Lean Engineering

Lean Systems Engineering (LSE) is the application of lean thinking (Womack 2003) to systems engineering (SE) and related aspects of enterprise and project management. LSE is an approach that is applicable throughout the system life cycle. The goal of LSE is to deliver the best life-cycle value for technically complex systems with minimal waste. Lean engineering is relevant to all of the traditional SE technical processes (see concept definition, system definition, system realization, system deployment and use, etc.). Lean engineering also interacts with and utilizes many of the specialty engineering disciplines discussed in Part 6.

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SE is an established, sound practice, but not always delivered effectively. Most programs are burdened with some form of waste such as: poor coordination, unstable requirements, quality problems, delays, rework, or management frustration. Recent U.S. Government Accountability Office (GAO), National Aeronautics and Space Association (NASA), and Massachusetts Institute of Technology (MIT) studies of government programs document major budget and schedule overruns and a significant amount of waste in government programs -

some reaching seventy percent of charged time. This waste represents a productivity reserve in programs and major opportunities to improve program efficiency.

LSE is the application of lean thinking to systems engineering and related aspects of enterprise and project management. SE is focused on the discipline that enables development of complex technical systems. Lean thinking is a holistic paradigm that focuses on delivering maximum value to the customer and minimizing wasteful practices. It has been successfully applied in manufacturing, aircraft depots, administration, supply chain management, healthcare, and product development, which includes engineering. LSE is the area of synergy between lean thinking and SE, which aims to deliver the best life-cycle value for technically complex systems with minimal waste. LSE does not mean less SE. It means more and better SE with higher responsibility, authority, and accountability (RAA), leading to better, waste-free workflow with increased mission assurance. Under the LSE philosophy, mission assurance is non-negotiable and any task which is legitimately required for success must be included; however, it should be well-planned and executed with minimal waste.

Lean Principles

Oppenheim (2011) describes the six lean principles for product development (PD) as follows:

1. **Capture the *value* defined by the customer.** One cannot over-emphasize the importance of capturing task or program value (requirements, CONOPS, etc.) with precision, clarity, and completeness before resource expenditures ramp up to avoid unnecessary rework.
2. ***Map the value stream (plan the program)* and eliminate waste.** Map all end-to-end linked tasks, control/decision nodes, and the interconnecting information flows necessary to realize customer value. During the mapping process, eliminate all non-value-added activities, and enable the remaining activities to flow (without rework, backflow or stopping). The term *information flow* refers to the packets of information (knowledge) created by different tasks and flowing to other tasks for subsequent value adding, such as: design, analysis, test, review, decision, or integration. Each task adds value if it

increases the level of useful information and reduces risk in the context of delivering customer value.

3. ***Flow* the work through planned and streamlined value-adding steps and processes, without stopping or idle time, unplanned rework, or backflow.** To optimize flow, one should plan for maximum concurrency of tasks, up to near capacity of an enterprise. Legitimate engineering iterations are frequently needed in PD, but they tend to be time consuming and expensive if they extend across disciplines. Lean PD encourages efficient methodology of *fail early - fail often* through rapid architecting and discovery techniques during early design phases. Lean flow also makes every effort to use techniques that prevent lengthy iterations, such as design frontloading, trade space explorations, set designs, modular designs, legacy knowledge, and large margins. Where detailed cross-functional iterations are indeed necessary, lean flow optimizes iteration loops for overall value.
4. **Let customers *pull* value.** In PD, the pull principle has two important meanings: (1) the inclusion of any task in a program must be justified by a specific need from an internal or external customer and coordinated with them, and (2) the task should be completed when the customer needs the output. Excessively early completion leads to “shelf life obsolescence” including possible loss of human memory or changed requirements and late completion leads to schedule slips. This is the reason that every task owner or engineer needs to be in close communication with their internal customers to fully understand their needs and expectations and to coordinate their work.
5. **Pursue *perfection* of all processes.** Global competition requires continuous improvements of processes and products. Yet, no organization can afford to spend resources improving everything all the time. Systems engineers must make a distinction between processes and process outputs. Perfecting and refining the *work output* in a given task must be bounded by the overall value proposition (system or mission success, program budget and schedule) which define when an output is "good enough." In contrast, engineering and other *processes* must be continuously improved for competitive reasons.
6. ***Respect* for people.** A lean enterprise is an

organization that recognizes that its people are the most important resource. In a lean enterprise, people are not afraid to identify problems and imperfections honestly and openly in real time, brainstorm about root causes and corrective actions without fear, or plan effective solutions together by consensus to prevent a problem from occurring again.

Lean Enablers for Systems

In 2009, the International Council on Systems Engineering's (INCOSE's) Lean SE Working Group (LSE WG) released an online product entitled *Lean Enablers for Systems Engineering (LEfSE)*. It is a collection of practices and recommendations formulated as "dos" and "don'ts" of SE, based on lean thinking. The practices cover a large spectrum of SE and other relevant enterprise management practices, with a general focus on improving the program value and stakeholder satisfaction and reduce waste, delays, cost overruns, and frustrations. LEfSE are grouped under the six lean principles outlined above. The LEfSE are not intended to become a mandatory practice but should be used as a checklist of good practices. LEfSE do not replace the traditional SE; instead, they amend it with lean thinking.

LEfSE were developed by fourteen experienced INCOSE practitioners, some recognized leaders in lean and SE from industry, academia, and governments (such as the U.S., United Kingdom, and Israel), with cooperation from the 160-member international LSE WG. They collected best practices from the many companies, added collective tacit knowledge, wisdom, and experience of the LSE WG members, and inserted best practices from lean research and literature. The product has been evaluated by surveys and comparisons with the recent programmatic recommendations by GAO and NASA.

Oppenheim (2011) includes a comprehensive explanation of the enablers, as well as the history of LSE, the development process of LEfSE, industrial examples, and other material. Oppenheim, Murman, and Secor (2011) provide a scholarly article about LEfSE. A short summary was also published by Oppenheim in 2009.

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