Systems engineering from a South African perspective

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Origins of Systems Engineering (SE) in South Africa South Africa is located within one of the fasted growing economic regions in the world. The race is now on to find the best way of doing business in the subcontinent and making the region attractive to international trade and investment.

While the state cannot in itself create economic growth, it can and must establish the infrastructure and framework within which trading can take place, private investment can flourish and industry can thrive and compete – if South Africa is to become the undisputed leader in trade and development on the continent.

This needed innovation, continuous improvement, world-leading research and high-level skills development. This needs a structured way of creating and fostering knowledge. This needed a new way of thinking.

Technology is often found at the centre of the required economic growth and technology is probably not what you think it is. The American Heritage Dictionary describes technology as **a.** The application of science, especially to industrial or commercial objectives. **b.** The entire body of methods and materials used to achieve such objectives."

In general, technology development lies within the context of part "**a"** of the definition. However, the engineering community often makes use of the term "technology" within the context of part "**b"**. In this context, technology may be "old," "off-the-shelf (commercially available)," or new. It is further complicated when "old" technology, i.e. "heritage elements" are used in completely new ways – a situation that encompasses both parts "**a**" & "**b**".

Unfortunately use of "heritage" or "legacy" system is so often fraught with danger because it is being asked to operate in an architecture or an environment that in all probability is different from that for which it was designed. And because we have not done the upfront analysis, we don't know we are in trouble until we are already there!

This needed Systems Thinking.

So when things drop through the crack during engineering and technology development projects, processes have been "invented" to correct the problem - hence we have developed processes to identify:

Design maturity, technology maturity, manufacturing maturity, material maturity, integration maturity, software maturity, capability maturity, system maturity, etc.

All of these processes are in reality part of the systems engineering process, but because of what they deal with – e.g. “technology,” “manufacturing,” “etc.,” the processes are “owned” by different disciplines other than systems engineering.

The result is a fragmented assessment process, which in the end fails to achieve the desired goal of ensuring successful programs and projects.

For those few who live and breathe the rarified vapors of systems thinking, it's pretty hard to fathom how life existed without Systems Engineering. Yet, it has been a short 30 years or so since the discipline was introduced in South Africa through the SA Defense R&D community. This started when Prof. Ad Sparrius studied the topic and started developing his training courses which provided foundation training to almost all South African Systems Engineers since about 1984.

What is Systems Engineering While there is general recognition that "Systems Engineering" plays an important role in the development and operation of large-scale systems, there is also a great deal of confusion about what "Systems Engineering" is. It currently means many different things to different people.

South Africa belongs to the International Council on Systems Engineering (INCOSE) and therefore generally subscribes to definition found on INCOSE website (www.incose.org), defining SE as:

“. . . an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:

Operations, performance, test, manufacturing, cost & schedule, training & support, and disposal

Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.”

According to Rechtin, Systems Architecting of Organizations: Why Eagles Can’t Swim:

“ Systems engineering is a methodical, disciplined approach for the design, realization, technical management, operations, and retirement of a system. A “system” is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hard-ware, software, facilities, policies, and documents; that is, all things required to produce system-level results. The results include system-level qualities, properties, characteristics, functions, behavior, and performance. The value added by the system

as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected.

- *It is a way of looking at the "big picture" when making technical decisions.*
- *It is a way of achieving stakeholder functional, physical, and operational performance requirements in the intended use environment over the planned life of the systems.*
- *It is a methodology that endeavors to foresee and contain the life-cycle cost of a system. "*

Systems Thinking Systems engineering uses a variety of techniques that may be divided into hard systems and soft systems. The original hard systems approach (more relevant to technical, engineered systems) and the more recent soft systems approach (more relevant to human and social systems)

The hard systems approach is essentially about defining the problem solving sequence. The approach starts with a basic acceptance of the objectives, problem specification, and organizational needs. Hard systems engineering aims to provide a solution to a defined problem in the terms in which the problem is posed, so these factors are generally taken as given.

Hard systems approach is mostly applicable to "Engineering Development" where the premise is that requirements are achievable and that any engineering difficulty can be overcome and the requisite performance achieved within cost and schedule constraints.

The "certainty" associated with engineering development lies in the past experience of the developers.

A number of problems arise when these hard systems approaches are applied to soft systems, especially those systems that involve humans.

Soft systems thinking has the starting point in 'unstructured' problems within social activity systems in which there is felt to be an ill-defined problem situation, or what others refer to as a "wicket" problem.

Soft systems approach is mostly applicable to "Technology Development", where the requirements may not be achievable and that it is not known with any certainty whether or not they can be met within a given cost and schedule.

A major element often ignored historically is the integration of human factors into the design of tools, machines and systems so that they can match and augment human abilities and limitations.

Technology development, therefore, is all about maximizing the probability of success by pursuing parallel paths, having alternate solutions and having fall-back positions.

Systems Engineering Education In South Africa, only three universities offer accredited systems engineering courses at Masters and Doctoral levels:

- University of Witwatersrand - School of Mechanical, Industrial and Aeronautical Engineering Industrial and Systems Engineering
- University of Pretoria - Department of Industrial and Systems Engineering Industrial and Systems Engineering
- University of Stellenbosch - Department of Industrial Engineering

About Transnet Centre of Systems Engineering The Wits Transnet Centre of Systems Engineering was established to introduce systems thinking as a means of addressing Transnet needs – as defined in their Market Demand Strategy over a 7 year period, and into the future, based on their Long-Term Planning Framework.

A large part of the responsibility of establishing South Africa as the undisputed leader on the continent lies with the ability of the State Owned Company (SOCs) to deliver the infrastructure and services critical to the process – efficiently, effectively and on an on-going basis.

The SOCs draw on various skills, competencies and technologies. They are characterised by highly regulated operating environments, challenging conditions, and a critical market place – but are examples of some of the most diverse and complex organisation in the modern world.

Right now they have to become world leaders at what they do. Nothing less is acceptable - and they know this.

And the State expects this.

The SOCs will achieve this by embracing complexity and developing methodologies of deconstructing themselves into manageable components, each of which can be understood and optimized, and the whole reconstructed, understood and optimized - in a manner as seamless and simple as loading a container onto a train.

This is Systems Engineering.

The engineering skills that these enterprises require to achieve their goals cover a wide spectrum and relate mainly to mechanical, electrical, software, mechatronics, civil and industrial engineering. As the effectiveness and efficiency of their complex operations is paramount, systems engineering will be the integrating force - embracing the concept that the whole should exceed the sum of the individual parts.

The Wits Transnet Centre of Systems Engineering offers an environment within which this new way of thinking can be managed, controlled and understood so that the gains made are guided and optimised in a manner that will provide a long-term benefit to the economy.

It being achieved this by:

- Co-operating and work-shopping with Transnet and other SOC leaders to offer synergistic, university-based guidance for possible new directions and perspectives;
- Identifying, undertaking and coordinating fundamental and applied research and development in areas of interest to Transnet and other SOCs;
- Fostering and improving graduate and post-graduate education and human capacity in Systems Engineering and other disciplines relevant to the needs of Transnet and other SOCs;
- Actively engaging with all Education, Training and Research entities working in relates fields, and becoming the main contact point (the "one stop shop") through which the transfer of knowledge and expertise is enabled via channels that are developed by means of local and overseas networking/linkages with industry, HEI's and research organizations;
- Developing an integrated knowledge repository to service the needs of Transnet and other SOCs over a wide range of parameters; and
- Developing technology advancement to serve the needs of Transnet and other SOCs into the future.

The TCSE is hosted within the Faculty of Engineering and the Built Environment (FEBE) at the University of the Witwatersrand, Johannesburg. The broad aim of the relationship between FEBE and Transnet is to enhance and invigorate the profound and considerable role that Transnet as a whole - with its various components - has in contributing towards the economy of South Africa.

Conclusion While it is evident that systems engineering found its roots in SA through the defense fraternity in the mid 80s, the concept is constantly evolving and adapting to the different disciplines and industries that require system level results.

Transnet, amongst others, needs to be commended for seeing through Aristotle's eyes when he realized that "The whole is greater than the sum of its parts."

It is also clear that when comparing the engineering development process to the technology development process one can see that it is extremely important to know in what type of development one is engaged. Technology development is distinguished from engineering development in that it requires venturing into the realm of unknowns - beyond the ability of individuals to make informed judgments based on their experience.

When dealing with complex systems or "wicket" problems, systems engineering remains one of the best solutions that considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

While the academic offering is mainly limited to the Witwatersrand, Pretoria and Stellenbosch Universities, many other education institutions offer elements thereof.

Finally, while not every engineer needs to be a Systems Engineer, every major project requires a systems engineer, at least one.

Systems engineering is a holistic, integrative discipline, wherein the contributions of structural engineers, electrical engineers, mechanical engineers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline

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