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SOFTWARE ARCHITECTURE

UNIT - 1.

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* INTRODUCTION.

→ The Architecture Business Cycle: where do architectures come from?

→ Software Processes & the architecture business cycle.

→ What makes a good architecture?

→ What Software Architecture is & what it is not.

→ Other Points of View

→ Architectural Patterns.

→ Reference Models & reference architectures.

→ Importance of Software architecture

→ Architectural Structures & Views.

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Note:- Refil Class Notes for Concepts, diagram & example..

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* Architecture has emerged as a Crucial Part of the design Process

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* Software architecture encompasses the Structure of large Software Systems.

* It is developed as the first Step toward designing a System that has Collection of desired Properties.

* The S/w Architecture of a Program (or) Computing System is the Structure (or) Structures of the System, which Comprise S/w elements, the externally Visible Properties of those elements, & relationships Among them

* S/w Architecture is a result of technical, business & Social influences. Its existence in turn affects the technical, business & Social environments that Subsequently influence ~~have~~ future architectures.

* We call this cycle of influences, from the Environment to the architecture & back to the

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environment, the architecture business cycle (ABC).

Where do architectures come from?

* Architecture is the result set of business & technical decisions. There are many influences at work in its design, & realization of these influences will change on the environment in which the architecture is required to perform.

* The design choices to design System by an architect depends on how the real time deadlines are believed.

ARchitecture influencing factors.

1) Architecture influenced by System Stakeholders.

* Many People & Organizations interested in the Construction of a S/w System are referred to as Stakeholders.

Eg:- Customers, end users, developers, Project managers....

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* Stakeholders have different concerns that they wish the system to guarantee.

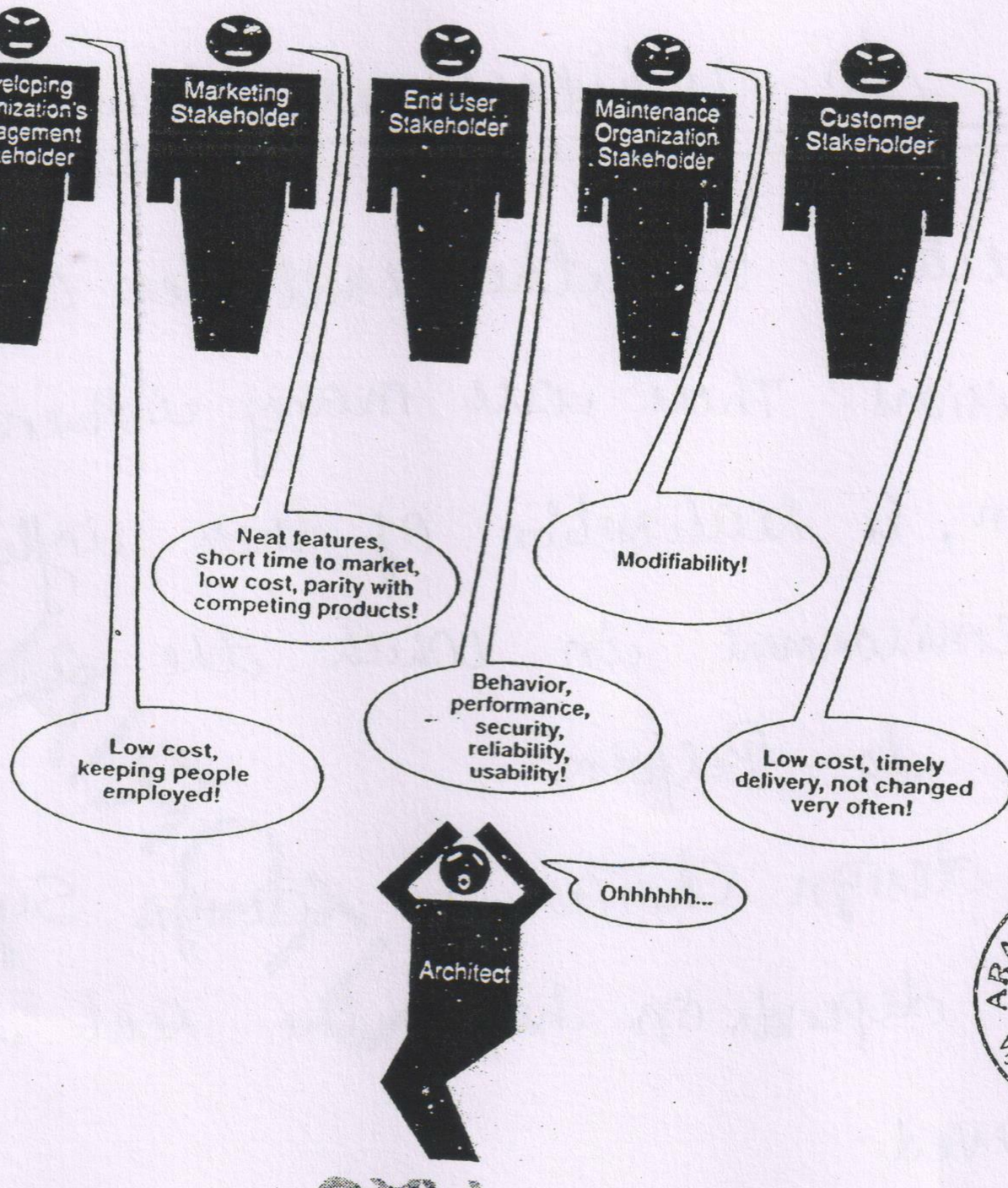

fig:- Influence of Stakeholders on the architect.

* The above figure shows the architect receiving helpful Stakeholder suggestions.

* Having an acceptable system involves properties such as performance, reliability, availability, Platform compatibility, Memory utilization, network usage, Security modifiability, usability & interoperability with other systems as well as behaviour.

* Indeed, these properties determine the overall

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design of the Architecture.

* The Problem here is that each Stakeholder has different Concerns & goals, Some of which may be Contradictory.

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2) Architectures are influenced by developing Organisations.

* Architectures is influenced by the Structure of nature of the development Organizations.

* There are 3 classes of influence that Come from the developing Organization: immediate business, long term business & Organizational Structure.

→ An Organization may have an immediate business investment in Certain assets, Such as existing architecture & Products based on them.

→ An Organization may wish to make a long term business investment in an infrastructure to Pursue Strategic goals & may view the Proposed System as one means of financing & extending that infrastructure

→ The Organizational Structures can Shape the S/w architecture.

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3) Architectures are influenced by the background & experience of architects.

* If the architects for a system have had good results using a particular architectural approach (such as distributed objects or implicit invocation) chances are that they will try that same approach on a new development effort.

* Conversely, if their prior experience with this approach was disastrous, the architects may be reluctant to try it again. Architectural choices may also come from an architects education & training, exposure to successful architectural patterns, or exposure to systems that have worked particularly poorly or particularly well.

4) Architectures are influenced by the technical environment

* A special case of the architects background & experience is reflected by the technical environment. The environment that is current when an architecture

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is designed will influence that architecture. It might include Standard industry Practices (or) S/w engineering techniques Prevalent in architect's Professional Community

⇒ Ramifications of influences on an architecture.

* Influence on an architecture come from wide Variety of Sources.
* It is very hard to understand the Properties required by the business & Organizational goals.
* However architects need to Know & understand the nature, Source & Priority of Constraints on the Project as early as Possible.
* Hence they must identify Stakeholders Needs & expectations.
* Early engagement of Stakeholders allows architects to understand:
  1) Constraints
  2) Manage expectations
  3) Negotiate Priorities.

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* For an effective Architect his Communication Skills are essential than Just technical Skills.

* The influence on Architect & hence on the architecture are Shown below in fig:

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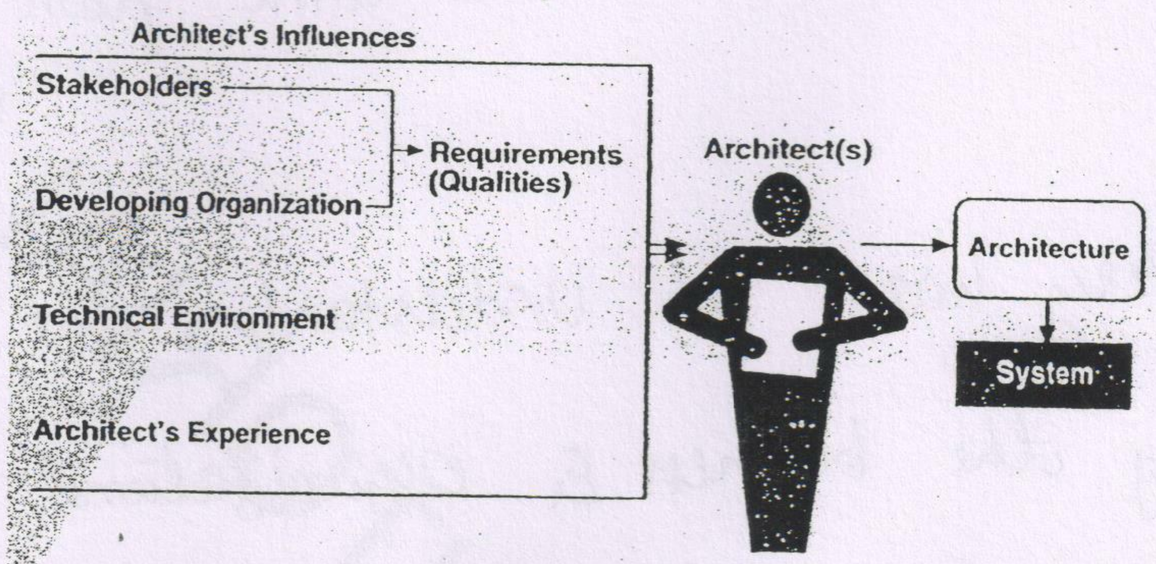

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The architecture affects the factors that influence them.

* Relationships among business goals, Product requirements, Architects experience, Architectures & fielded systems form a cycle with feedback loops that a business can manage:

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* The fig below shows the feedback loops. Some of the feedback comes from the architecture itself, & some comes from S/m built from it.

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The cycle works as:-

1) The architecture affects the structure of the developing organisation. An architecture prescribes a structure for a system, it particularly prescribes the units of S/w that must be implemented & integrates to form the system. Teams are formed for individual S/w units & development, test & integration activities all revolve around the units. Likewise, schedules & budgets allocate resources in chunks corresponding to the units. Teams become embedded in the organization structure. This is feedback from the architecture to developing organization.

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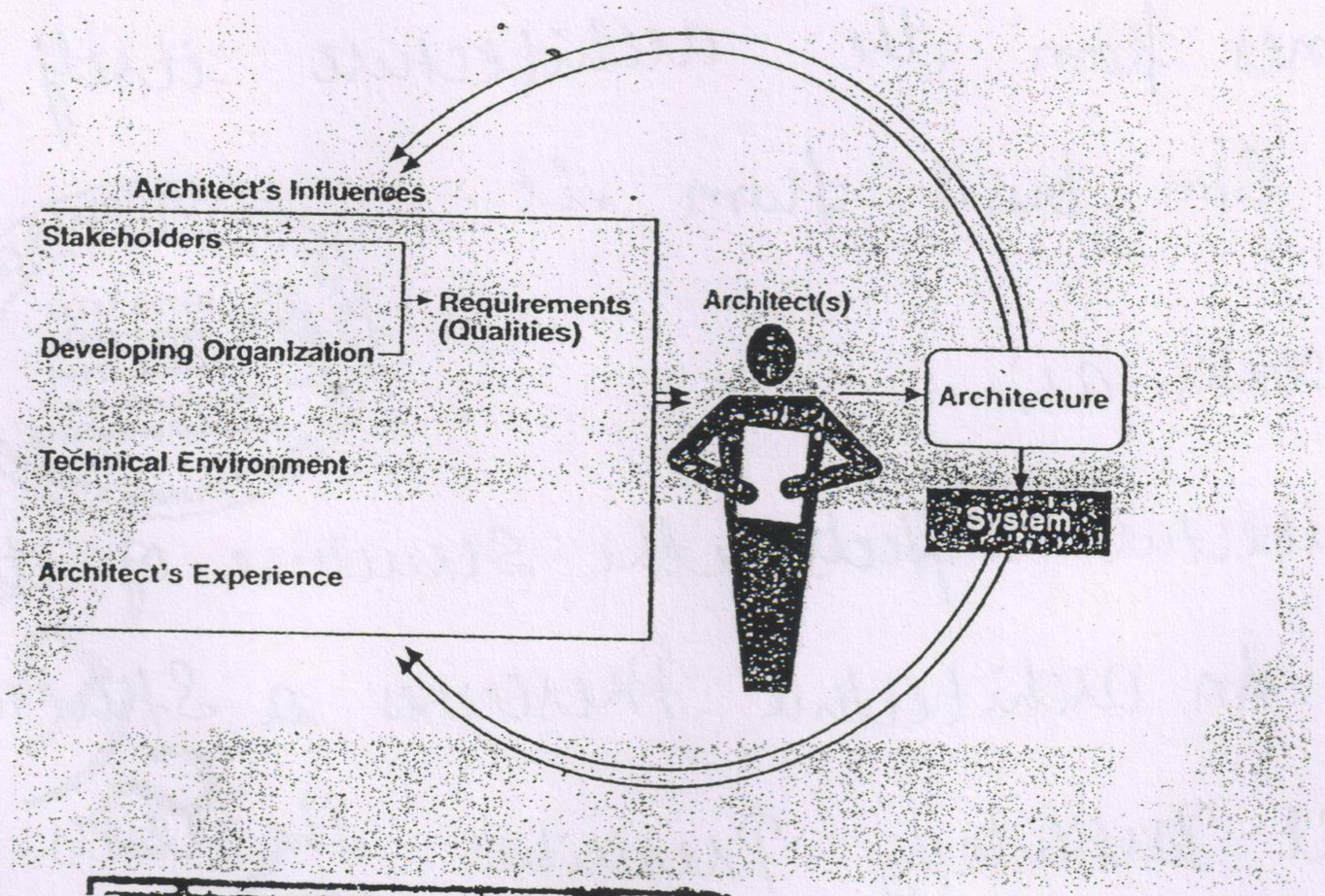
2) The architecture can affect the goals of developing organization: A successful system built from it can enable a company to establish a foothold in a particular market area. The architecture can provide opportunities for the efficient production



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& deployment of Similar Systems & the organisation may adjust its goals to take advantage of its newfound expertise to plumb the market. This is feedback from S/m to developing organization & Systems it builds.

3) The Architecture can affect Customer requirements for the next System by giving the Customer the opportunity to receive a System in a more reliable, timely & economical manner than if the Subsequent System were to be built from Scratch..

4) The Process of System building will affect the Architect's experience with Subsequent Systems by

adding to the corporate experience base.

5) A few systems will influence & actually change the S/w engineering culture i.e the technical environm-ent in which system builders operate & learn.

Software Processes & the architecture Business cycle.

* Software Proces is the term given to the organisation, visualization & management of S/w development activites.

The activities involved are:

* Creating the business case for the system.
* Understanding the requirements.
* Creating or selecting the architecture.
* Documenting & Communicating the architecture.
* Analyzing or evaluating the architecture.
* Implementing the system based on architecture.
* Ensuring that implementation conforms the architecture.

As discussed architecture activities have feedback relationships with each other.

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1) Creating the business case for the System :-

* It is an important Step in Creating & Constraining any future requirements.

* How much Should Product Cost ? what is its targeted market ? what is its targeted time to market ? will it need to interface with other Systems ? Are there System limitations that it must work within ?.

+ These are all Questions that must involve the S/m Architects.

2) Understanding the requirements :

* There are a variety of techniques for eliciting requirements from the Stakeholders. For eg Object Oriented analysis Uses Scenarios, (or) Use cases to embody requirements. Safety-Critical Systems Use more rigorous approaches such as finite State machine models (or) formal Specification language.

* Another technique that helps us Understand requirements is the Creation of Prototype.

+ Regardless of the technique Used to elicit the

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requirements, the desired qualities of the System to be Constructed determine the Shape of its architecture.

3) Creating or Selecting the architecture.

* Fred brooks argues that Conceptual integrity is the Key to Sound S/m design & that Conceptual integrity Can only be had by a Small number of minds Coming together to design the Systems architecture.

4) Communicating the architecture

* For the architecture to be effective as the backbone of the Projects design, it must be Communicated Clearly & Unambiguously to all Stakeholders.

5) Analyzing (or) Evaluating the architecture.

* Choosing among multiple Competing designs in a rational way is one of the architects greatest Challenges.

* Evaluating an architecture for the Qualities that it Supports is Essential to ensuring that the S/m Constructed from that architecture Satisfies its Stakeholders needs.

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+ Use Scenario-based techniques (or) Architecture Trade-off Analysis Method (ATAM) (or) Cost benefit Analysis Method (CBAM).

6) Implementing based on the architecture.

* This activity is Concerned with Keeping the developers faithful to the Structures & interaction Protocols Constrained by the architecture.

* Having an explicit & well Communicated architecture is the first Step toward ensuring architectural Conformance.

7) Ensuring Conformance to an architecture.

* Finally when an architecture is Created & Used it goes into a maintainance Phase. Constant Vigilance is required to ensure that the actual architecture & its representation remain faithful to each other during this Phase.

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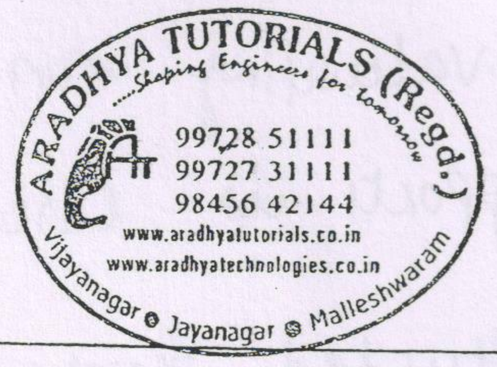

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What Makes a Good Architecture?

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* For the given technical requirements for a System, two different architects in different Organizations will Produce different architectures, how can we determine if either one of them is the right one!

* There is no such thing as an existing good (or) bad Architecture.

* We divide our observations into two clusters: Process Recommendations & Product (or Structural) Recommendations.

* Process as follows:

1) The Architecture Should be the Product of a Single Architect (or) a Small group of architects with an identified leader.

2) The Architect Should have the functional requirements for the System & an articulated, Prioritized list of Quality attributes that the Architecture is expected to Satisfy.

3) The Architecture Should be well documented, with at least one Static View & One dynamic View,

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Using an agreed-on Notation that all Stakeholdees Can understand with a minimum of effort

4) The Architecture Should be Circulated to the System's Stakeholdees Can understand with a minimum of effort who Should actively involved in its review.

5) The Architecture Should be analyzed for applicable Quantitative measures (Such as maximum throughput) & formally Evaluated for Quality attributes before it is too late to make Changes to it.

6) The Architecture Should lend itself to incremental implementation Via the Creation of "Skeletal" System in which the Communication Paths are exercised but which at first has minimal functionality. This Skeletal S/m Can then be used to grow S/m incrementally, easing integration & testing efforts.

7) The Architecture Should result in a Specific Set of Resource Contention areas, the resolution of which is Clearly Specified, Circulated & maintained. For eg if network Utilization is an Area of Concern, the Architect Should Produce guidelines which result in minimum network traffic.

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* Structural Rules of thumb as follows :-

1) The Architecture Should feature well defined modules whose functional responsibilities are allocated on the Principles of information hiding & Seperation of Concerns.

2) Each Module Should have a well defined interface that hides Changeable aspects from Other S/w that uses its facilities. These interfaces Should allow their respective development teams to work largely independently of each other.

3) Quality attributes Should be achieved using well known Architectural tactics Specific to each attribute.

4) The architecture Should be achieved using well known architectural Patterns that depend on a Particular Version of a Commercial Product or tool.

5) Modules that Produce data Should be Separate from modules that Consume data. This Tends to increase modifiability.

6) For Parallel. Processing S/m's, the Architecture Should feature well-defined Process or tasks that do not necessarily mirror the module decomposition Structures.

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7) Every Task (or) Process Should be Written So that its Assignment to a Specific Processor Can be easily Changed, Perhaps even at Runtime.

8) The architecture Should feature a Small number of Simple interaction Patterns. That is the S/m Should do the Same things in the Same way throughout.

What S/w Architecture is & what it isn't:

The below figure taken from a desription of an Underwater Acoustic to describe the S/m' top level Architecture"

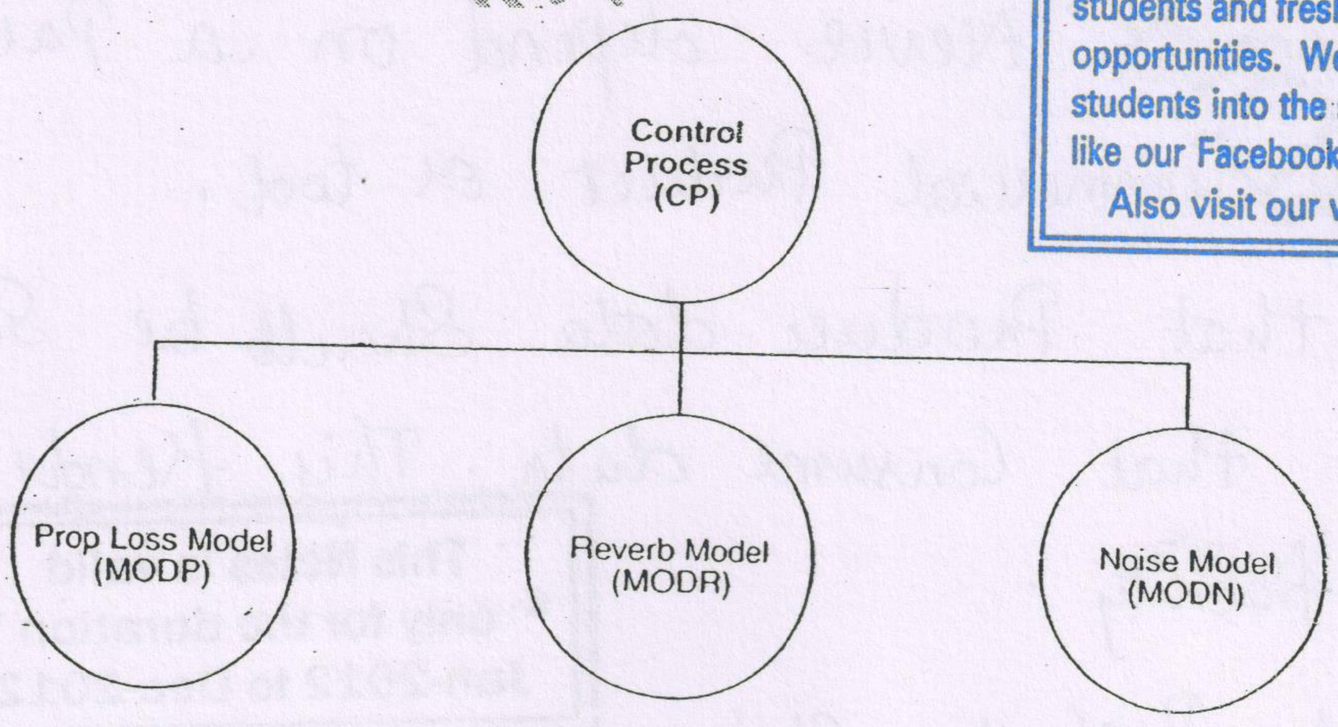

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Fig:- Typical, but Uninformative, Presentation of S/w architecture.

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The S/m Consists of 4 elements

* Three of elements - Prop Loss Model (MODP), Reverb Model (MODR) & Noise model (MODN) are Common with each other than with the fourth - Control Process (CP) because they are Positioned next to each other.

* There exists Some relationship between all Components. Since they are Connected as shown in diagram.

* By Seeing this architecture we Cannot describe Certain things :-

1) What is the nature of the elements?
2) What is the Significance of their Seperation?
3) Do they run on Seperate Processors?
4) Do the elements Consists of Program / Process / both?
5) Are they objects, functions, Programs (or) Something else?
6) What are the responsibilities of elements? What is the function? what it is they do?
7) What is the Significance of: connections? Do they Communicate each other (or) exchange data (or) Synchro-nize?

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8) What is the Significance of layout? Why is CP on Separate level? Does it Call other 3 elements.

So all these Questions are raised inorder to understand S/m well.

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* This diagram represent how they start & no other information Provided.

" The Software architecture of a Program or Computing S/m is the Structure or Structures of the S/m, which Comprise S/w elements, external Visible Properties of those elements & relationship among them".

a) First architecture defines S/w elements.

* Information like how elements relate to each other.

b) Second, the definition makes clear that S/m can & do Comprise more than one Structure:

For eg:- All Projects are Partitioned into implementation Units, these Units are given Specific Responsibilities & are frequently the basis of assignments for teams

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* Are any of these Structures alone the architecture?

No, it Consists of Structures as well as many others.

c) Third the definition implies every computing System with S/w has a S/w architecture because every S/m has elements & relations among them.

d) Fourth, the behaviour of each element is part of the architecture. The behaviour can be observed & shows how exactly elements interact with each other.

e) Finally, the definition is indifferent as to whether the architecture for a S/m is a good (or) bad one. Meaning that it will allow (or) Prevent S/m to meet its requirements.

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Other Points of View.

* S/w architecture has evolved by observation of design Principles.

* Few heard definitions follow!-

1) Architecture is a high level design; only Outlines are described & other detailed information are encapsulated.

2) Architecture is the Overall Structure of the System.

3) Architecture is the Structure of the Components of a Program (or) System, their interrelationships & the Principles & Guidelines Governing their design & evolution over time.

4) Architecture is Components & Connectors. Connects all a Runtime Mechanism for Transfering Control & Data around Sm.

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Architectural Patterns Reference Models & Reference Architectures

*1) An Architectural Pattern is a description of element & relation types together with a Set of Constraints on how they may be Used.

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eg:- Client Server is a Common Architectural Pattern. Client & Server are two elements & their Co-ordination described in terms of Protocol that the Server Uses to Communicate with each of its Clients.

- The Useful Aspects of Patterns is that they exhibit Known Quality attributes.

* An architecture Pattern is not an architecture.

* Architecture Style uses the same concept as Patterns.

2) A reference model is a division of functionality together with data flow between the Pieces.

* It is a Standard decomposition of a known Problem into Parts that Co-operatively Solve the Problem.

3) A reference architecture is a reference model mapped Onto S/w elements (that Cooperatively implement the functi-onality defined in the reference model) & data flows between them.

Whereas a reference model divides the functionality, a reference architecture is the mapping of the functionality Onto a S/m decomposition. The mapping may be but by no means necessarily is one to one.

The relationship among them shown in below fig:

* A S/w Architect must design a S/m that Provides Concurrency, Portability, modifiability, Usability, Security.

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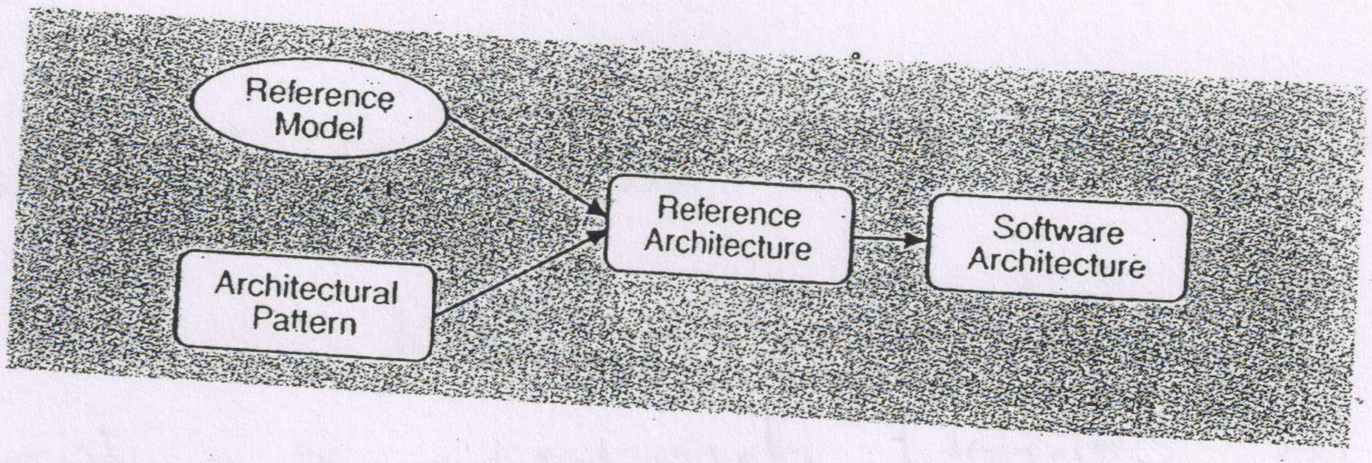

Fig:- Relationship of reference models, architectural Patterns, reference architectures & S/w architectures

Why is Software Architecture important?.

* There are 3 reasons for S/w architectures importance from a technical Perspective.

1) Communication among Stakeholders: S/w architecture represents a common abstraction of a S/m that most if not all of S/m's Stakeholders can use as a basis for mutual understanding, negotiation & Communi-cation.

2) Early design decisions:- It is the earliest Point at which design decisions governing the S/m to be built can be Analyzed.

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3) Transferable abstraction of a System: S/w architecture model is transferable across S/m's. It can be applied to other S/m's exhibiting similar quality attributes & functional requirements & can promote large scale re-use.

Architecture is the vehicle for Stakeholder communication.

* Each Stakeholder of a S/w S/m is concerned with different S/m characteristics that are affected by the architecture.
* For eg: the user is concerned that S/m is reliable & available when needed, the customer is concerned that the architecture can be implemented on schedule & to budget, the manager is worried that the architecture will allow teams to work largely independently, interacting in disciplined & controlled ways.
* Architecture provides a common language in which different concerns can be expressed, negotiated & resolved at a level that is intellectually manageable even for large, complex S/m.

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Architecture Manifests the earliest Set of design decisions

Software architecture represents a s/m. earliest set of design decisions. These early decisions are the most difficult to get correct & hardest to change later in the development Process & they have most far reaching effects.

* The architecture defines Constraints on implementation
* An implementation exhibits an architecture if it conforms to the Structural design decisions described by the architecture.
* This means that the implementation must be divided into Prescribed elements, the elements must intract with each other in the Prescribed fashion & each element must fulfill its responsibility to the others as dictated by architecture.
* Resource allocation decisions also Constrain implementations.

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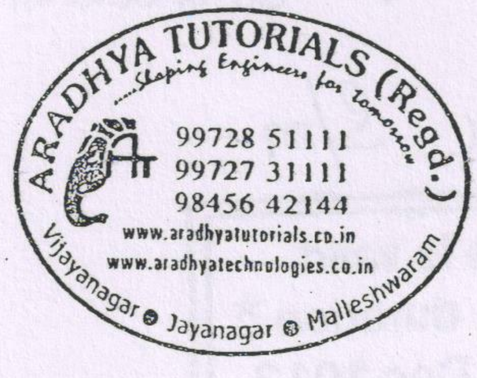

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2) The Architecture dictates Organizational Structure.

* Not only does architecture Prescribe the Structure of the S/m being developed, but that Structures becomes engraved in the Structure of development Project (& Sometimes, the Structure of entire Organization).

* The normal method for dividing up the labor in a large S/m is to assign different groups different Portions of the S/m to Construct. This is called work breakdown Structure of S/m

* A Side effect of establishing the work breakdown Structure is to freeze Some aspects of S/w architecture.

* Once the architecture has been agreed on, then it becomes almost impossible to modify it.

3) The Architecture inhibits (or) enables a S/m Quality attributes.

* Whether a S/m will be able to exhibit its desired Quality Attributes is Substantially determined by its architecture. However architecture alone cannot Guarantee functionality (or) Quality.

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Points to remember:

1) If Sys requires high Performance, need to manage the time based behavior of elements.

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2) If Modifiability is important, need to Assign Responsi-bilities to elements such that Changes to S/m do not Change functionality.

3) For highly Secure, need to manage & Protect inter ele-ment Communication

4) For Scalability, Search resources to introduce higher Capacity replacements.

5) Intr Component Usage to deliver incrementally.

6) For re-usable need to restrict inter-element Coupling..

4) Predicting S/m Qualities by Studying the Architecture.

* It is POSSible to make Quality Predictions about a S/m based Solely on an evaluation of its architecture.
* Architecture evaluation techniques Such as Architecture Tradeoff Analysis Method Support top-down insight into attributes of S/w Product Quality that is

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Possible and Constrained by S/w architecture.

5) The architecture makes it easier to reason about & manage change.

* S/w Systems Change over their lifetimes.
* Every architecture Partitions Possible changes into 3 Categories: local, nonlocal & Architectural.
→ Local Change can be accomplished by modifying a Single element.
→ A non local Change requires multiple element modifications but leaves the Underlying Architectural Approach intact.
→ An Architectural Change affects the fundamental ways in which the elements interact with each other.

6) The architecture helps in evolutionary Prototyping.
* Once an architecture has been defined, it can be analyzed & Prototyped as a Skeletal S/m. This aids the development Process in 2 ways:
a) The S/m is executable early in the Product's life cycle. Its fidelity increases as Prototype Parts are replaced by Complete versions of S/w

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b) A Special Case of having the S/m executable early is that Potential Performance Problems Can be identified early in Products life cycle.

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7) The Architecture enables more accurate Cost & Schedule estimates.

* Cost & Schedule estimates are an important Management tool to enable the manager to acquire the necessary resources & to understand whether a Project is in trouble.
* The more knowledge about Scope of a System, more accurate the estimates.

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Architecture as a transferable, Re-usable model.

* The earlier in the life cycle re-use is applied, the greater the benefit that can be achieved. While Code re-use is beneficial, re-use at the architectural level Provides tremendous leverage for Systems with Similar requirements.

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1) Software Product lines share a common architecture.

* S/w Product line or family is a set of S/w intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission & that are developed from a common set of core assets in a prescribed way.

* Product line architects choose architecture that will serve all members of product line & making other decisions that apply to individual members later.

2) Systems can be built using large, externally developed elements.

* Whereas earlier S/w paradigms focused on programming as prime activity, with progress measured in lines of code, architecture-based development often focuses on composing (or) assembling elements that are likely to have been developed separately, even independently from each other.

* One key aspect of architecture is organisation element structure, interfaces & operating concepts.

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* Architectural mismatch :- If the Subsystem built with conflicting architectural assumptions & unanticipated complications which increases effort to integrate their functions. This situation is called architectural mismatch.

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3) Less is more! It Pays to restrict the vocabulary of design alternatives.

* We wish to minimize the design complexity of the S/m we are building. Advantages to this approach include enhanced re-use, more regular & simpler designs that are more easily understood & communicated, more capable analysis, shorter selection time, & greater interoperability.

4) Architectural Permits Template-based development.

* Templates can be used to capture in one place the inter element interaction mechanisms.

5) An Architecture can be basis of training

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* The Architecture, including a description of how elements interact to carry out the required behaviour, can serve as introduction to S/m for new Project members.

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Architectural Structures & Views

* We will be using the related terms Structure & View when discussing architecture representation.

* A View is a representation of a coherent set of architectural elements, as written by & read by S/m Stakeholders. It consists of representation of a set of elements & the relationships among them.

* A Structure is the set of elements itself, as they exist in S/w (or) hardware.

* For eg. a module Structure is the set of the S/m's modules & their Organization. A module View is the representation of that Structure, as documented by & used by some S/m Stakeholders.

* Architectural Structures can be divided into 3 groups:

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1) Module Structures :- Here the elements are modules, which are units of implementation. Modules represent a code based way of considering the S/m. They are assigned areas of functional responsibility.

2) Component & Connector Structures :- Here the elements are Runtime Components, (which are Principal units of computation) & Connectors (which are Communication vehicles among Components).

3) Allocation Structures :- Allocation Structures show the relationship between the S/w elements & the elements in one (or) more external environments in which S/w is created & executed.

These 3 structures correspond to 3 broad types of decision that architectural design involves

* How S/m to be structured as set of Code Units (modules)

* How S/m do be structured as set of elements that have runtime behaviour (components) & interactions (connectors)?

* How S/m to relate to non S/w structures. eg. CPU's

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file Sim, network, development teams, etc.. ?

Software Structures.

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Some of most Common & Useful S/w Structures are shown in below fig. The Sections are described as follows;

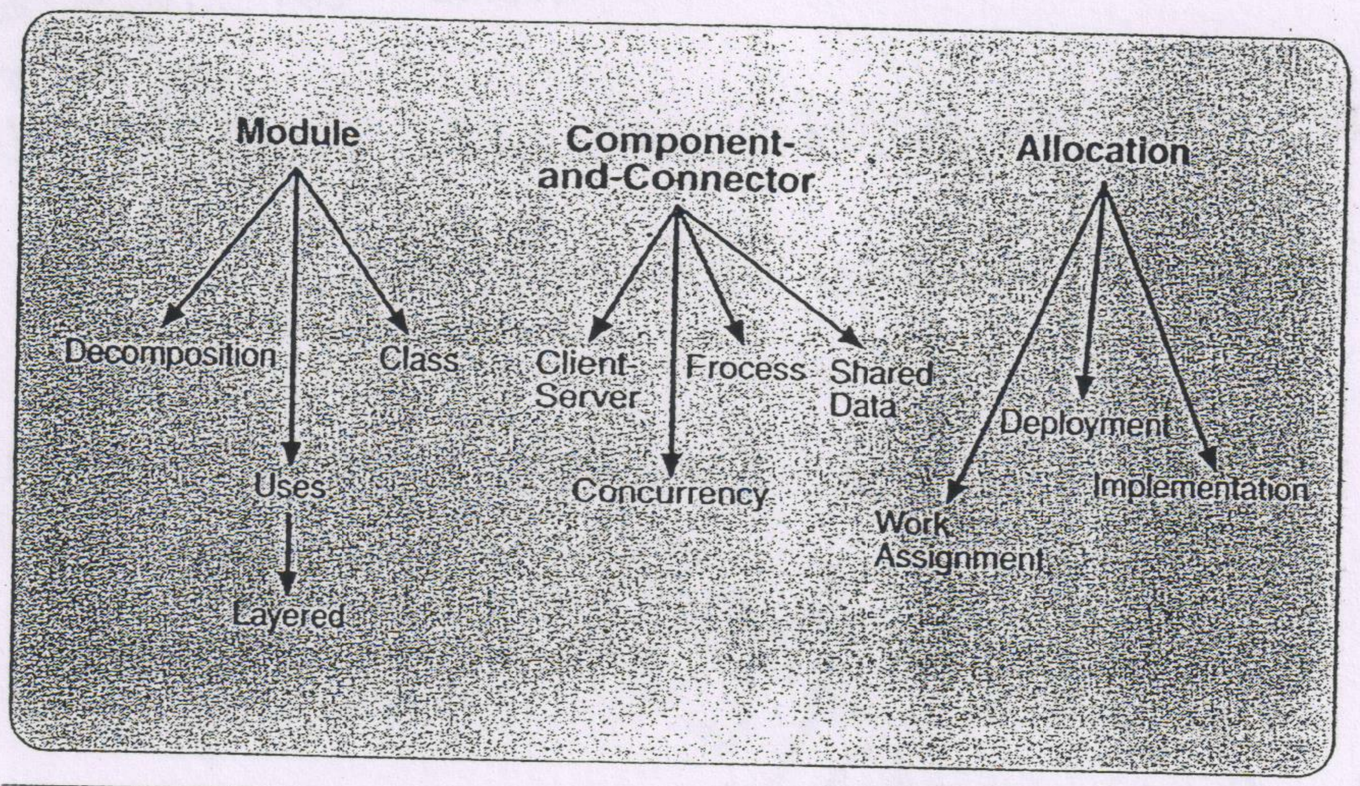

fig:- Common Software architecture Structures.

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1. Module: Module based Structures include the following;

a) Decomposition :- The modules are decomposed into Smaller ones Recursively Untill they are Small enough to be easily Understood. Modules in this Structure represent, a Common Starting Point for design.

* Modules often have Associated Products (interface Specifications, Code, test Plans ...)

b) Uses :- The Units are related by Uses relation.

* One Unit Uses another if Correctness of first requires the Presence of a Correct Version of the Second.

* the Uses Structure is Used to Extend (or) Add functionality.

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c) Layered :- When Uses relations in this Structure are Carefully Controlled in a Particular Way, a S/m of layers ~~emerges~~ emerges.

* In a Strictly layered Structure, layer n may only Uses the Services of layer n-1.

d) Class (or) generalization :- The Module Units in this Structure called Classes.

* the Class Structure allows us to reason about Re-use & incremental Additions of functionality.

2) Component & Connector : These Structures include

a) Process (or) Communicating Processes :- Like all Component & Connector Structures, this one is Orthogonal to Module based Structures & Deals with dynamic Aspects of S/m.

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* The Units here are Processes or threads.

b) Concurrency :- This Structure allows architect to determine opportunities for Parallelism & locations where resource Contention may occur.

* The Units are logical threads.

* logical thread is a Sequence of Computation that can be allocated to Separate Physical threads late in design Process.

c) Shared data (or) Repository :- This Structures Consists of Components/Connectors that Create/Store/access data.

* It Shows how data Produced & Consumed in runtime.

d) Client - Server :- The Components are Clients & Servers.

* They use Protocols to Share messages.

3) Allocation :- Structures included :

a) Deployment :- It is where S/w is assigned to hardware Processing & Communication elements. The

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elements are S/w, H/w, & Communication Pathways.

b) Implementation :- This Structure shows how S/w elements are mapped to file.. Structures.

* This is Critical for development & build Process.

c) Work assignment :- This Structure assigns responsibility for implementing & integrating the modules to appropriate development teams.

* It Clearly shows the work done in the Procss.
* Useful in large multi-Sourced distributed Projects.

Below table Shows Architectured Structures of a S/m.

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Software Structure	Relations	Useful for
Decomposition	Is a submodule of; shares secret with	Resource allocation and project structuring and planning; information hiding, encapsulation; configuration control
Uses	Requires the correct presence of	Engineering subsets; engineering extensions
Layered	Requires the correct presence of; uses the services of; provides abstraction to	Incremental development; implementing systems on top of "virtual machines" portability
Class	Is an instance of; shares access methods of	In object-oriented design systems, producing rapid almost-alike implementations from a common template
Client-Server	Communicates with; depends on	Distributed operation; separation of concerns; performance analysis; load balancing
Process	Runs concurrently with; may run concurrently with; excludes; precedes; etc.	Scheduling analysis; performance analysis

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Software Structure	Relations	Useful for
Concurrency	Runs on the same logical thread	Identifying locations where resource contention exists, where threads may fork, join, be created or be killed
Shared Data	Produces data; consumes data	Performance; data integrity; modifiability
Deployment	Allocated to; migrates to	Performance, availability, security analysis
Implementation	Stored in	Configuration control, integration, test activities
Work Assignment	Assigned to	Project management, best use of expertise, management of commonality

Relating Structures to each other

* Each Structures Provides different Perspective & design handle on a S/m.
* the Structures are not Independent.
* Elements of one will be related to Others & we need to reason about these relations.

eg:- A Module in decomposition Structure may be
* manifested as one (or) Part of Components in Component & connector Structures.
* Larger the S/m, the more differences between the Structures.

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* Structures represent Primary Points of Architecture.

Which Structures to Choose?

* As We Seen there are many Structures. Which to Choose & Work on?

* Kruchtens " Four Plus one" / four views to follow:

1) Logical: The elements are Objects & Objects Classes. This is a module View.

2) Process: Addresses functionality. This is Component-Connector View.

3) Development: Shows Organization of S/w modules, Libraries, Sub S/m. It is allocation View.

4) Physical: Maps elements Onto Processing & Communication nodes & is also in allocation View.

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