SAASS 660
TECHNOLOGY AND MILITARY INNOVATION

TECHNOLOGICAL EVOLUTION FROM THE STONE AGE TO AI

AY 2019-2020

"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.*

This course begins where Axelrod and Cohen left off. 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, 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.

INNOVATION STRATEGY (60%):

Instead of writing a traditional essay for this course, you will develop and pitch a strategy for executing a specific innovation. The Appendix to this Syllabus explains the assignment in detail. Deliverables include a white paper (40%) and a pitch on the last day of class (20%).

COURSE FACULTY:

Lt. Col. Mark Jacobsen (Course Director)

Col. Jeff "Push" Donnithorne

REQUIRED READINGS:

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

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

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.

Govindarajan, Vijay and Chris Trimble. *The Other Side of Innovation: Solving the Execution Challenge*. Boston, MA: Harvard Business Publishing, 2010.

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

Ito, Joi and Jeff Howe. *Whiplash: How to Survive Our Faster Future*. New York, NY: Grand Central Publishing, 2019.

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

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.

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

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

WEEK 1: THE ALGORITHM OF INNOVATION

Lesson 1: The algorithm of innovation (Mo, Feb 3)

Readings:

- Beinhocker. *The Origin of Wealth*. pp. xi-20, 187-380, 451-454.
- Arthur. "Complexity Economics" (link).

Optional but helpful:

- Review Axelrod and Cohen's *Harnessing Complexity* prior to Beinhocker.
- Miles. "Hill Climbing Algorithm and Artificial Intelligence." https://www.youtube.com/watch?v=oSdPmxRCWws

This lesson introduces the theoretical framing for the course: complexity economics. It builds on Axelrod's model of the economy as a complex adaptive system in which numerous agents continuously experiment with new technologies and strategies in pursuit of advantage.

Beinhocker goes much deeper into economics, computation, and evolution. The book is dense and challenging but the concepts are critical to understanding the algorithm underlying *all* innovation, ranging from pre-technological societies to the modern era. Understanding these principles is also essential to understanding artificial intelligence and recognizing how AI extends computational processes that have always been at work in human history.

The Robert Miles video helps to introduce a critical concept called *fitness landscapes* for visualizing how agents optimize their behavior. The Arthur reading contains rich insights into how complexity economics can help us understand real-world phenomena.

Viewing innovation through the lens of algorithmic process raises a number of questions. 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 (Tu, Feb 4)

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? What about the relationship between military forces and private industry?

Lesson 3: "Selection" in military history – exogenous influences (Th, Feb 6)

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 (next lesson) are classics in the military innovation literature. Both investigate 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 4: "Selection" in military history – endogenous influences (Fr, Feb 7)

Readings:

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

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?

WEEK 2: EXECUTING INNOVATION

Lesson 5: Government-led innovation (Mo, Feb 10)

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 6: Innovating within bureaucracies (Tu, Feb 11)

Readings:

- Govindarajan and Trimble. *The Other Side of Innovation.*
- Wallace, Mark. "How the U.S. Air Force learned to code—and saved the Pentagon millions." (link)

It is a truism in today's world that large organizations excel at *sustaining innovations* but struggle to embrace *disruptive innovations*. Almost by definition, organizations exist to optimize behavior known to have a high level of fitness. That also makes them resistant to exploring the fitness landscape and experimenting with innovative behaviors that might have lower fitness (at least in the short term) or even undermine the core business. A voluminous literature explores

how small, agile startups can embrace disruptive innovation to run circles around entrenched organizations. But how do you innovate *within* a large organization? The question is especially salient for military officers, who must innovate within one of the largest and most bureaucratic organizations in existence. Govindarajan and Trimble suggest that established organizations must create *Dedicated Teams* uniquely resourced and tasked to innovate, but they also argue that these teams must have a symbiotic and positive relationship with the main organization. They suggest practical advice about how to build and sustain such teams. Wallace describes one such team in the DoD: Kessel Run.

What are best practices for innovating within large organizations? How well do these apply within DoD? Is DoD capable of providing Dedicated Teams with the resourcing, talent, and senior leader protection that they need? How? What is the right relationship between Dedicated Teams and the establishment?

Lesson 7: Disruptive innovation and system building (Th, Feb 13)

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 8: The challenge of practice at DARPA (Fr, Feb 14)

Readings:

- Weinberger. *The Imagineers of War.*

This book depicts DARPA as 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?

WEEK 3: LOOKING TO THE FUTURE

Lesson 9: Artificial Intelligence and geopolitical competition (Tu, Feb 18)

Readings:

- Lee. *AI Superpowers.*
- Jacobsen. "Fitness Function" (available here).

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

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?

The short story raises questions about DoD's preparedness to operate in the fast-moving world of AI. Can DoD handle 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 10: Navigating an uncertain future (Th, Feb 20)

Readings:

- Ito and Howe. *Whiplash*.
- Schmidt. Testimony to House Armed Services Committee (link).

Futurists are notoriously bad at prediction. Science Fiction writers of the 1950s to 1970s foresaw moon colonies and household robots, while missing the Internet, mobile phones, and political instability fueled by social media. We have no reason to believe today's futurist predictions are any better, and the rate of technological and social change only seems to be accelerating. Given that level of ambiguity, how should military leaders prepare for the future? Ito and Howe do not make specific predictions but offer a set of principles for navigating the future. Eric Schmidt, former CEO of Google and Executive Chairman of Alphabet, offers his own guidance for how DoD needs to evolve.

What are *your* principles for navigating the future? What is the proper balance between forecasting and planning, and expecting the unknown? How does an organization test its hypotheses, learn, and adapt quickly? What skill sets and character traits must tomorrow's Air Force leaders possess?

Lesson 11: Pitches (Fri, Feb 21)

No readings are assigned. You are encouraged to seek out and share any helpful resources for pitching, which is a skill in its own right. Your instructors have personally found the following resources to be helpful, among others.

- Miller, Donald. *Building a Storybrand.*
- Miller, Donald. "Building a StoryBrand One-Liner Exercise." (YouTube).
- Klaff, Oren. Pitch Anything. (AudioBook). Apply with care!
- See resources at www.duarte.com

INNOVATION STRATEGY ASSIGNMENT

Pick a specific innovation that you care about—a desired change that you believe would add value to DoD if implemented. It might be a new technology, TTP, process, organization, policy, or something else. It could be as modest as a squadron-level process improvement or as ambitious as a major United States foreign policy initiative.

Your assignment is to develop an actionable strategy for testing the value of this innovation and then—if it proves its value—driving it into adoption. You will pitch your strategy to a senior leader of your choosing (role-played by your classmates), who would be well-positioned to champion your strategy. You will also write a short white paper explaining how you developed your strategy. You can work on this strategy alone or with a partner. Should you choose to work with a classmate, you will give the pitch as a team but each of you will submit your own white paper.

Context

Assume that you are in a SAASS follow-on assignment. Use your imagination about the specific assignment but be realistic. Assume you have the usual resources that come with that position but nothing more. Pick a proposed innovation that you can realistically nudge along from that role, even if success would require help from well above you. Assume that you will be able to allocate some of your time towards executing this strategy over the coming year. In other words, the burden is on you to bootstrap this initiative, validate and demonstrate the value, and garner enough support to see DoD adopt it.

Adoption of nearly any innovation within government requires support from higher-level champions. You will select a target audience who might become a champion of your innovation strategy. Be ambitious but choose someone you might realistically be able to access. This could be someone in your chain of command, someone in a relevant staff, a senior leader, etc. Your champion should be a key stakeholder in the innovation's success, be uniquely positioned to help you, or be a possible blocker that you need to win over in order to succeed.

Elements of an Innovation Strategy

Your strategy should be a matching of ends, ways, and means that will result in the successful adoption of a value-adding innovation. What outcome are you trying to achieve? What are the actions you will take? What resources will you need?

Presentations should loosely cover the following. This is not intended to be a formula. Be creative but thorough in your presentations.

- A description of the proposed innovation, the problem or issue it addresses, and the value it could bring
- Assumptions and hypotheses
- Key stakeholders
    - Who stands to win? Who might help you?
    - Who stands to lose? How will you manage them?
- Resources required
    - What do you need to get started?
    - What kind of team? How much time?
    - How do you propose to get these resources?
- Learning objectives and a discussion of how you will test your hypotheses
- Phasing and decision gates
    - How do you get started from where you are today?
    - What does a minimum viable product look like?
    - How do you obtain the next level of resourcing?
    - How and when do you decide if the initiative is succeeding or failing?
- Risks and mitigation measures

Deliverable #1: Innovation and Audience Selection (NLT Friday, February 14th).

Each team should meet with their instructor outside of class to discuss their proposed innovation and target audience. Innovations and audiences must be verbally approved by the instructor. Teams may schedule an optional practice pitch on Wedneday, February 19th with their instructor.

Deliverable #2: The Pitch (group effort) – Friday, Feb 21

Your deliverable on the last day of class is a pitch of no more than 10 minutes with 10 minutes for questions. Your goal is to convince your target audience to give you a green light, champion your plan, and offer any desired support. To do that, you must convince your audience that you are offering an important and value-adding innovation with a realistic, actionable plan for success. Visual aids or slides are not required, but if used, should be primarily *visual* in nature and not text-intensive. Use slides if you decide that pictorial or graphical exhibits enhance your ability to tell and sell your story. *Grading criteria: significance to target constituency, logic of strategy, actionability, persuasiveness, and clarity of presentation.*

All teams will observe all pitches. However, each team will take the lead in role-playing the target audience for one other brief. Students should come prepared to act in their assigned role (provided beforehand), ask appropriate actions, and realistically evaluate the pitch from that stakeholder's perspective. Student participation in audience roles will contribute to their individual course participation grades.

Deliverable #3: White Paper (individual effort) – due 1800L on Friday, Feb 21

Write a white paper of approximately 1000-1500 words that explains the logic behind your strategy. You should include key elements of the topics/questions in the notional pitch outline above. This is your opportunity to demonstrate mastery of course material, so you should draw on both theory and history to justify your strategy. *Grading criteria: logic, synthesis of course material, clarity, quality of writing.*

Examples of Innovation Strategies

Example #1: You expect to return to a squadron as a DO and want to pitch using Slack as an internal communications tool. Your pitch targets the Squadron Commander. You anticipate resistance on cost and protecting FOUO information in a commercial cloud-based software product. You propose a 3-month trial effort, paid for with the GPC, and a policy of not using Slack to discuss operational missions. You also present data on other Air Force organizations using Slack and information on Slack's FedRAMP certification. You present learning objectives for the experiment. If the experiment shows value, you propose a full 1-year contract paid with Squadron Innovation Funds.

Example #2: You expect to return to fly in the MAF and propose the installation of a non-precision approach at an austere VFR-only field in Afghanistan that you flew into prior to SAASS. You know from previous experience that crews are routinely launched to the field in marginal weather, only to abort overhead and return home. You believe the cost savings from wasted fuel would easily pay for a TACAN. Your pitch targets the 385th Air Expeditionary Group commander, who has responsibility for most airlift operations into the field. Your "ask" is for her staff to aggregate data on aborted missions into the field. You will simultaneously reach out to friends at the 621st Contingency Response Wing to discuss what is entailed at installing approaches at new airfields. If all of this data confirms your intuition that installing an approach is feasible and cost-saving, you will work through your Wing Commander to present a specific proposal to AMC/A3 and AMC/A4.

Example #3: You expect to take command of a F-15E maintenance squadron and believe that a machine-learning-enabled Predictive Maintenance program would yield higher readiness rates and safer aircraft at lower cost. You know that DIU and AFWERX are both running Predictive Maintenance prototype programs for other types of aircraft. Your pitch targets the Program Executive Officer (PEO) for the F-15E. You present a plan where your Squadron would embed a liaison officer at AFWERX for nine months to work full-time on integrating the F-15E into an existing AFWERX predictive maintenance program. You are asking the PEO to pledge $750k to expand the prototype effort, as well as partner in sharing F-15E maintenance data with the vendor.