Systems Engineering

Does it facilitate or hamper our work?

What is

Systems Engineering

about?

Overburdening designers with paperwork?

Impeding creativity?

Systems Engineering is often perceived as leaning toward an

overly normative approach

ISO/IEC FDIS 15288:
Systems engineering — System life cycle processes

ISO/IEC JTC 1/SC 7/WG 7 N0586

Date: 2002-02-18

ISO/IEC FDIS 15288:2002(E)

ISO/IEC JTC 1/SC 7/WG7

Secretariat: Canada

Systems engineering — System life cycle processes

Document type: International Standard
Document subtype:
Document stage: (50) Approval
Document language: E

C:\Documents and Settings\jndrouin.BELL\My Documents\SC7 Documents To Issue\07n2594.doc STD Version 1.0

Contents

ISO/IEC FDIS 15288:
Systems engineering — System life cycle processes

The Technical Processes consist of the following processes:

a) Stakeholder Requirements Definition Process;

b) Requirements Analysis Process;

c) Architectural Design Process;

d) Implementation Process;

e) Integration Process;

f) Verification Process;

g) Transition Process;

h) Validation Process;

i) Operation Process;

j) Maintenance Process;

k) Disposal Process.

N0586
2-02-18
002(E)
7/WG7
Canada

Contents

5.5.3.3 Requirements Analysis Process Activities

The project shall implement the following activities in accordance with applicable organization policies and procedures with respect to the Requirements Analysis Process.

Just a misperception?

But there is much more in

Systems Engineering

than rules, norms, standards,

and prescriptions

so, please,

Don't throw the baby out with the bath water!

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- System Engineering and the “Two Cultures” of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?
- Some personal ideas

Some diverse perspectives on Systems Engineering and Systems Engineers

- **Twelve Systems Engineering roles (INCOSE)**
- The Art and Science of Systems Engineering
- System Engineering and the "Two Cultures" of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?
- Some personal ideas

TWELVE SYSTEMS ENGINEERING ROLES

"... roles ... which are occasionally or frequently assumed to constitute the practice of systems engineering:

1) **Requirements Owner**
2) **System Designer**
3) **System Analyst**
4) **Validation/Verification Engr.**
5) **Logistics/Ops Engineer**
6) **Glue Among Subsystems**
7) **Customer Interface**
8) **Technical Manager**
9) **Information Manager**
10) **Process Engineer**
11) **Coordinator**
12) **Classified Ads SE**

(This [last] role was added to the first eleven in response to frustration encountered when scanning the classified ads, looking for the INCOSE-type of systems engineering jobs. Approximately half of the advertisements for "systems engineers" in a recentb newspaper seemed to be asking for other things.)

TWELVE SYSTEMS ENGINEERING ROLES Sarah A. Sheard Proceedings for the Sixth Annual International Symposium of the INCOSE, 1996

Glue among subsystems role:

In this role, the systems engineer serves as a ***proactive troubleshooter, looking for problems and arranging to prevent them***. Since many problems happen at interfaces, this role ***involves a very close scrutiny of interfaces***, particularly internal, subsystem-to-subsystem interfaces. While the designers of the subsystems struggle to make their subsystems do what they are supposed to, the "Glue" Systems Engineer is ***watching to ensure that each subsystem is not going to interfere with the others.***

TWELVE SYSTEMS ENGINEERING ROLES Sarah A. Sheard Proceedings for the Sixth Annual International Symposium of the INCOSE, 1996

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- ➢ The Art and Science of Systems Engineering
- System Engineering and the “Two Cultures” of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?
- Some personal ideas

... the complete systems engineer ... embodies

the art *and* science of Systems Engineering

Technical Leadership

Culture

(the art)

+

Systems Management

(the science)

Organizations that **focus solely on technical issues** often create products or services that are *inoperable*, or suffer from lack of coordination and become *too expensive* or *belated* to be useful.

Organizations that **focus mainly on systems management** often create products that *fail to meet stakeholder objectives* or are *not cost effective*. The *process* often *becomes an end unto itself*

The Personal Characteristics of Good Systems Engineers:

- Intellectual *curiosity*.
- Ability to see the *big picture*
- Ability to make *system-wide* connections
- Exceptional *two-way* communicator
- Strong team *member* and leader
- Comfortable with *change*
- Comfortable with *uncertainty*
- *Proper* paranoia
- *Diverse* technical skills.
- *Self confidence* and *decisiveness*
- Appreciate the *value of process*

THE ART AND SCIENCE OF SYSTEMS ENGINEERING Michael Ryschkewitsch, Dawn Schaible, Wiley Larson, *NASA - Stevens Institute of Technology - 1/18/09*

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- ➢ System Engineering and the "Two Cultures" of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?
- Some personal ideas

System Engineering is NOT about the details of requirements and interfaces between and among subsystems.

System Engineering and the “Two Cultures” of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

System Engineering is NOT about the details of requirements and interfaces between and among subsystems.

Such details are important, of course, in the same way that accurate accounting is important to the Chief Financial Officer of an organization. But accurate accounting will not distinguish between a good financial plan and a bad one, nor help to make a bad one better.

Accurate control of interfaces and requirements is necessary to good system engineering, but ***no amount of care in such matters can make a poor design concept better****.*

System Engineering and the "Two Cultures" of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

System Engineering is NOT
about the details of requirements and interfaces between and among subsystems.

Such details are important, of course, in the same way that accurate accounting is important to the Chief Financial Officer of an organization. But accurate accounting will not distinguish between a good financial plan and a bad one, nor help to make a bad one better.

*Accurate control of interfaces and requirements is **necessary** to good system engineering, but **no amount of care in such matters can make a poor design concept better**.*

System engineering is about getting the right design.

System Engineering and the "Two Cultures" of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

The Artistic Side of Engineering

But at least for now, there remains an ***artistic side of engineering***, and it is fully as much an art for its practitioners as any painting, sculpture, poem, song, dance, movie, play, culinary masterpiece, or literary work. The difference between the cultural and engineering arts lies not so much in the manner of creation of a given work, but in the standards by which that work is judged.

System Engineering and the “Two Cultures” of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

The Artistic Side of Engineering

But at least for now, there remains an ***artistic side of engineering***, and it is fully as much an art for its practitioners as any painting, sculpture, poem, song, dance, movie, play, culinary masterpiece, or literary work. The difference between the cultural and engineering arts lies not so much in the manner of creation of a given work, but in the standards by which that work is judged.

In the ***humanistic disciplines***, human ***aesthetics sets the standard*** by which merit is assigned to a finished product. In the end, aesthetic sensibilities vary with place and time, and are ultimately matters of opinion.

System Engineering and the “Two Cultures” of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

The Artistic Side of Engineering

But at least for now, there remains an ***artistic side of engineering***, and it is fully as much an art for its practitioners as any painting, sculpture, poem, song, dance, movie, play, culinary masterpiece, or literary work. The difference between the cultural and engineering arts lies not so much in the manner of creation of a given work, but in the standards by which that work is judged.

In the ***humanistic disciplines***, human ***aesthetics sets the standard*** by which merit is assigned to a finished product. In the end, aesthetic sensibilities vary with place and time, and are ultimately matters of opinion.

In ***engineering***, more ***objective methods*** are employed to judge the degree to which the completed work meets the ***standards*** established for it, or fails to do so.

System Engineering and the “Two Cultures” of Engineering - Michael D. Griffin, Administrator, NASA, Boeing Lecture, Purdue University, 28 March 2007

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- System Engineering and the "Two Cultures" of Engineering
- ➢ Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?
- Some personal ideas

The research about the cognitive and personality characteristics of engineers with high "*engineering systems thinking*" thinking skills was conducted with a survey based on more than 300 interviews and questionaries.

Based on the research findings, a literature review, and Senge's laws for systems thinking, were evolved

30 engineering systems thinking laws

Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

1. **In all the project's phases/stages take into account: the problems to be solved, and the customer's organization, vision, goals, tasks, needs, requirements and preferences.**
2. **The whole has to be seen as well as the interaction between the system's elements.**
3. **Consider that every action could have implications also in another place or at another time.**
4. **Always look for the synergy stemming from the integration of sub-systems.**
5. **The solution is not always only engineering one. The systems engineer has also to take into account: Cost, Reuse, and Organizational, managerial, "political" and personal considerations.**
6. **Take as many different perspectives as possible, and review other aspects from all points of view.**

Adapted from: Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

7. **Always take into account: Electrical, Mechanical, Environmental conditions , Quality assurance, and Benefit indices (reliability, availability, maintainability, testability, and productibility).**
8. **In all development phases the future logistic requirements have to be taken into account**
9. **When carrying out a modification in the system, take into account: the engineering and non-engineering implications, the effects on the form, fit, and function, the delays and the time durations of the modification incorporation, the system's response time to the changes, the needs, difficulties, and attitudes of those supposed live with the modifications, and that the change could bring short-term benefit but long-term damage.**
10. **Each problem may have more than one possible working solution. All possible alternatives should be examined and compared to each other**

Adapted from: Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

11. **Engineering design is not necessarily maximal. At every stage engineering trade-offs and cost-effectiveness considerations should be considered.**
12. **In case of system’s malfunction, problem, or failure, repeated structures and patterns should be looked for and analyzed, and lessons drawn accordingly**
13. **Look always for the leverage point - changes that might introduce significant improvements by minimum effort.**
14. **Pay attention to and take into account slow or gradual processes.**
15. **Avoid adapting a known solution for the current problem “Today’s problems come from yesterday’s solutions”**
16. **Take into account development risks. the strategy of eliminating uncertainties has to be taken.**

Adapted from: Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

17. It is impossible to run a project without control, configuration management, milestones, and management and scheduling methods.

18. At each stage, the human element has to be considered.

19. The engineering design is a top-down design The integration and tests are bottom-up.

20. At every stage, systemic design considerations should be used

21. Engineering systems thinking requires the use of simulations.

22. Engineering systems thinking requires the integration of expertise from different disciplines. Systems thinking, by its nature requires the examination of different perspectives, calling for teamwork to cover the various perspectives.

23. Try to anticipate the future at every stage

Adapted from: Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

24. **Selecting partners and subcontractors could be critical.**

25. **When selecting the software language or software development tools and platforms, make sure that they are usable and supportable, or changeable, throughout the system's life.**

26. **When selecting components for production take into account their shelf life.**

27. **In engineering systems thinking, it is recommended not to start development at all, if the serial production budgets are not guaranteed in advance.**

28. **Always examine the external threats against the system**

29. **Engineering systems thinking resorts probability and statistical terms,**

30. **In engineering systems thinking it is advisable to limit the responsibility assigned to an external factor (such as external counselor) Teach people to fish, rather than giving them fish.**

Adapted from: Engineering Systems Thinking and Systems Thinking, Moti Frank, Systems Engineering, Vol. 3, No. 3, 2000

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- System Engineering and the "Two Cultures" of Engineering
- Engineering Systems Thinking
- ➢ **Systems Thinking and Process**
- What is a Systems Engineer?
- Some personal ideas

“the tools and artifacts of *standardized processes can enable collaborative systems thinking* **…**

… standardized process provide structure beyond that found in an organizational chart”

Promoting Systems Thinking Through Alignment of Culture and Process: Initial Results, Caroline Twomey Lamb, Donna H. Rhodes, PROCEEDINGS CSER 2007

“standardized *processes are not sufficient* to ensure success …

… *organizational culture* [is an important] *complement to processes* …

… *process needs context*. Organizational culture is an essential part of this context”

Promoting Systems Thinking Through Alignment of Culture and Process: Initial Results, Caroline Twomey Lamb, Donna H. Rhodes, PROCEEDINGS CSER 2007

“By forming a set of *shared assumptions and accepted behaviors*, cultural norms likely support collaborative systems thinking.

***When* an organization’s basic *underlying assumptions* are in *harmony* with its *standardized processes*, culture and process interact in a** *reinforcing loop*”

Promoting Systems Thinking Through Alignment of Culture and Process: Initial Results, Caroline Twomey Lamb, Donna H. Rhodes, PROCEEDINGS CSER 2007

“Engineering is a *sociotechnical activity* requiring many people to interact.

There is a concept of a *shared mental model*, a shared view of reality that is built up within a group over time …

[Design] Reviews, by *emphasizing requirements* and *surfacing assumptions* may help to form shared mental models, thus facilitating systems thinking.”

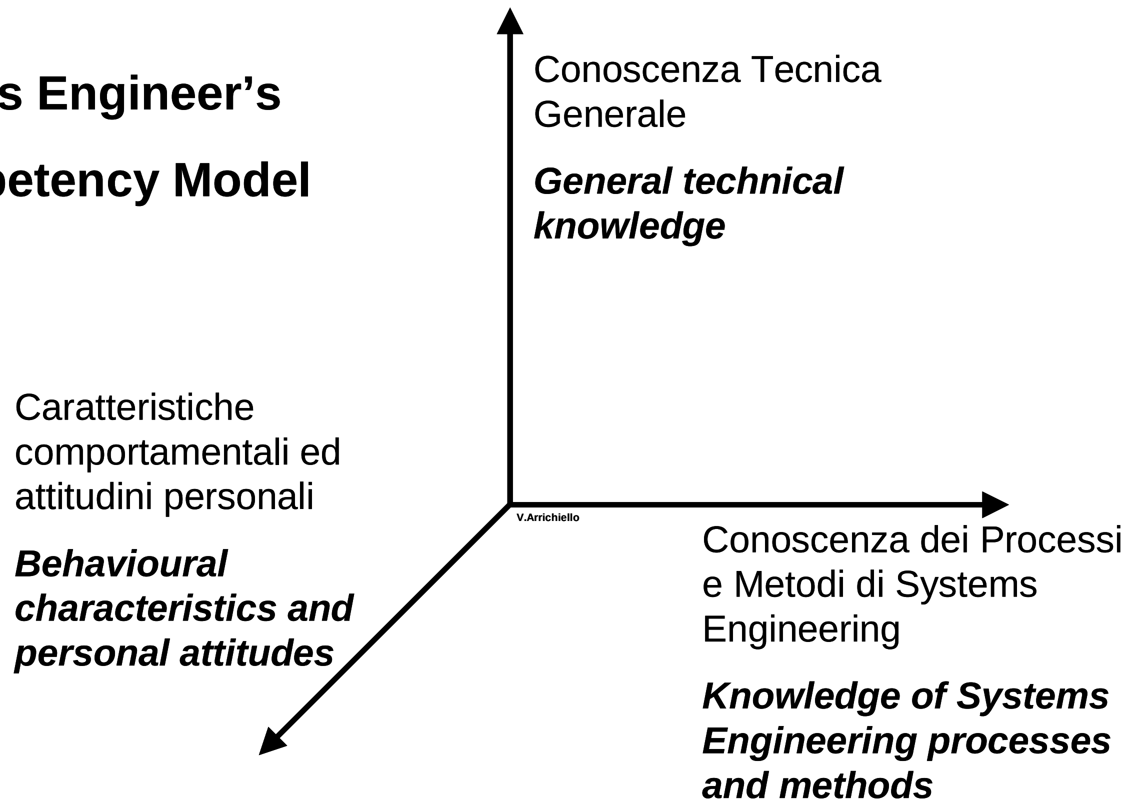
Promoting Systems Thinking Through Alignment of Culture and Process: Initial Results, Caroline Twomey Lamb, Donna H. Rhodes, PROCEEDINGS CSER 2007

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- System Engineering and the “Two Cultures” of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- ➢ **What is a Systems Engineer?**
- Some personal ideas

Systems Engineer’s

3D Competency Model



Behavior Model/Competencies

Top Level Themes	Middle Competencies
Leadership	Appreciates/Recognizes Others
	Builds Team Cohesion
	Understands the Human Dynamics of a Team
	Creates Vision and Direction
	Ensures System Integrity
	Possesses Influencing Skills
	Sees Situations Objectively
	Coaches and Mentors
	Delegates
	Ensures Resources are Available
Attitudes & Attributes	Remains Inquisitive and Curious
	Seeks Information and Uses the Art of Questioning
	Advances Ideas
	Gains Respect Credibility, and Trust
	Possesses Self-Confidence
	Has a Comprehensive View
	Possesses a Positive Attitude and Dedication to Mission Success
	Is Aware of Personal Limitations
	Adapts to Change and Uncertainty
	Uses Intuition/ Sensing
	Is Able to Deal with Politics, Financial Issues, and Customer Needs

NASA Systems Engineering Leadership Development Program (SELDP) Program Plan, NASA Office of the Chief Engineer, January 26, 2009

Behavior Model/Competencies (cont.)

Communication	Listens Effectively and Translates Information
	Communicates Effectively Through Personal Interaction
	Facilitates an Environment of Open and Honest Communication
	Uses Visuals to Communicate Complex Interactions
	Communicates Through Story Telling and Analogies
	Is Comfortable with Making Decisions
Problem Solving & Systems Thinking	Identifies the Real Problem
	Assimilates, Analyzes, and Synthesizes Data
	Thinks Systemically
	Has the Ability to Find Connections and Patterns Across the System
	Sets Priorities
	Keeps the Focus on Mission Requirements
	Possesses Creativity and Problem Solving Abilities
	Validates Facts, Information and Assumptions
	Remains Open Minded and Objective
	Draws on Past Experiences
	Manages Risk
Technical Acumen	Possesses Technical Competence and Has Comprehensive Previous Experience
	Learns from Successes and Failures

NASA Systems Engineering Leadership Development Program (SELDP) Program Plan, NASA Office of the Chief Engineer, January 26, 2009

Some diverse perspectives on Systems Engineering and Systems Engineers

- Twelve Systems Engineering roles (INCOSE)
- The Art and Science of Systems Engineering
- System Engineering and the “Two Cultures” of Engineering
- Engineering Systems Thinking
- Systems Thinking and Process
- What is a Systems Engineer?

➢ **Some personal ideas**

Orchestration or Choreography?

The Systems Engineer should act,

rather than as a *conductor*,

Techno music: The ASIMO humanoid robot conducts the Detroit Symphony Orchestra (AFP: Honda)

more **as a** *choreographer!*

The Washington Post - Erin Baiano

Systems Engineering,

in a way, is just

common sense,

applied with discipline,

made explicit

Backup slides

Systems Thinking can help in avoiding being caught in the *”vicious cycle”* trap

Meeting customer's schedule

Lot of problems in test phase

Meeting customer's schedule

Lot of problems in test phase

Reserve long time to test phase

Meeting customer's schedule

Lot of problems in test phase

Reserve long time to test phase

Start building before the requirements are complete

"Vicious cycle"

Meeting customer's schedule

Reserve long time to test phase

Start building before the requirements are complete

Lot of problems in test phase