Lean Enablers for Systems Engineering

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A new product named Lean Enablers for Systems Engineering (LEfSE) is described. It is a collection of 194 practices and recommendations formulated as "dos" and "don'ts" of SE, and containing collective wisdom on how to prepare for, plan, execute, and practice SE and related enterprise management using Lean Thinking. The enablers are focused on mission assurance and the satisfaction of stakeholders achieved with minimum waste. The product has been developed by experts from the Lean Systems Engineering (LSE)[1] Working Group (WG) of the International Council on Systems Engineering (INCOSE). LEfSE are organized into six well-known Lean Principles called Value, Value Stream, Flow, Pull, Perfection, and Respect for People. The LEfSE are not intended to become a mandatory practice. Instead, they should be used as a checklist of good practices.

Systems engineering is regarded as an established sound practice but not always delivered effectively. Sixty-two recent successful space launches indicate that mission assurance can be practiced well. At the same time, recent U.S. Government Accountability Office (GAO) and NASA studies of space systems [1, 2, 3, 4] document notorious major budget and schedule overruns, some exceeding 100 percent. Most programs are burdened with waste, poor coordination, unstable requirements, quality problems, and management frustrations. Recent studies by the MIT-based Lean Advancement Initiative (LAI) researchers [5, 6, 7, 8] have identified a mind-boggling amount of waste in government programs, reaching 70 percent of charged time. This waste represents a vast productivity reserve in programs and major opportunities to improve program efficiency.

The new field of LSE is the application of Lean Thinking to SE and to the related aspects of enterprise management. SE is focused on the flawless performance of complex technical systems. Lean Thinking is the holistic management paradigm credited for the extraordinary rise of Toyota to the most profitable and the largest auto company in the world [9]. Toyota is well-known for practicing excellent Product Development and SE (what Toyota refers to as simultaneous engineering). For example, the Prius car design was completed in nine months from the end of styling, a performance level unmatched by any competitor [10]. Lean Thinking has been successfully applied in defense industry and in the U.S. military itself, (e.g., [5], and the Air Force Lean initiative named AFSO-21). It has become an established paradigm in manufacturing, aircraft depots, administration, supply chain management, health, and Product Development, including engineering.

LSE is the area of synergy of Lean and SE with the goal 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 and waste-free workflow and mission assurance. Under the LSE philosophy, mission assurance is non-negotiable, and any task which is legitimately required for success must be included, but it should be well-planned and executed with minimal waste.

Fundamentals of Lean Thinking

Three concepts are fundamental to the understanding of Lean Thinking: value, waste, and the process of creating value without waste (also known as Lean Principles).

Value

The value proposition in engineering programs is often a multi-year complex and expensive acquisition process, involving thousands of stakeholders and resulting in hundreds or even thousands of requirements, which, notoriously, are rarely stable (even at the Request for Proposal phase). In Lean SE, Value is defined simply as mission assurance (the delivery of a flawless complex system, with flawless technical performance during the product or mission life cycle), satisfying the customer and all other stakeholders, which implies completion with minimal waste, minimal cost, and the shortest possible schedule.

Waste in Product Development

LAI classifies waste into seven categories: 1) Overproduction; 2) Transportation; 3) Waiting; 4) Over-processing; 5) Inventory; 6) Unnecessary movement; and 7) Defects. These wastes, in the SE context, are elaborated on in [11].

Lean Principles

Womack [9] captured the process of creating value without waste into six Lean Principles[2]. The Principles are abbreviated as Value, Value Stream, Flow, Pull, Perfection, and People, defined as follows:

1. **The customer (either external or internal) defines value.** The value proposition must be captured with crystal clarity early in the program.
2. **Map the value stream.** Prepare for and plan all end-to-end linked actions and processes necessary to realize value, streamlined, after eliminating waste.
3. **Make value flow continuously.** This should happen without stopping, rework, or backflow (legitimate optimized iterations are okay).
4. **Let (internal or external) customers pull value.** The customer's *pull/need* defines all tasks and their timing.
5. **Pursue perfection.** Constantly improve, and make all imperfections visible to all, which is motivating to the continuous process of improvement.
6. **Respect for people.** Create a system of mutually respectful, trusting, honest, cooperating, and synergistic relationships of key stakeholders, motivating staff to exhibit top capabilities.

Lean Enablers for SE

LEfSE is a major product recently released in the field of Lean SE. It is a comprehensive checklist of 194 practices and recommendations formulated as the *dos and don'ts* of SE, containing tacit knowledge (collective wisdom) on how to prepare for, plan, execute, and practice SE and related enterprise management using Lean Thinking. Each enabler enhances the

program value and reduces some waste. As a set, the enablers are focused on providing more affordable solutions to increasingly complex challenges and improving response time from the identification of need to the release of the system. The enablers deal with mission assurance and promote practices that optimize workflow and reduce waste.

The enablers are formulated as a Web-based addendum to the traditional SE manuals—such as "The International Council on Systems Engineering [INCOSE] Handbook," ISO 15288, and similar NASA, DoD, or company manuals—and do not repeat the practices made therein, which are regarded as sound.

The LEfSE practices are organized into the previously mentioned six Lean Principles. The practices cover a large spectrum of SE and other relevant enterprise management practices, with a general focus to improve program value and stakeholder satisfaction, and reduce waste, delays, cost overruns, and frustrations[3]. The full text of the LEfSE is too long for the present article, therefore only a brief summary is given herein. The full text is available online[4].

- Under the **Value Principle**, the enablers promote a robust process of establishing the value of the end-product or system to the customer with crystal clarity. The process should be customer-focused, involving the customer frequently and aligning the enterprise employees accordingly.
- The enablers under the **Value Stream Principle** emphasize waste-preventing measures, solid preparation of the personnel and processes for subsequent efficient workflow and healthy relationships between stakeholders (customer, contractor, suppliers, and employees); detailed program planning; frontloading; and use of leading indicators and quality metrics.
- The **Flow Principle** lists the enablers which promote the uninterrupted flow of robust quality work and first-time right; steady competence instead of hero behavior in crises; excellent communication and coordination; concurrency; frequent clarification of the requirements; and making program progress visible to all.
- The enablers listed under the **Pull Principle** are a powerful guard against the waste of rework and overproduction. They promote pulling tasks and outputs based on need (and rejecting others as waste) and better coordination between the pairs of employees handling any transaction before their work begins (so that the result can be first-time right).
- The **Perfection Principle** promotes excellence in the SE and enterprise processes; the use of the wealth of lessons learned from previous programs in the current program; the development of perfect collaboration policy across people and processes; and driving out waste through standardization and continuous improvement. A category of these enablers calls for a more important role of systems engineers, with RAA for the overall technical success of the program.
- Finally, the **Respect-for-People Principle** contains enablers that promote the enterprise culture of trust, openness, respect, empowerment, cooperation, teamwork, synergy, good communication and coordination; and enable people for excellence.

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LEfSE were developed by 14 experienced practitioners organized into two teams, some recognized leaders in Lean and System Engineering from industry, academia and governments (from the U.S., United Kingdom, and Israel), with cooperation from the 100-member strong international LSE WG of INCOSE [11].

Both SE and Lean represent challenging areas for research as they are grounded in industrial and government practice rather than laboratory work or theory. It is well-known that hard data about SE in large programs is difficult to obtain because:

- The programs are classified and proprietary.
- The companies are not willing to release such data even when it exists.
- In many cases, the data is non-existent, of a poor quality, lacks normalization, suffers from discontinuities over long program schedules, and is convoluted with other enterprise activities.

As a result, it is difficult to collect the data needed to perform hypothesis testing. Therefore, rather than to rely on explicit program data, the enablers were developed from collective tacit knowledge, wisdom, and experience of the LSE WG members. Such an approach has been practiced for ages by numerous institutions, and is being described in [12]. LEfSE have been formulated for industry SE practitioners, but the development benefited from academic depth, breadth, and rigor; the latter emphasis provided by surveys and benchmarking to published data, as follows.

The development of LEfSE included five phases: Conceptual, Alpha, Beta, Prototype, and Version 1.0. It was evaluated by separate surveys in the Beta and Prototype phases and by comparisons with the recent programmatic recommendations by GAO and NASA [1, 2, 3, 4]. The surveys indicated that LEfSE are regarded as important for program success but are not widely used by industry. The comparisons indicated that LEfSE are consistent with the NASA and GAO recommendations, but are significantly more detailed and comprehensive.

Intended Use

The LEfSE are not intended to become a mandatory tool. Instead, they should be used as a checklist of good holistic practices. Some are intended for top enterprise managers, some for programs, and others for line employees. Some are more actionable than others, and some are easier to implement than others. Some enablers may require changes in company policies and culture. However, employee awareness of even those least actionable and most difficult to implement enablers should improve the thinking at work.

The creators believe that as many systems (and other) engineers, enterprise managers, and customer representatives as possible should be trained in the LEfSE, as it will lead to better programs. At this time, a large effort of offering tutorials and lectures about the LEfSE throughout INCOSE chapters, industry, and academia is ongoing.

The published product includes examples of the programs and companies that practice the given enablers. Also listed is the average value measuring the use of a given enabler in industry, obtained from the surveys.

A formal online process of continuous improvement and periodic new releases of

the LEfSE has been set up as new knowledge and experience becomes available. A comprehensive description of the history of LSE, the development process of LEfSE, the full text of the enablers, the surveys, and industrial examples can be found in [11]. ◆

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Notes

1. The early use of the term LSE is sometimes met with concern that this might be a "re-packaged faster, better, cheaper" initiative, leading to cuts in SE at a time when the profession is struggling to increase the level and quality of SE effort in programs. Our work clearly disproves this concern.
2. The original formulation had five principles; the sixth (the Respect-for-People Principle) was added at a later time.
3. LEfSE practices do not deal, however, with explicit financial steps such as cost estimating or earned value analysis, which are regarded as a separate activity.
4. A PowerPoint presentation is available in PDF format at: <http://cse.lmu.edu/Assets/Colleges+Schools/CSE/Lean+Enablers+for+SE+Version+1.01.pdf>.