.*
- Kissinger. "How the Enlightenment Ends."

This book offers a Chinese-American perspective on the race for AI between the United States and China. The author is Kai-Fu Lee, the former head of Google China. Lee does a good job of surveying key concepts in AI, but also makes the provocative argument that China is poised to win the race for AI across many dimensions. The book also argues that AI will bring about dramatic changes in the nature of work itself, with significant economic and social consequences. The Kissinger piece contemplates broader philosophical questions about AI. As a side note, Defense Secretary Mattis included a copy with a note to President Trump imploring him to create a national strategy for AI.

Is Lee right? Is this book Chinese propaganda (a claim some make) or a well-reasoned argument? What can the United States do to compete more effectively? If economic and social upheaval is indeed in store, what are the implications for military strategists?