

# CH1 - Introduction

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- **Software:** Computer programs & associated documentation
  - **Software engineering:** concerned with theories, methods, tools for software development
    - Fundamental activities: software specification, development, validation, evolution
    - A part of system engineering (hardware + software + process engineering)
  - Often: Software costs > computer system / hardware cost
  - Software maintenance cost > development cost
  - Software products: "Generic" or "customized"
  - Essential attributes of good software:
    - **Maintainability:** Critical attribute. To be able to evolve with changing needs
    - **Dependability:** Security, reliability, safety. Should not cause damage in case of failure
    - **Efficiency**
    - **Acceptability:** Compatible with other systems, understandable, usable
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## Application Types

### Stand-alone

- Run on a local machine (e.g a PC).
- Need not to be connected to a network
- Has all required functionality

### Interactive transaction-based

- Accessed by users externally, runs on remote computer
- Web app.s (e.g e-commerce app.s)

### Embedded control systems

- Controls and manages HW

### Batch processing systems

- Processes individual inputs in large batches

### Data collection systems

- Collect data using sensors, send to other systems to process

## Entertainment systems

## Modelling & simulation systems

- Developed by scientists & engineers for modeling
- Usually includes many separate interacting objects

## Systems of systems

- Composed of other software systems

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- Web-based systems: Distributed & complex. Need "agile development": impractical to specify all the requirements for such systems in advance.
  - Service-oriented systems: All components considered as replaceable services. Allows rapid configurations & incremental updates as new services become available.

# CH2 - Software Processes

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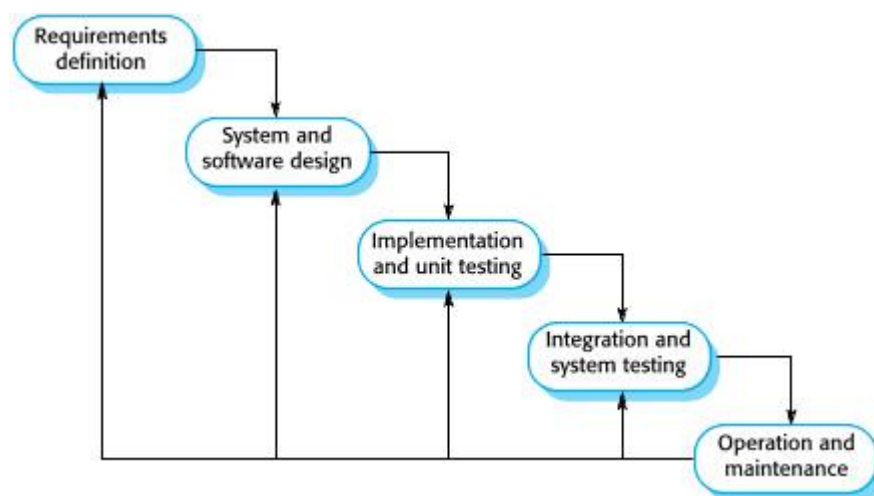
- "Software process": Structured set of activities required to develop a software system
- Many different ones but all involve: Specification, design & implementation, validation, evolution
- "Plan driven process": all activities planned in advance, progress is measured against the plan

"Agile process": Incremental planning, easier to change process to changing requirements

Often, elements from both approaches are used.

## Software Process Models

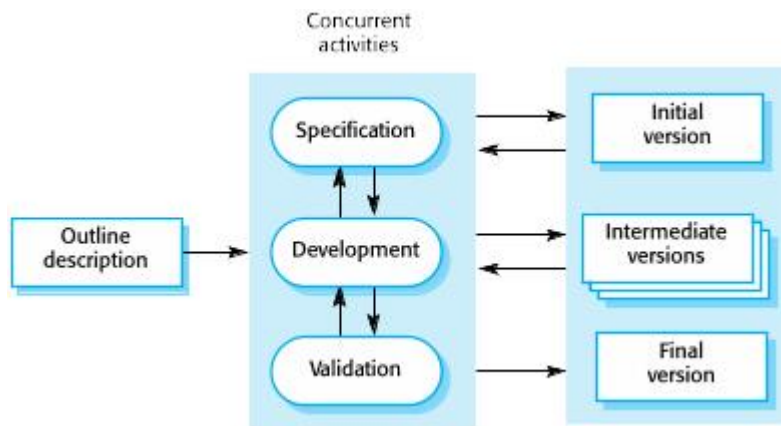
### The Waterfall Model



- Plan-driven
- Separate identified phases

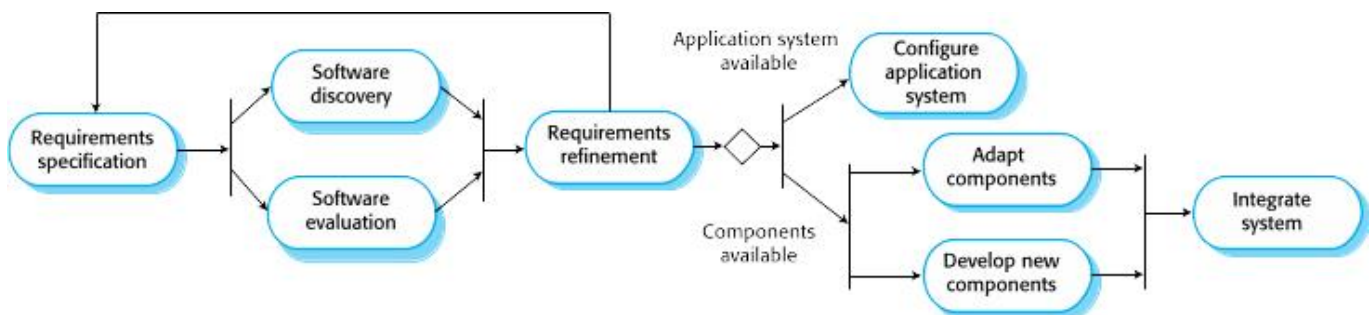
- Drawback: a phase has to be completed before moving onto next, hard to accomodate changes
  - Only appropriate when the requirements are well understood & changes will be limited
- Mostly used for large system engineering projects where a system is developed at several sites

## Incremental Development



- Cost of making changes reduced
- Easier to get customer feedback
  - Customers can comment on demonstrations
  - Customers can be provided with useful software earlier
- Drawbacks:
  - Regular changes may corrupt project structure - incorporating changes becomes harder and costlier as time progresses
  - Cost-ineffective to document each system version -> Measuring progress is hard

## Integration & Configuration (Reuse-oriented SW. Eng.)



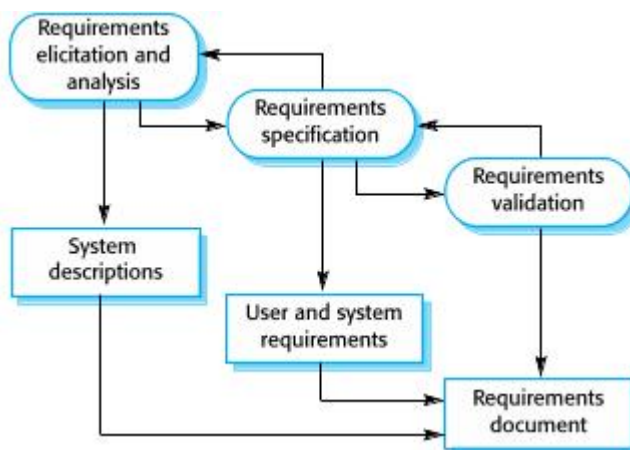
- Based on software reuse - reused elements can be configured according to requirements
- Standard approach for many business system types

- Faster delivery
- Less SW developed from scratch -> Reduced risks & costs
- Drawbacks:
  - Some requirements are likely to be unsatisfied
  - Lost control over the evolution of reused components

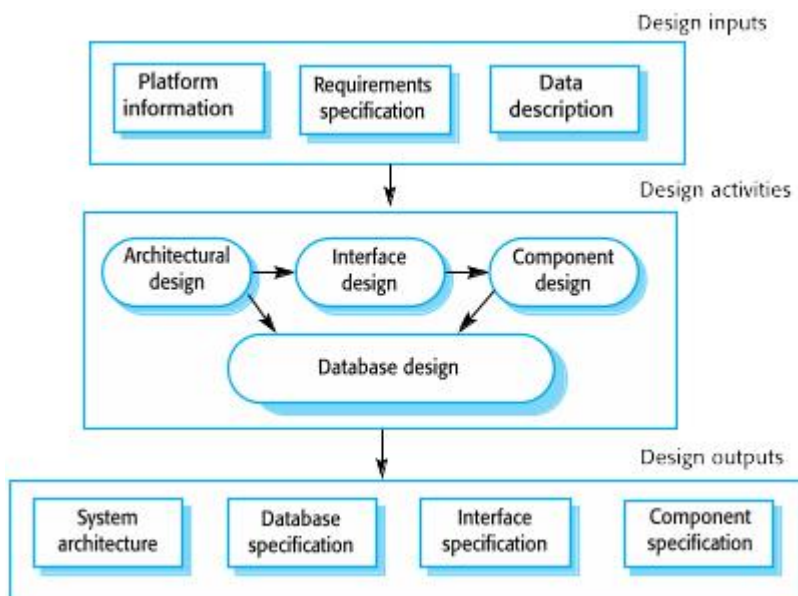
## Process Activities

- Can be ordered sequentially or interleaved according to the model

## Requirements Engineering Process



## Software Design & Implementation



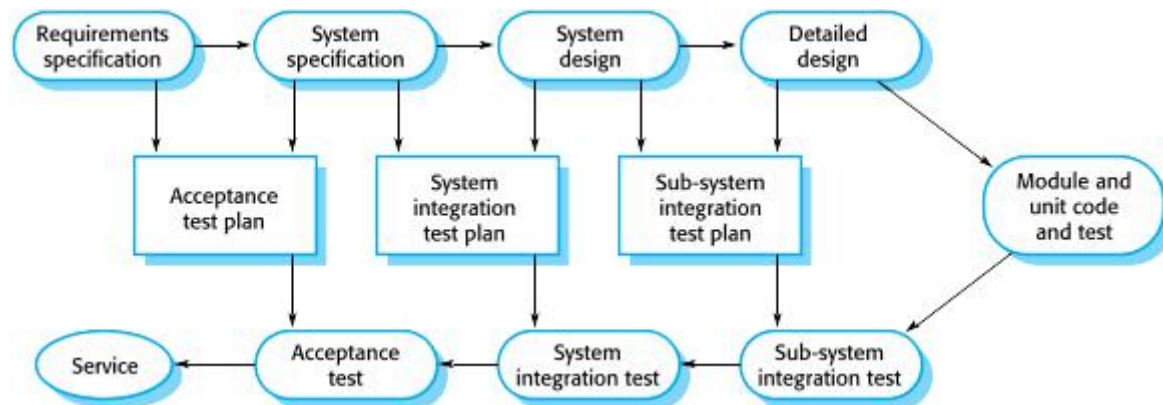
- Design: Creating software structure
  - Architectural, database, interface (between components), component selection & design
- Implementation: translating the structure into an executable
  - Design & implementation can be closely related or interleaved

## Software Validation

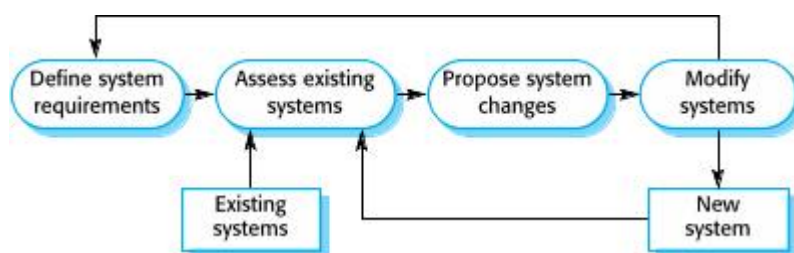
- Testing: Most common verification & validation activity



- V-model: Testing phases in a plan-driven software process:

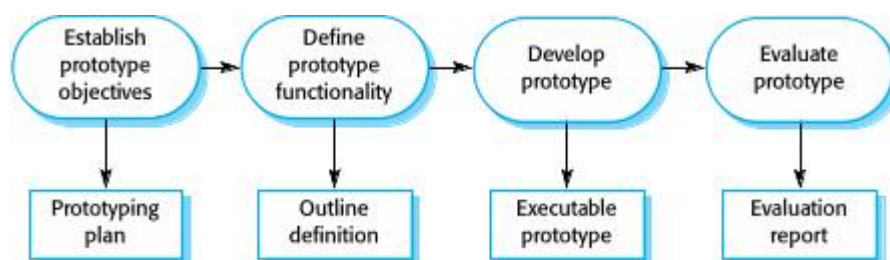


## System Evolution



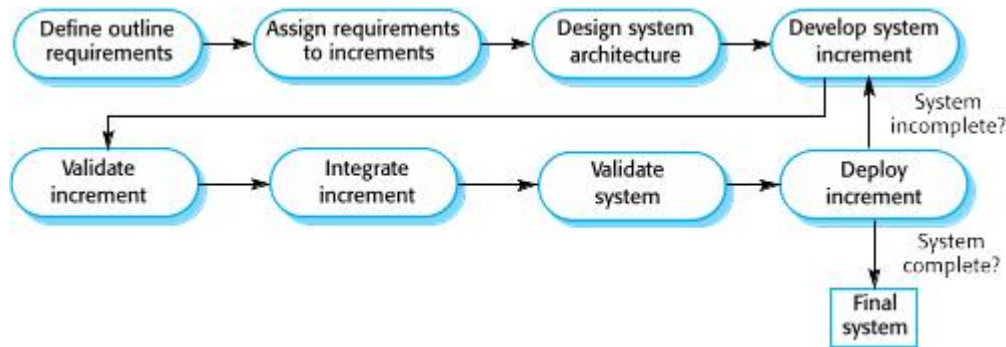
- Change anticipation: Possible changes can be anticipated without much rework
- Change tolerance: Process is designed so that changes are applied without much cost

## Software Prototyping



- Discarded after development: usually unstructured, undocumented and not standard-compliant

## Incremental Development & Delivery



- Early increments serve as prototypes
- Requirements are not changed throughout the development of an increment
- Highest priority services receive most testing
- Specification is developed together with the SW itself
  - May contradict procurement models of some organizations

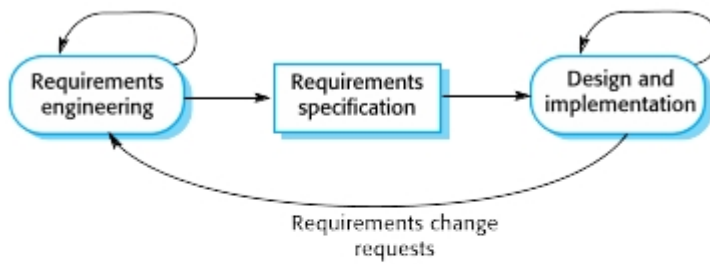
## Process Improvement

- Process maturity approach: ? Agile approach: focus on iterative development & reduction of overheads. Emphasis on rapid functionality delivery & adapting to requirement changes
- improvement cycle: Change -> Measure -> Analyze -> Change ...
- Process metrics:
  - Taken time to complete activities
  - Required resources for activities
  - Number of occurrences of a specific event (e.g. an error)
- SEI capability maturity model:
  1. Initial: uncontrolled
  2. Repeatable: Defined & used product management procedures
  3. Defined: Defined & used process management procedures
  4. Managed: Defined & used quality management strategies
  5. Optimising: Defined & used process improvement procedures

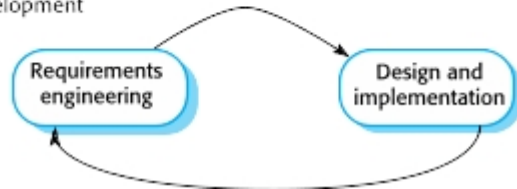
## CH3 - Agile SW Development

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## Plan-based development



## Agile development



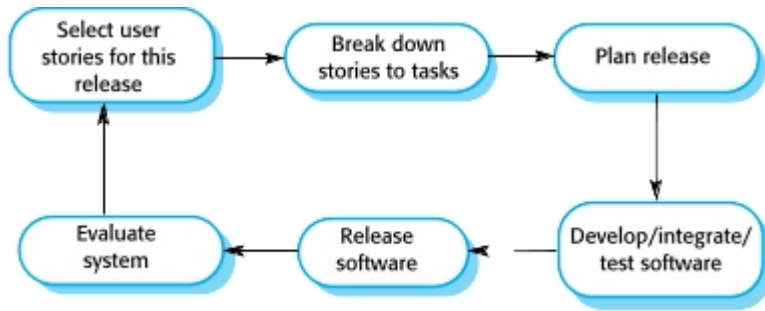
- Program specification, design and implementation are inter-leaved
- The system is developed as a series of versions or increments with stakeholders involved in version specification and evaluation
- Frequent delivery of new versions for evaluation
- Extensive tool support (e.g. automated testing tools) used to support development.
- The aim is to reduce overheads in the SW process, to be able to respond quickly to changing requirements without excessive rework.
  - e.g. Minimal documentation - focus on working code

## Principles

- Customer involvement: Evaluating iterations, provide and prioritize requirements
- Incremental delivery
- People over processes: Skill of the team should be recognized - members should develop their own ways of working without prescribed processes
- Embrace change
- Maintain simplicity

## Agile development techniques

### Extreme programming (XP)



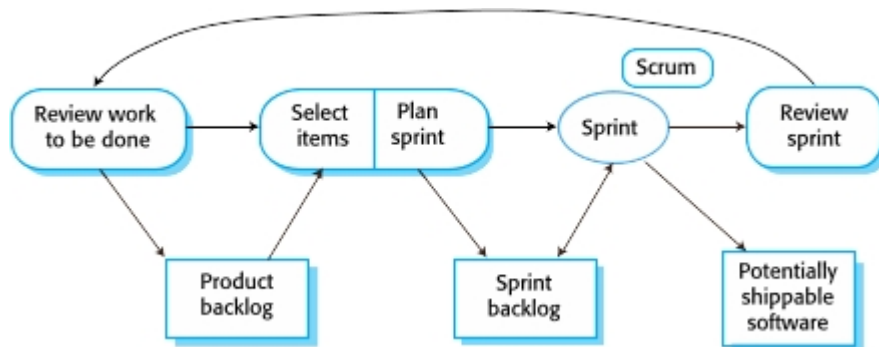
- "Extreme" iterative development:
  - New versions may be built several times per day
  - Increments are delivered to customers every 2 weeks
  - All tests must be run for every build and the build is only accepted if tests run successfully.
- Has a technical focus - usually not easy to integrate with management practice
- XP practices:
  - Incremental planning: Requirements recorded onto "story cards" -> Broken down into "Tasks"
  - Minimal useful set of functionality is developed first, frequent small releases. Functionality added incrementally.
  - Minimum design to satisfy current requirements is carried out
  - Test-first development: A functionality's test framework is implemented earlier than the functionality itself
  - Constant refactoring: All developers are expected to refactor code as soon as possible, even if there is no immediate need
    - Improves software understandability & reduces need for documentation
    - Well-structured code -> Changes are easier to make
    - Changes requiring architecture refactoring are much more expensive
  - Collective ownership: Everyone works on everything, no islands of expertise develop
  - Pair programming
    - Helps develop collective ownership
    - Informal review process
    - Encourages refactoring & sharing of knowledge
  - Continuous integration: After each task is completed, it is integrated & tested (must pass the test)
    - Test-driven development clarifies the requirements to be implemented
    - Tests are written as programs rather than data -> they can be executed automatically after integrating each new functionality
  - The customer should be available full-time as a member of the development team



- Customer may be reluctant - may feel that providing requirements was enough
- Large amounts of overtime are not acceptable: Reduces productivity & quality on long term

## Agile Project Management

### Scrum



- Agile method focusing on managing iterative development rather than agile practices
- "product backlog": a "TODO list", may be feature definitions, SW. requirements, user stories, supplementary tasks (e.g user documentation, architecture definition), etc.
- "scrum"s: daily meetings reviewing progress and daily tasks, ideally short f2f meeting including whole team
- "velocity": estimate of backlog covering rate of the team
- 3 phases:
  - Initial: plan outline, establish objectives (choose from backlog), design architecture
  - "Sprint cycles" of developing increments
    - fixed length (~2-4 weeks)
  - Project closure: wrap-up & complete documentation (e.g system help frames)
- Team is isolated from distractions & customer communication. Only the "scrum master" handles communication with the customer.
- Benefits:
  - Breaks down product into manageable chunks
  - Unstable requirements do not hold up
  - Whole team has visibility on everything
  - Customers see on-time increment delivery, can provide feedback
    - Establishes customer-developer trust

## Scaling Up Agile Methods

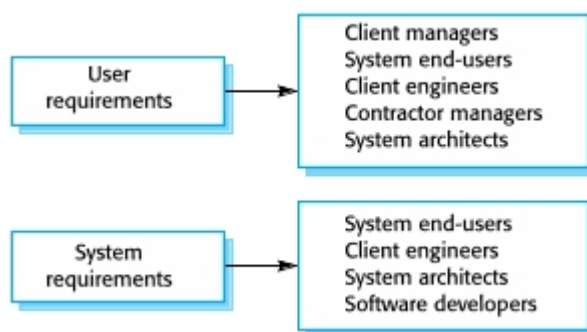
- Agile methods are successful for small & medium sized projects with small teams
  - "Scaling up": Agile methods for large SW systems with large teams
  - "Scaling out": Introducing agile methods to a large, experienced organization

## Practical problems

- Agile is informal -> incompatible with legal approach to contracts in large companies
  - Agile is more appropriate for new software rather than maintenance
    - In large companies usually: Maintenance cost > development cost
  - Agile is more appropriate for small co-located teams
    - SW development involves worldwide distributed teams
    - Design documents may be needed for distributed teams
      - If not available: IDE support for visualisation & program analysis is essential
    - Cross-team communication mechanisms are needed
  - Agile works best when team has high skill level, but large companies have a wide range of skill level
  - Software contracts are based around specifications; however, agile interleaves specification and development
    - Contract based on time rather than functionality is required for agile -> considered risky
  - Maintenance problems:
    - Lack of SW documentation
      - Also needed if system is subject to external regulation
    - Customers are kept involved in development
      - Diverse set of stakeholders in large systems -> hard to involve them all in development
    - Need to keep the original team
      - Problem for long-lifetime systems
  - Prioritizing changes may be difficult: Multiple stakeholders have different priorities
  - Incremental delivery: Can be hard for business planning and marketing
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- Several integrated systems: Significant amount of development on system configuration rather than development
  - Completely incremental approach to requirements engineering is impossible
  - Continuous integration practically impossible. However, frequent system builds & regular releases are essential
  - Multi-team Scrum:
    - Releases are aligned
    - Each team has their own scrum masters and product owners
    - Each team chooses "product architect"s to design & evolve overall system architecture
    - "scrum of scrums" are done where representatives of each team meet and discuss progress

## Chapter 4 - Requirements Engineering

- Req. eng: Establishing services a customer requires from a system & its operation and development constraints
- System requirements: Descriptions of the system services & constraints. Generated during requirements engineering.
- "Requirement": Ranges from an abstract statement of a service / system constraint to a detailed functional specification
  - Dual function: May be the basis for a bid for a contract or for the contract itself
- User requirements: Statements in natural language + diagrams of services & operational constraints
  - Must be understandable by the end-users & customers without technical knowledge
- System requirements: Structured document, detailed descriptions of system functions, services, operational constraints.
  - Defines things to be implemented -> May be a part of a contract
- Readers of requirements specification types:



- "Stakeholder": Any person or organization who is affected by the system in some way and thus has a legitimate interest
  - End users, system managers, system owners, external stakeholders
- Agile methods use incremental requirements engineering and may express requirements as "user stories"
  - Practical for business systems
  - Problematic for systems requiring pre-delivery analysis (e.g critical systems) or systems developed by multiple teams

## Functional & Nonfunc. Requirements

- **Functional requirements:** Statements of system services, describing system's reactions to particular inputs and situations
  - May state what the system should not do
  - Depends on SW type, expected users & type of system where the SW is used
  - Functional user req.s: May be high-level statements of what the system should do
  - Functional system req.s: describes system services in detail

- **Non-functional requirements:** Constraints on system services or func.s
    - Timing constraints, development process constraints, standards, etc.
    - Often apply to the system as a whole, rather than individual features
    - May be more critical than functional requirements
    - May be difficult to state precisely, which may be difficult to verify
      - "Goals" (general intentions of the user) can be specified instead
      - A "verifiable nonfunc. req." uses some measure that can be tested objectively
        - Speed: operation time, response time, refresh rate etc.
        - Size
        - Ease of use
        - Reliability: Failure rate, availability etc.
        - Robustness: Recovery from failure
        - Portability: Target-dependent statement rate
    - A single nonfunc. requirements may generate several related
    - Product requirements: execution speed, reliability etc.
    - Organizational requirements: Consequence of organizational policies & procedures (e.g standards, implementation requirements etc.)
    - External requirements: interoperability requirements, legal requirements etc.
  - **Domain requirements:** System constraints from the operation domain
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- In principle: Requirements should be complete & consistent:
  - Completeness: include descriptions of all required system facilities
  - Consistency: No conflicts in the descriptions of the system facilities
  - Complexity of environment & system -> impossible to produce a complete and consistent requirements document

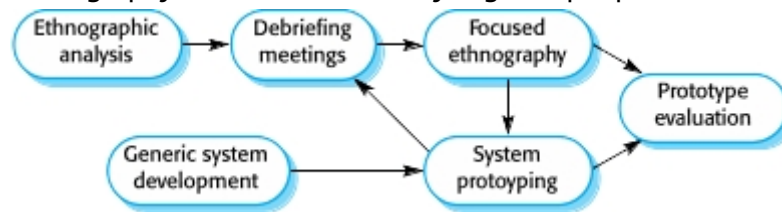
## Requirements Engineering Process

- An iterative activity in which req. elicitation, analysis, validation and management are interleaved

### Req.s Elicitation / Discovery

- Technical staff works with stakeholders to find out about application domain, system services & system's operational constraints
- Stages (in a cycle):
  - Req.s discovery
    - Getting info. from stakeholders about the required & existing systems
      - Interviewing:
        - closed (pre-determined questions) or open, or mixed
        - Not good for understanding domain requirements

- Ethnography: Social scientist analyzing how people work



- Important social & organizational factors can be observed
- Effective for understanding existing processes
- Cannot identify new features to be added to a system
- Specifying user & system requirements from the gathered info.
  - Req.s classification & organization
  - Req.s prioritization & negotiation
    - Conflicts are resolved here
  - Req.s specification
    - Req.s are documented here
- Problems:
  - Stakeholders may have unstable decisions
  - Stakeholders express req.s in their own terms
  - Stakeholders' req.s may conflict
  - Organizational & political factors may influence the req.s
  - Stakeholders & business environment may change -> Req.s change during analysis process
- User stories: Real-life system usage examples
  - Practical situation -> stakeholders can relate and comment
- Scenarios: Structured form of user stories
  - Should include starting situation, normal event flow, what can go wrong, state when scenario finishes, other concurrent activities

## Requirements specification

- Process of documenting the req.s
- Requirements are written using natural language + diagrams & tables
- Problems with NL:
  - Lack of clarity: Hard to be precise without being complex
  - Functional & nonfunc. req.s may get mixed up
  - Several req.s can be expressed together
- Form-based specifications: Definition of function/entity, description of inputs, outputs, computations, pre & post conditions, any side effects of the function
- Tabular specification: Supplements NL
  - Useful when there are alternative courses of action

- Use-cases: Identifies an interaction and involved actors
  - A set of use-cases should describe all possible interactions with the system
- SW Req. document should describe "what" the system should do rather than "how" it should do
- Incremental development -> Less detail in req.s document

## Requirements Validation

- Validating that the requirements define the system that the customer really wants
- Important: Errors in req.s are costly
- Check:
  - Validity (whether system provides func.s tht best supports customer's needs)
  - Consistency
  - Completeness
  - Realism (whether implementation with given budget & tech is possible)
  - Verifiability (whether the req.s can be tested)
- Techniques:
  - Reviews (systematic manual analyses)
    - Both client and contractors should be involved
    - Formal or informal
    - Check: Verifiability, comprehensibility, traceability (whether origin of the req. is clear), adaptability (whether the req. can be changed wtihout large impact on other req.s)
  - Prototyping
  - Test-case generation

## Requirements Management

- Managing changing req.s during req. engineering and system development
  - New req.s emerge as system is being developed and after is deployed
- Req.s mng. planning:
  - Req.s identification: Needed so that a req. can be cross-referenced with other req.s
  - Change management process: Set of activities to assess impac & cost of changes
  - Traceability policies: Define relationships between req.s
  - Tool support

