TALLINN UNIVERSITY OF TECHNOLOGY

IAF0320

Computer Systems Engineering

Gert Jervan
Department of Computer Engineering
Tallinn University of Technology

Plan for the lecture

- Introduction of the lecturer
- Outline of the subject and policies
- General introduction to the Systems Engineering
- Discussion of the first assignment

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Gert Jervan

- MSc from TTÜ in 1998
  - Exchange student at TIMA Labs (Grenoble, France), Fraunhofer Institute (Dresden, Germany), Linköping University (Sweden)
- PhD from Linköping University (Sweden) in 2005
- Senior research fellow at TTÜ since 2005, professor since 2012
- Vice-Dean for Research at the Faculty of IT (2012), Dean (2013)
- Published more than 50 papers at international conferences and journals
- Organized many international conferences and coordinated several research projects, incl. 7-year project CEBE (Centre for Integrated Electronic Systems and Biomedical Engineering)

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This is NOT a course about software engineering

NOR about hardware engineering

This is a course about Systems Engineering (containing software, hardware, people, ...)

Systems Engineering - SE

The course aims are:

- To give an overview of the systems engineering discipline, to introduce the main principles and history.
- To describe the nature of life cycle and its role in systems engineering.
- To explain the role of requirements analysis and different aspects of requirements.
- To give an overview of different types of specifications, to learn how to use specifications throughout the design process.
- To introduce architectural design and its implications.
- To learn about systems testing, maintenance and management.
- To get acquainted with project management principles, version management and quality assurance.
- To learn how to develop complex hardware-software systems.

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Having completed the course, a student:

- has an understanding about the systems engineering principles and knows the terminology;
- recognizes the need for a disciplined approach to system development;
- knows different requirements analysis techniques and knows how to apply one of a range of techniques to elicit and then describe the requirements for a particular system;
- recognizes the characteristics of a high quality specification and can create a high quality specification of a given system;
- knows how to select and implement an appropriate approach to design for a range of possible applications;

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Having completed the course, a student:

- recognizes the range of tests appropriate for each stage of the systems life cycle;
- can select an appropriate combination of tests for ensuring the quality of a system;
- understands the nature of maintenance in computer systems engineering;
- recognizes and knows how to address the major problems of project management in computer engineering including multi-disciplinary issues;
- knows the main design steps for designing complex computer-based systems.

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Course materials

- Course homepage:
  - http://www.pld.ttu.ee/IAF0320/
  - Provides access to:
    - Required reading materials
    - Handouts
    - Homework assignments
- LinkedIn group:
  - IAF0320 - Computer Systems Engineering
  - Discussions
  - Announcments
  - **Join and communicate!!**

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Course Plan

- 16 occasions, á 1,5 hours
  Mondays 17:45-19:15
  - Short Lectures, incl. a few invited lectures from the companies
- 8 occasions, á 1,5 hours, weeks 5-12
  Thursdays 17:45-21:00
  - Teamwork sessions/presentations
- Project work
  - Presentations
  - Written reports
  - Discussions
- Tests

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Reading

- No textbook. Recommended reading: Systems Engineering Principles and Practice, 2nd Edition. A. Kossiakoff, W. N. Sweet, S. Seymour, S. M. Biemer. April 2011
- Various papers on the course homepage
  - www.pld.ttu.ee/IAF0320
- Slides posted min. ½ hour prior to the lecture
- Some reading material will be distributed as hardcopies during the lecture
- Please prepare and read the papers in advance!
- The homework assignments and teamwork sessions require reading the papers

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Grading

- Project work (divided into sub-tasks): 70%
  - Combination of individual tasks and team-work
  - Written reports
  - Presentations
  - Prototype (extra points)
- Mid-term test: 10%
- Final test: 10%
- Participation in discussions: 10%

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Project work

- The goal is to apply the system engineering methods and tools to a topic that fits your interest/background/daily life
- Acceptable topic examples include:
  - Design of a new system (technical organizational, enterprise level, etc.). The project must have enough detail so that it can demonstrate the use of the methods and tools taught in the class
  - In-depth investigation of a successful or failed project
- The system must include (at least) software and hardware, preferrably more
- Choose a project that you have access to information and data

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Handing in your work

- Please submit your reports/presentations to me by e-mail: **gert.jervan@ttu.ee**
- The e-mail should carry course code (IAF0320) in the Subject
- Please submit your work as a PDF (preferred) or MS Office files
- Please observe the deadlines! One grade is lost per day late!
- In case of unusual circumstances or unavoidable conflicts please contact me **in advance** to discuss the details and explore alternatives

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History

- Some kind of System Engineering capability cannot be a modern invention, witness great civil engineering projects such as the Pyramids
- Explicit SE can be traced to the development of telephone communication systems (INCOSE, 2005)
- WW2 increased complexity and urgency of systems development and SE concepts developed alongside Operations Research
- 50's cold war systems and 60's space race
- Impact of software and communications technologies
- '00 increased cost and time-to-market pressure at the same time as increases in scale
- Major project failures continue despite advances in SE theory

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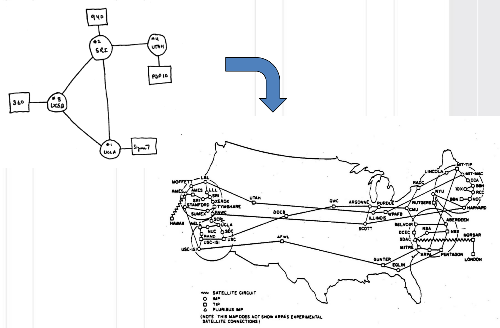
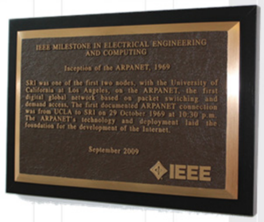
ARPANET



ARPANET

- A prime example of scalable architecture
- New trends in management of big projects
  - Flatter, less centralized, meritocratic



- To think at home: in which modern systems these principles exist? Explain!

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Definitions - system

- 1. A system is a complex set of dissimilar elements or parts so connected or related as to form an organic whole.
- 2 The whole is greater in some sense than the sum of the parts, that is the system has properties beyond those of the parts. Indeed the purpose of building systems is to gain those properties. (Eberhardt Rechtin,1991)
- A collection of components organised to accomplish a specific function or set of functions (IEEE STD 610.12)

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Definitions - system

- An integrated set of elements that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services and other support elements (INCOSE,2004)
- Examples:
  - Hardware / Software
    - A380
  - Products / People
    - A380 + staff + passengers in flight
  - Products / Organisations
    - A380 + ground systems (ATC..)
  - Services
    - Aviation fuelling system
  - Processes
    - The A380 realization system at Airbus (Martin)
    - Systems Engineering process defined by ISO 13288
    - Organisational learning and process improvement

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Definitions: engineering

- Engineer: one who designs or makes or puts to practical use, engines or machinery of any type, including electrical; one who designs or constructs public works.. engineering: the art or profession of an engineer. (Chambers, 1978)
- The application of scientific principles to practical ends (Kossiakoff and Sweet, 2003)

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Definitions: Systems Engineering

- Systems Engineering is an organised method for decomposing a large problem into a series of smaller, hierarchically arranged problems and the integration of the solutions to these smaller problems into a solution for the large problem. (Grady, 1993)
- An interdisciplinary approach and means to enable the realization of successful systems.. (INCOSE, 2004)

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SYSTEMS engineering

- Emphasis on
  - the nature of systems in general
    - General systems theory
    - Systems Thinking
  - socio-technical systems
  - the system in its operational context
  - problem identification and negotiation
  - emergent (holistic) properties of systems
  - system architecture

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systems ENGINEERING

- Emphasis on
  - Life cycle processes and their integration
  - Project and resource management
  - Trade studies, evaluation of alternative solutions though computer simulation and cost analysis
  - Multi-factor design optimisation
  - Tracking of changes in requirements through life cycle stages
  - Management of multiple stakeholder interests
  - Knowledge and data management
  - Cutting out steps in the life cycle though automation and model-driven development (CAD/CAM)

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Systems Engineering

- 'Common sense' joined-up thinking
  - Identify the problem before selecting a solution
  - Occam's razor
    - "entities should not be multiplied without necessity"
  - Linear cause-effect analysis
  - Feedback loops
  - Pareto law – 80/20

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System of Systems

- Large-scale inter-disciplinary problems involving multiple, heterogeneous, distributed systems.
  - *System elements operate independently.*
  - *System elements have different life cycles.*
  - *The intial requirements are likely to be ambiguous.*
  - *Complexity is a major issue.*
  - *Management can overshadow engineering.*
  - *Fuzzy boundaries cause confusion.*
  - *SoS engineering is never finished.*

Source: INCOSE SE Handbook V3.2

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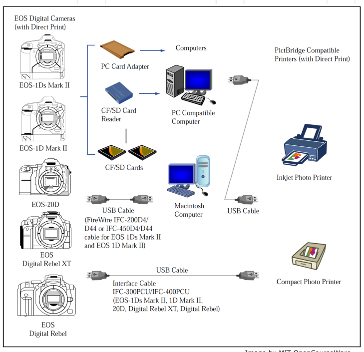
Systems of Systems



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Systems of Systems

- A/V & Home Automation

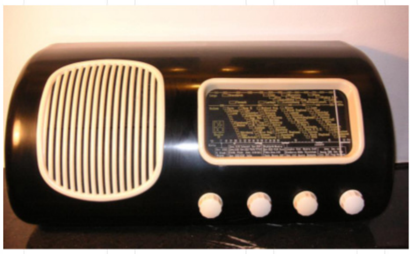

Image: Elgaard Holger, Wikimedia Commons

Some slides from here on: John Fitzgerald, Newcastle University, UK

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Systems of Systems

- A/V & Home Automation

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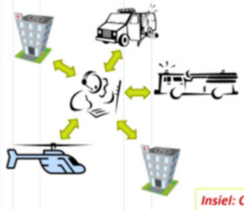
Example: Emergency Dispatch



- Very wide range of stakeholders (patients to government departments).
- Centralised system with human intervention required for many interactions.
- Complex integration of new services.
- Assurance of global performance and security properties
- **Faults & Fault Tolerance**

Insiel: Can we manage evolution to a decentralised system while gaining assurance of global properties?

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More Examples

Type	System	SoS
Human-made "ICT Powered"	Car, Road	Product range, Integrated Traffic System
	Aeroplane	Airport, Air Traffic Control System
	Train	Station, Signalling Rail Network
	Wind Turbine, PV, fossil fuel	Smart Grid
	Building	Town, Shopping Mall
	Computer	Distributed IT System
Biological	Animal, Plant	Herd, Forest
Social	Family, Club , School	Town, Nation, Education System, Religion
Environmental	Weather, River	The Ecosystem
Organisational	Company	Supply Chain, Global Enterprise, Stock Market
Political	Town Council	National Government, EU, UN

Directions in Systems of Systems Engineering, Unit A3-DG CONNECT, July 2012

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Systems of Systems Engineering

- Do SoS "just happen"?
  - Decisions are made (constituents, allocation of responsibilities, coordination policies,...)
- Activities supported in SoS **Engineering** should include:
  - Selecting constituent systems on limited evidence
  - Allocating responsibilities, trade-off analysis
  - Managing fault/failure
  - Managing testing of implementations

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SoS Engineering - Challenges

- **Managing complexity** of the constituent systems and the SoS;
- **Understanding behaviours and interactions** between constituent systems;
- **Communicating effectively** between diverse stakeholders and constituent systems; and
- **Evidence** on which to base reliance in global end-to-end behaviours.

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SoS Engineering - Challenges

- **Increasing uncertainty, but demand for trustworthiness!**
  - Complexity: cognitive and computational
  - Dependability: defect avoidance, detection, elimination, tolerance/resilience
  - Heterogeneity: of systems, models, stakeholders
- **Candidate technologies – are they any use?**
- **Communities of interest**
- **Examples and case studies**

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Systems Engineering Roles

- SE Roles (Sheard, 1996)
  - Requirements Owner
  - Systems Designer
  - Systems Analyst
  - Validation/Verification Engineer
  - Logistics/Operations Engineer
  - Glue among subsystems
  - Customer Interface
  - Technical Manager
  - Information Manager
  - Process Engineer
  - Coordinator
  - (as defined by job ads e.g. MCSE)

Comparison with other disciplines

- Core engineering disciplines
  - Mechanical
  - Electrical
  - Civil
  - **Software**
  - **Information Systems**
  - …
- Project Management
- Business Management
- Quality

Software and information engineering

- Important in three ways:
  - as increasingly important components in mechanical systems – due to the complexity and customisation possible with software
  - as enabling technologies in the engineering process
    - for managing and communicating engineering data and documentation
    - for simulation and computation in solution analysis
    - for complex transformation – from design to machining instructions, from model to code
  - as a source of new approaches to systems engineering
    - spiral and iterative process models
    - new approaches to requirements analysis such as Use cases, scenarios
    - modelling languages – UML, SysML, XML

Waterfall Process Model

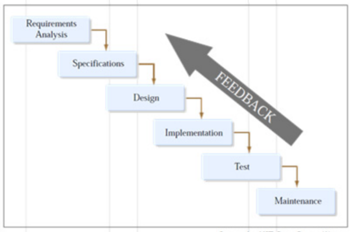


Image by MIT OpenCourseWare.

Introduced by Royce in 1970, initially for software development.

Source: Blanchard, Fabrycky, Systems Engineering and Analysis, 5th ed.

Waterfall Process Model

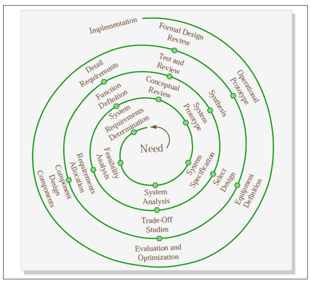
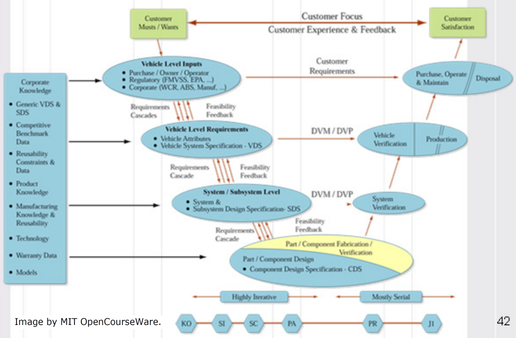


Image by MIT OpenCourseWare.

- Boehm, 1986
- Adapted from Waterfall model
- Iterative
- Prototyping

Source: Blanchard, Fabrycky, Systems Engineering and Analysis, 5th ed.

System Engineering Implemented in FPDS



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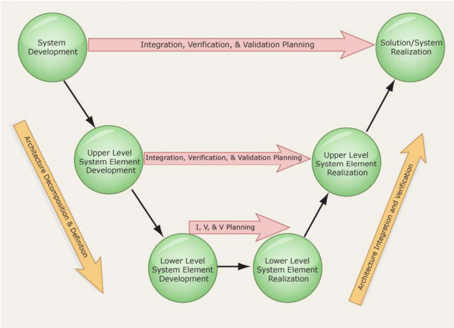
INCOSE VEE Model



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Is there a winner?

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The value of Systems Engineering

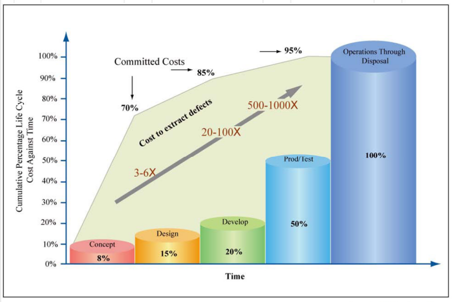

Image by MIT OpenCourseWare.

- SE efforts reduce cost and schedule overrun

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Home assignment

- If you have been working with systems development, then please describe these briefly. Why do you call it a system and what makes it a system? Please identify the differences on developing these systems compared to a product development.
- If you have no working experience with systems then choose one arbitrary system and answer to the same questions
- Why and how can application of SE principles reduce cost and schedule overrun?
  - Think about the characteristics of systems: interaction, hierarchical, emergence, dynamic, interdisciplinary, ...

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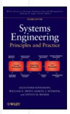
References

- Chris Wallace, Foundations of Systems Engineering, Bristol and West of England Consortium for Continuing Professional Development in Aerospace (CPDA)
- MIT Open Courseware - http://ocw.mit.edu/terms/
- The International Council on Systems Engineering (INCOSE) – http://www.incose.org
  - INCOSE Systems Engineering Handbook v.3+
- Systems Engineering Principles and Practice, 2nd Edition. A. Kossiakoff, W. N. Sweet, S. Seymour, S. M. Biemer. April 2011



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First homework

- Read the texts presented at the course homepage
- Prepare a document (ca. 1 page, use predefined template), detailing your personal objectives and expectations towards the course (detailed instructions are available at the homepage)
- Give an answer to questions raised during the lecture (ca. 1 page)

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Administrative issues

www.pld.ttu.ee/IAF0320

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Questions?

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