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## SYSTEMS PLANNING

Sociotechnical Systems

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### Class content

#### What to expect from this class?


- A definition of **sociotechnical systems**
- An introduction to **factors that influence sociotechnical systems**
- **Characteristics** of sociotechnical systems
- An introduction to the fundamental **process of developing and deploying sociotechnical systems**



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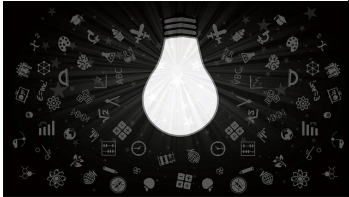
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Class learning goals



## What should be your learning outcome?

- Understand the **difference between a technical and a sociotechnical system**
- Know the main **characteristics and challenges of sociotechnical systems**
- Know the processes involved in **building and deploying sociotechnical systems**




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Sociotechnical Systems


## (Computer) Systems


- In a **computer software and hardware are independent**
- **Software** is an abstraction, which is a simple **representation of human knowledge**
- **Hardware** is a set of **electronic devices**
- **Together**, however, they create a **machine that can carry out complex computations**
- This illustrates a **fundamental characteristic** of a system i.e. **it is more than the sum of its parts!**
- Software systems themselves are part of more extensive systems that have some **human, social or organizational purpose**



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## Sociotechnical Systems




### Sociotechnical System Layers

Systems include **nontechnical elements** such as **people, processes, regulations**, etc. as well as **technical components** such as computers, software, and other equipment!

It is **almost impossible to understand** them. Rather we have to view them as **layers**:

- The equipment layer
- The operating system layer
- The communications and data management layer
- The application layer
- The business process layer
- The organizational layer
- The social layer



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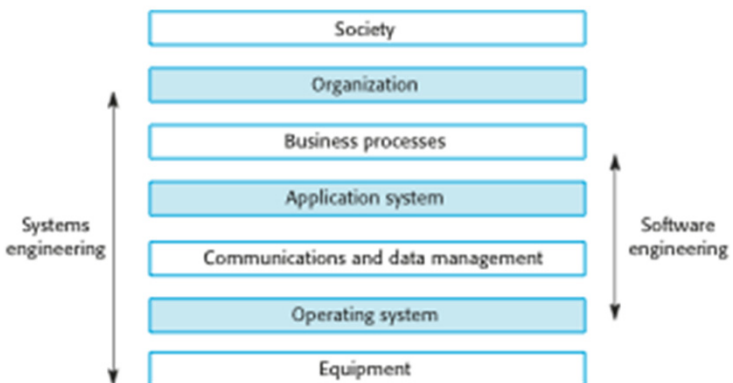
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## Sociotechnical Systems



### Sociotechnical System Stack



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## Sociotechnical Systems




### Changes in Sociotechnical Systems

- Most **interactions** happen **between neighboring layers**
- However, this is **not always the case**

**Example**

A **change in the law** governing access to personal information.

- Comes from the **social layer**
- Leads to new **organizational procedures and business processes**
- **Application layer** would need to implement them
- There may be changes in the **communication and data management layer**



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**Note:** One should think **holistically** rather than simply considering **software in isolation**. Software damage can usually be easily and cheaply restored.

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## Sociotechnical Systems



### Failures in Sociotechnical Systems

- Yet, **software failures** may affect the **software's physical and human environment**  
e.g. people may need to do **extra work**; there may be **physical damage** to equipment; there may be **corrupted data**; etc.
- Hence, you should take a **system level view** when designing software (in particular when it has to be **secure and dependable**)
- **Understand the consequence** of software failures **for other elements in the systems**



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## Sociotechnical Systems



### Understanding Sociotechnical Systems

You need to examine how software **interacts with its environment** to ensure that:

- Software **failures are contained** and **do not lead to system failures**
- You understand how failures in the **non-software layers affect the software** (think about mechanisms that help detect these failures and those that provide recovery from failures)



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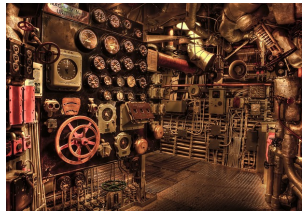
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## Sociotechnical Systems



### System Engineering

- Many so-called **software failures are not a consequence** of inherent **software problems**
- Rather they are the **result of trying to change** the software to accommodate system engineering requirements
- The main cause of the problem may lie in a **faulty system design**
- System engineering is the **process of designing entire systems** whose main cost component is usually software
- It is important to **understand the limits of software to design** and build better systems



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Sociotechnical Systems



## Complex Systems

- The term system is **universally used**  
e.g. computer systems, operating systems, payment systems, education systems, etc.
- A characteristic of all systems is that **properties and behavior are intermingled**
- The **functioning of a system component depends on the functioning of other components**  
e.g. software can only function if the **processor is operational**; the processor can only carry out computations if the **software system has been successfully installed**
- **'Complex' systems** are usually hierarchical systems that consist of other systems, **so-called subsystems**



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Sociotechnical Systems


## Complex Systems


Systems that include software fall into two categories:

- **Technical computer-based systems**  
Systems that include **hardware and software but not procedures and processes**; e.g. TVs, mobile phones, even PCs (**Personal** Computers);
- **Sociotechnical systems**  
Include **one or more technical system(s)** but also **people who understand the purpose of these systems** within the system itself; sociotechnical systems have **defined processes and people** (operators being part of the system); e.g. a **book** is created through a sociotechnical publishing system




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Sociotechnical Systems



## Sociotechnical Systems

- Sociotechnical systems are **enterprise systems**
- They are **intended to deliver a business goal** e.g. increase sales, reduce material used in manufacturing, collect taxes, etc.
- They are influenced by the **organization's policies and procedures**
- The users of the system are also influenced by **how the organization is managed** and by the **interactions with other people** inside and outside the organization
- When you develop a sociotechnical system you need to **understand the organizational environment** in which it is/it should be used



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## Sociotechnical Systems


Organizational factors that may affect sociotechnical systems include:

- **Process changes**  
Changes may require changes in the work processes (training may be required)
- **Job changes**  
New systems may de-skill the user (change the way they need to work). This may lead to users actively resisting
- **Organizational changes**  
A system may change the political power structures in an organization



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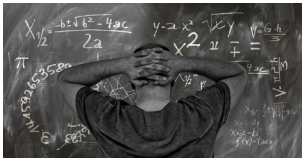
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## Sociotechnical Systems


Sociotechnical systems have three characteristics:

- They have **emergent properties** that are often properties of the system as a whole rather than associated with single components. These properties depend on both the single **components** and the **relationships** between them.
- These systems are often **nondeterministic**
- The extend to which they **support organizational objectives** does often **not depend on the system itself**. A different management may interpret objectives differently.



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Sociotechnical Systems


## Systems Engineering

**Systems engineering** encompasses all of the activities involved in **procuring, specifying, designing, implementing, validating, deploying, operating and maintaining** a sociotechnical system

You need to think about

- **Services** that the system provides
- **Constraints** under which the system must be built and operated
- **Ways** in which the system is used to **fulfill its purpose(s)**




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**Note:** The main difference between systems and software engineering is that systems engineering involves a **range of professional disciplines** throughout the lifetime of a system.

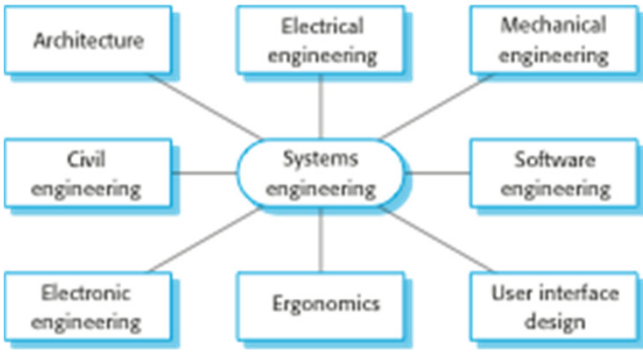
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## Sociotechnical Systems



**Example**  
Disciplines involved in the procurement and development of an **air traffic management** system



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## Sociotechnical Systems



**Example**  
Disciplines involved in the procurement and development of an **air traffic management** system

- **Architects and civil engineers:** the system has to be installed in a new building
- **Electrical and mechanical engineers:** specify and maintain power and air conditioning
- **Electronic engineers:** computers, radars, other equipment
- **Ergonomists:** workstation design
- **Software engineers and user interface designers:** software system



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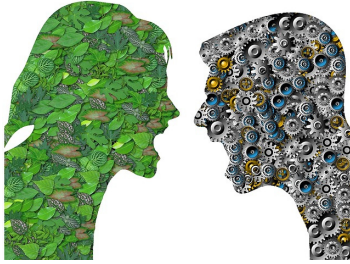
## Sociotechnical Systems



### Systems Engineering Challenges

**Different disciplines** may introduce **vulnerabilities**:

- Different **disciplines** use the same words to **mean different things**
- They **make assumptions** about what can or cannot be done by other disciplines
- They try to **protect their professional boundaries**



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## Sociotechnical Systems



### System Procurement

The **initial phase** of systems engineering is **system procurement**. This includes decisions related to:

- The **state of the other organizational systems**
- The need to comply with **external regulations**
- External **competition**
- Business **re-organization**
- Available **budget**




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## System Procurement

- Large, complex systems usually consist of a mixture of **off-the-shelf** and **specially built components**
- **Software** often acts as **'glue'** to make hardware components work together
- Hence, off-the shelf components are sometimes **more expensive than expected**


### Lessons to be learned

- Commercial Off-the-shelf components (**COTS**) do not usually match requirements exactly
- Specifically built systems **require system specification**
- After a contractor has been selected, there is a **contract negotiation period**

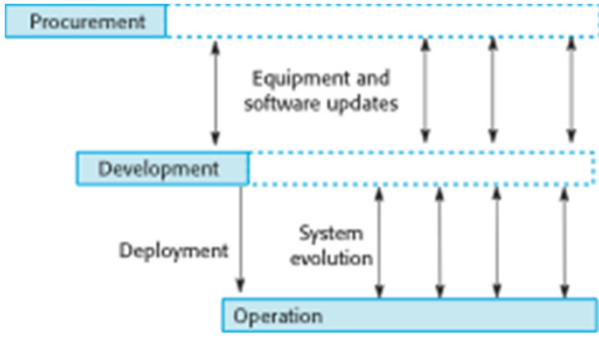


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## System Procurement




```

graph TD
    subgraph Procurement_Box [ ]
        direction TB
        P[Procurement]
    end
    subgraph Development_Box [ ]
        direction TB
        D[Development]
    end
    subgraph Operation_Box [ ]
        direction TB
        O[Operation]
    end
    P -- "Equipment and software updates" --> D
    D -- "Deployment" --> O
    O -- "System evolution" --> D
    
```

Source: Sommerville, I. (2011). Software Engineering, 9<sup>th</sup> Ed. Boston, MA, USA: Pearson Education Inc.

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## Sociotechnical Systems



### System Procurement


Decisions and choices made during the system procurement have a **profound effect on the system**

**Example: Off-the-shelf system**

- Limited influence over the security
- May require complex configuration

**Example: Custom system**

- Require significant understanding of processes and requirements



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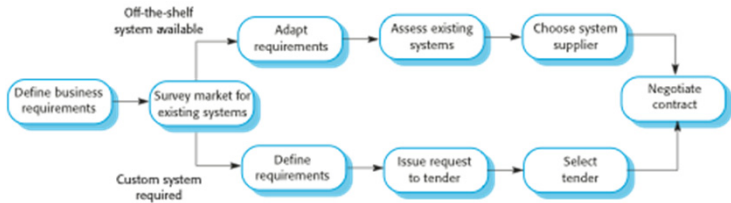
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## Sociotechnical Systems



### System Development

- The goal of system development is to **develop or acquire** components of a system
- Then **integrate** these components to create the final system
- **Requirements engineering** is the **bridge between procurement and development**



Source: Sommerville, I. (2011). Software Engineering, 9<sup>th</sup> Ed. Boston, MA, USA: Pearson Education Inc.

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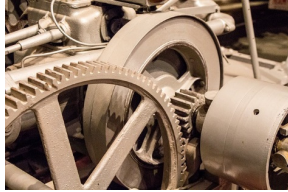
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Sociotechnical Systems



## System Development

- The system **engineering process** was an important **influence on the 'waterfall' model**
- Although the **'waterfall' model is not always the appropriate model** for software development **most systems are developed using a plan-based process**
- This is because **different parts are being developed at the same time**
- When **hardware is involved, changes can be very expensive**
- Hence, **requirements need to be fully understood** before building begins
- Now, **functionalities are often software-based** as it is easier to change them during the development



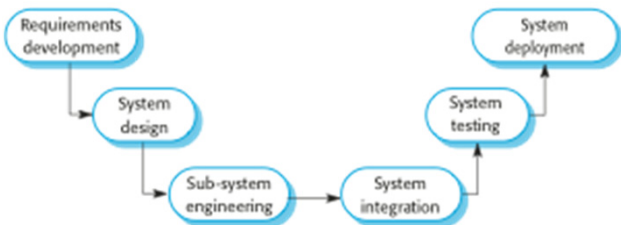
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Sociotechnical Systems


## System Development

There are essentially **6 fundamental activities** in system development:



```


graph TD
    A([Requirements development]) --> B([System design])
    B --> C([Sub-system engineering])
    C --> D([System integration])
    D --> E([System testing])
    E --> F([System deployment])
            
```

Source: Sommerville, I. (2011). Software Engineering, 9th Ed. Boston, MA, USA: Pearson Education Inc.

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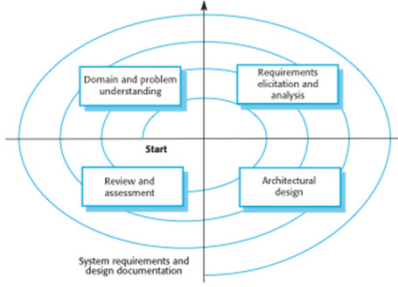


## Sociotechnical Systems



### System Development

- Although the overall process is plan-driven, **requirements development and system design are linked**
- They **are developed concurrently** and may require **iterative changes**
- Hence, you may think of these processes as being **best represented by a spiral**



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## Sociotechnical Systems



### System Operation

- Operational processes, i.e. **how to operate a new system**, have to be **defined**
- **Operators** may have to be **trained**
- **Undetected problems may arise** as soon as the system is operational
- **Operators** may not **use the system as it was envisioned/intended**
- Problems may be caused by the **operation of a new system** alongside existing systems
- **Physical problems** or inconsistencies
- **Interface problems** that may hinder exchange of data
- **Different systems** have **different interfaces** which could lead to operators using wrong/old commands



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## Summary

### What you should have taken away from this class:

- **Sociotechnical systems include computer hardware, software, and people, and are situated within an organization.** They are designed to support organizational or business goals and objectives.
- Human and organizational factors such as **organizational structure and politics** have a significant **effect on the operation of sociotechnical systems.**
- The emergent **properties of a system are characteristics of the system as a whole** rather than of its component parts.
- The fundamental system engineering processes are **system procurement, system development, and system operation.**
- **System procurement** covers all of the activities involved in **deciding what system to buy and who should supply that system.**
- **System development** includes **requirements specification, design, construction, integration and testing.** System integration, where sub-systems from more than one supplier must be made to work together, is particularly critical.
- When a system is put in use, the **operational processes** and the system itself have to change to **reflect changing business requirements.**

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