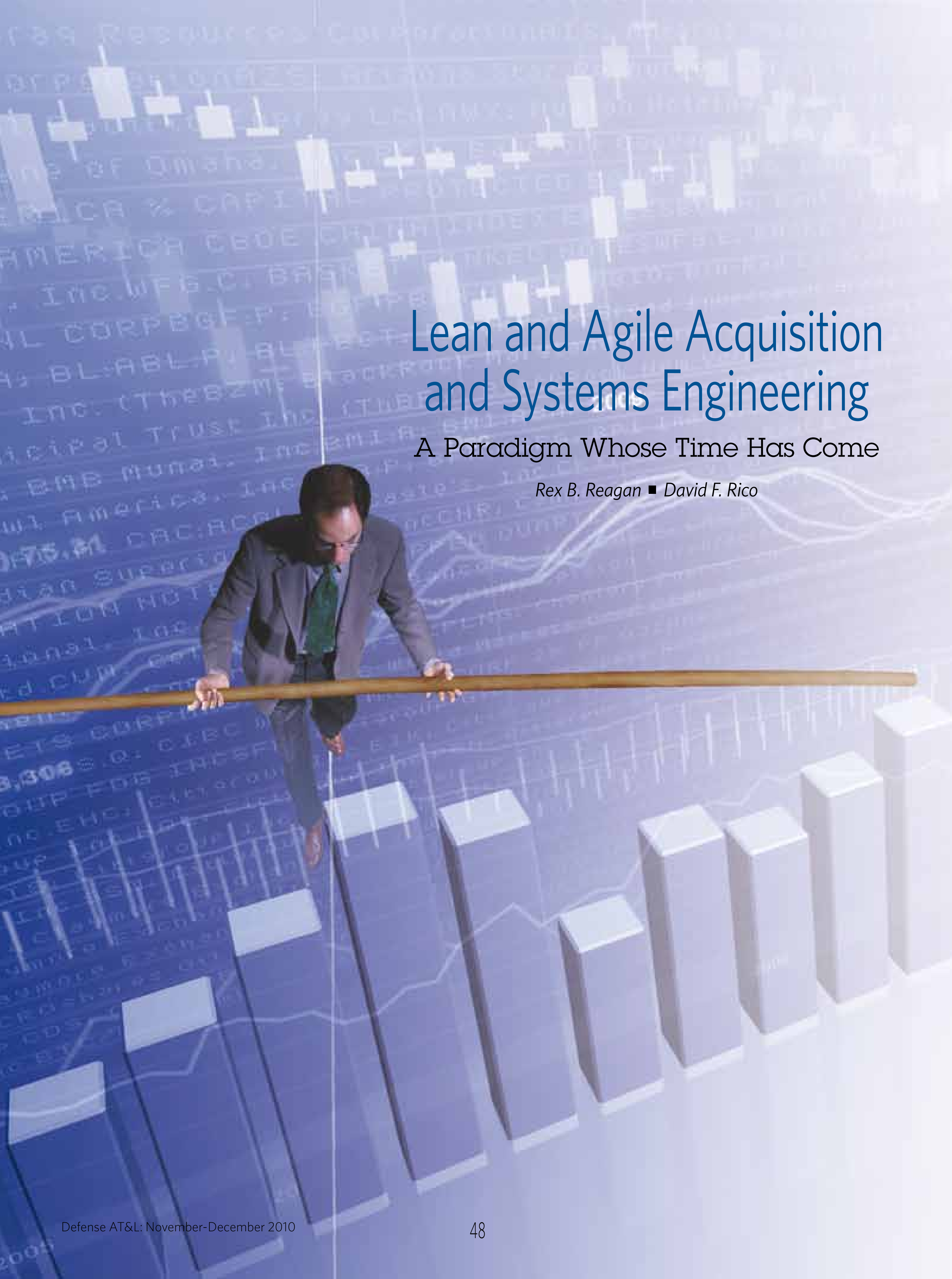

Lean and Agile Acquisition and Systems Engineering

A Paradigm Whose Time Has Come

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Today's U.S. Department of Defense acquisition system is faced with historically unprecedented and seemingly insurmountable challenges that are leading to cost and schedule overruns, poor technical performance, reduced delivery order quanti-

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ties, and outright program failure. Modern weapons have become enormously complex internetworked systems of systems, technology is evolving at an increasing rate, and current acquisition practices may be exacerbating poor program performance.

Lean and agile acquisition and systems engineering practices are emerging to help overcome the challenges of rapidly fielding complex new systems in the face of dynamic and uncertain market conditions and ever increasing military and intelligence threats in order to satisfy enterprise and mission needs today.

Lean and agile acquisition and systems engineering as we know it today is a relatively new paradigm for managing high-risk, time-sensitive, research and development-oriented new product development projects. It seems to be the ideal model for modern, post-industrial information age knowledge workers. In reality, however, it has a long and rich history and lineage. Its tenets can be traced back to Roman Infantry Tactics, Leonardo da Vinci, Michelangelo, Sir Isaac Newton, and the principles of experimentation used by Louis Pasteur in the 1800s and Thomas Edison in the early 1900s. DoD also used its basic tenets to develop experimental aircraft throughout the 20th century. But today, the art and science of lean and agile principles have reached sophisticated new heights.

The fundamental theory underlying the principles is that modern systems are complex, not well-understood, subject to dynamic and unstable market conditions, technology-intensive, and constantly changing.

A common myth is that lean thinking is characterized by automation and elimination of waste. However, deeper examination reveals two major pillars: continuous improvement and respect for people. Researchers have further refined its pillars into six principles: let customers define value, map the value stream, make value flow continuously, pull value, pursue perfection, and respect people. Others express it in terms of eight principles: take an economic view, manage queue size, exploit variability, reduce batch size, manage work-in-process, control cadence, use fast feedback, and decentralize control. It's now a little easier to see the intersection of lean and agile principles: definition, prioritization, and valuation of requirements is performed by customer collaboration; decentralization and respect for people is achieved by empowering teams to make decisions; batch size, queue size, and work-in-process are lowered and cadence and variability are controlled with iterative development; fast feedback, value stream mapping, customer pull, continuous improvement, reduction of waste, and the pursuit of perfection are achieved by responding to change and using flexible technologies.

The Old Versus the Emerging New

Counter to lean and agile principles are traditional methods based on scientific management pioneered by Adam Smith and Frederick Taylor in the British and American industrial revolutions of the 1800s and 1900s. Key ideas emerging from this paradigm were division of labor, specialization, time and motion, Gantt charts, mass production, hierarchical organizations, and most other principles associated with 20th century manufacturing. The basic notion behind traditional methods is that all system requirements can and should be documented; work breakdown structures should be carefully constructed; all activities should be defined and scheduled; cost and effort should be estimated; and meticulously detailed project plans should be tracked using earned value management to control programs within a 5- or 10-percent level of precision. After technology-intensive systems started becoming too complex in the 1960s, the terms "management crisis" and "software crisis" were coined, and many people began applying principles of manufacturing as a means of controlling project scope, time, and cost.

While the proponents of Taylorism attempted to control chaos with scientific management principles, others began to rediscover the job-shop practices of highly creative and innovative artisans, mathematicians, and scientists used throughout the ages. Although management scholars had already discovered in the 1970s that incremental planning was superior to long-term strategic planning, it wasn't until the 1990s that traditional manufacturing paradigms were deemed inappropriate for managing the acquisition of complex technology-intensive systems. The basic notion behind modern ideas is that inductive thinking is better than reductionism, chaos can't be controlled, planning should be done a little bit at a time, planning should be participative with key stakeholders, products should be built in smaller chunks, and projects should be frequently replanned to dynamically adapt to constantly changing market conditions.

For the last century, management scholars have been critically analyzing the global impacts of Tayloristic principles on enterprises and industrial competitiveness. They gradually came to the realization that standardization was good, but so was individual creativity; hierarchical command and control

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structures were good, but flatter organizations were better; and mass production push-systems were good, but flexible pull-systems to react to shifting market needs were even better. They also realized that long-term strategic, operational, and project planning were good; but lighter-weight and more flexible planning was better. Zero-defect quality programs and cost efficiency were good; but market effectiveness, customer satisfaction, and profitability were even better. Their turning point was the advent of the Oil Shock of the 1970s, when scholars realized that Taylorism was insufficient in spite of its overly structured and infinitely detailed strategic plans, replete with all of its scientific management trappings.

DoD, however, was headed in the opposite direction to become less lean and agile. From the 1950s to 1970s, DoD had used lean and agile principles to usher in the jet age and to rapidly evolve experimental aircraft such as X-15, SR-71, U-2, F-111, F-117, and many others. In spite of these successes, the principles used to develop experimental aircraft throughout the early jet age and Cold War were not deemed suitable for the acquisition of production aircraft as it pertained to engineering, manufacturing, production, deployment, operations, and support.

In the late 1950s, DoD planners came to believe that the key to successful weapon systems was to apply rigid manufacturing principles to acquisition and systems engineering. A myriad of standards, tools, and practices gradually replaced research-oriented paradigms: Cost/Schedule Performance Criteria, MIL-STD-1521 [*concerning system design review*], DoD-STD-2167 [*specifying software documentation deliverables*], MIL-STD-498 [*establishing "uniform requirements for software development and documentation*], Earned Value Management, and DoD 5000 Series. These were only the tip of an iceberg of thousands of lower-level standards making up what came to be known as the defense acquisition system.

While the U.S. DoD was busily slowing down its acquisitions based on Tayloristic principles, others were not. The notion of iterative development emerged in 1975, incremental development in 1976, evolutionary development in 1978, and spiral development in 1986. The paradigms of overlapping development, simultaneous engineering, and concurrent engineering also emerged by 1990. Even agile methods for information technology projects gained traction around 1999. All of these emerging paradigms ran counter-intuitive to Tayloristic mega-standards.

Lean and Agile and DoD

A commonly asked question is, "Does the use of lean and agile systems engineering improve the performance of major acquisitions within the U.S. Department of Defense?" It is basically a new product development approach for creating innovative systems in the 21st century. If the two pillars of lean thinking are continuous improvement and respect for people, then its five pillars are: (1) intensive customer collaboration and interaction instead of contract negotiation, (2) small high-performance multi-disciplinary teams instead of bureaucratic processes, (3) iterative development of working operational systems and technology demonstrations instead of a mountain of documentation, (4) responding to changing customer needs, market conditions, and military threats instead of using earned value management to track an obsolete program plan until all of the money is spent, and (5) using powerful, high-level, flexible, and adaptive technologies instead of building every system one circuit board and one line of code at a time.

A fundamental issue is that DoD acquires some of the most complex systems in the history of world, all requirements cannot be known in advance, and customer requirements always change before the ink dries on the paper. In addition, technology is advancing and so are our enemies' capabilities. Thus, lean and agile systems engineering is basically a four-step process of:

- Identifying and prioritizing customer needs such as high-level enterprise and mission goals, objectives, and capabilities
- Decomposing the highest-priority customer needs into manageable chunks that are technologically feasible and implementable in a short timeframe
- Designing, implementing, and evaluating working operational systems including technology demonstrations that satisfy high priority customer needs
- Rinsing and repeating the process of scanning the environment, assessing current technologies, analyzing new threats, identifying new and emerging enterprise and mission customer needs; and re-prioritizing, re-planning, and re-allocating resources.

After a protracted period of bureaucratization, lean and agile principles started making a comeback within the U.S. DoD in the very end of the 20th century. As a direct result of the systems and software engineering movements of the 1990s, "evolutionary acquisition" sprang into action in the Pentagon, U.S. Air Force, and U.S. Navy in 1999. DoD 5000 first mentioned evolutionary acquisition in 2000. Then-under secretary of defense for acquisition, technology and logistics E. C. Aldridge Jr. wrote the Evolutionary Acquisition and Spiral Development Policy in 2002. DoD 5000 Series directly incorporated evolutionary acquisition in 2003. Numerous acquisition articles, research reports, academic studies, and the first textbooks emerged to deal with evolutionary acquisition. However, most were critical—cautionary tales of the dangers, pitfalls, and perils of using evolutionary principles from the 1970s on large-scale programs.

Crisis is a catalyst for change, and DoD has certainly been a community in crisis since Sept. 11, 2001. Our enemies were inside the gates, and DoD quickly and successfully responded with lean and agile principles instituted at the enterprise level to roll out new capabilities to the warfighter in 30, 60, and 90-day increments—and sometimes even in days. The U.S. Army used lean and agile principles to complete elements of its Ground Mobile Radio program on time and within budget. The U.S. Air Force is using them to complete subsystems for the F-22 and F-35, as well as bring the MC-12W from concept to operation in as little as two years. Defense contractors are standardizing their operations using the principles. As late as February 2010, Army Gen David H. Petraeus called for "adaptive, responsive, and speedy acquisitions" because "the enemy that the United States is fighting is unlike any enemy fought in the past, demonstrating different tactics, techniques, and procedures from those found in conventional warfare."

Lean and agile acquisition and systems engineering is here to stay. The traditional process of amassing a mountain of documentation to acquire a single weapon system over a period of decades is obsolete. The U.S. defense acquisition system has been improved, with its overall reduction in size and complexity, introduction of evolutionary concepts such as increments and spirals, and focus on improving overall acquisition performance. However, there is a long way to go in terms of the prioritization and valuation of mission needs; reduction of batch, increment, and spiral sizes; use of smaller higher-performing project teams; development of lightweight, flexible, and near-term strategic planning and program management approaches; and exploitation of commercialized technologies instead of building each weapon system one circuit board and one line of code at a time.

Now is the time for the Defense Department to institutionalize lean and agile principles to help overcome the challenges of rapidly fielding complex new systems in the face of dynamic and uncertain market conditions, the exponential rate of technological change, ever increasing military threats, and insurmountable risks, in order to satisfy emerging enterprise and mission needs today.

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