27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

Ontological Description of Module in System Design

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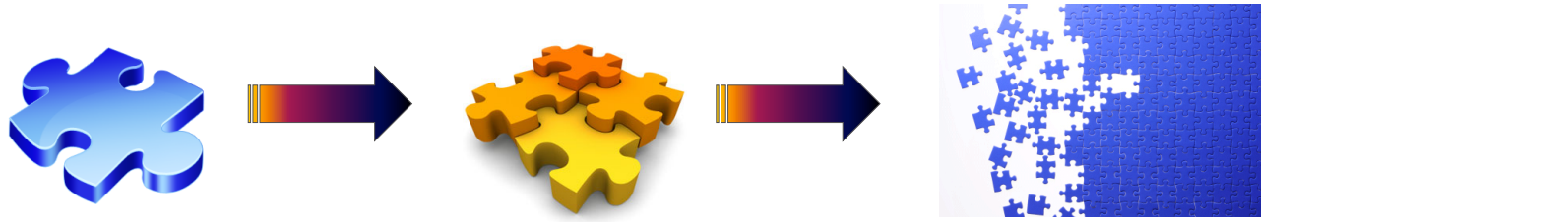
Module definition

- The term module is not part of the system hierarchy description in any of the Systems Engineering standards and handbooks.
- SEVOCAB (Software and Systems Engineering Vocabulary) gives the following definitions for module:
  - A program unit that is discrete and identifiable with respect to compiling, combining with other units, and loading (ISO/IEC 19506:2012 …)
  - Logically separable part of a program (ISO/IEC 19506:2012 …)
  - Set of source code files under version control that can be manipulated together as one (ISO/IEC/IEEE 24765:2010 …)
  - Collection of both data and the routines that act on it (ISO/IEC/IEEE 24765:2010 …)

Module definition

- Module and modularity are widely used in product design and product engineering.
- The terms 'module', 'component' ,'subsystem' and 'unit' are often used interchangeably or defined to be sub elements of one another in different ways, depending upon the context.
- The relationships of these terms are not yet standardized.
- The purpose of this work is to provide separate ontological descriptions for each of these terms.



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https://seattleducation2010.files.wordpress.com/2014/09/puzzle-pieces-filling-in.gif

Common Descriptions of a Module

http://www.thefreedictionary.com/module

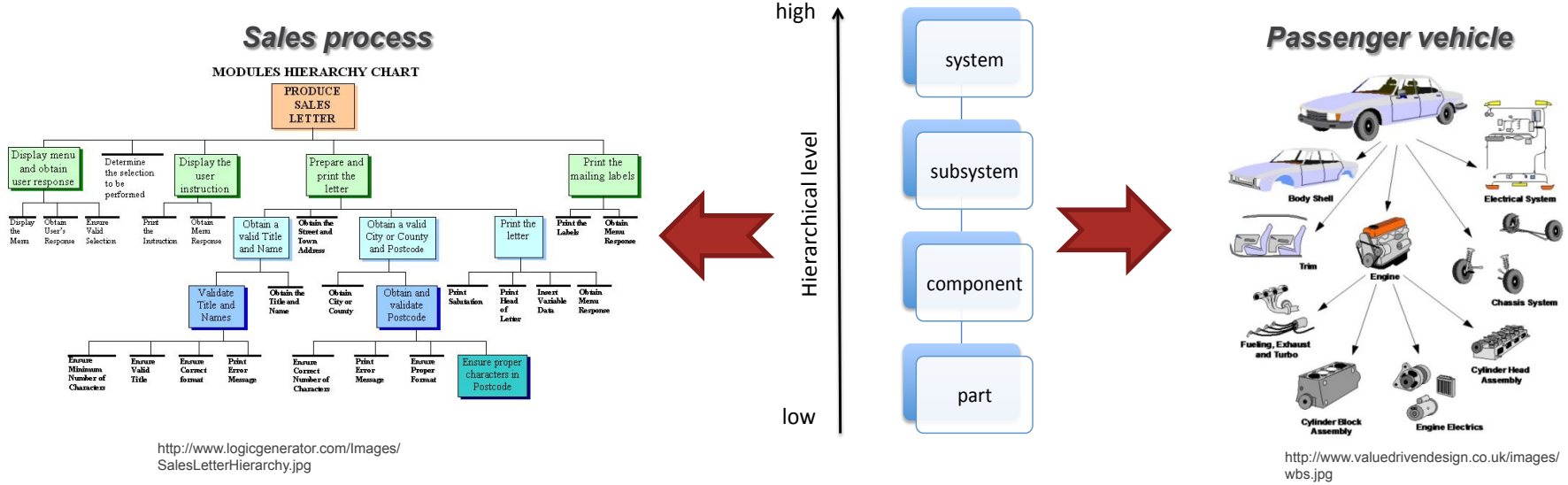
- *Engineering:* A standardized, interchangeable component of a system or construction that is designed for easy assembly or flexible use.
- *Electronics:* A self-contained assembly of electronic components and circuitry, that is installed as a unit.
- *Computers:* A portion of a program that carries out a specific function and may be used alone or combined with other modules.
- *Aviation:* A self-contained unit of a spacecraft that performs a specific task or class of tasks in support of the major function of the craft.
- *Education:* A unit of education or instruction with a relatively low student-to-teacher ratio, in which a single topic or a small section of a broad topic is studied for a given period of time.
- *Biology:* A unit of modular growth, such as a coral polyp.

Questions about a module

- Can we consider anything well encapsulated and isolated as a module 
- Can we consider anything with an interface as a module 
- Does every module need an interface 
- Is it necessary that this interface is standard 

Natural Hierarchy with SE

- A system is composed of subsystems that are composed of components that are in turn composed of parts (IEEE 1220).
- The system hierarchy is a natural result of a one-to-one allocation of a set of hierarchical requirements to physical descriptions that satisfy those requirements.



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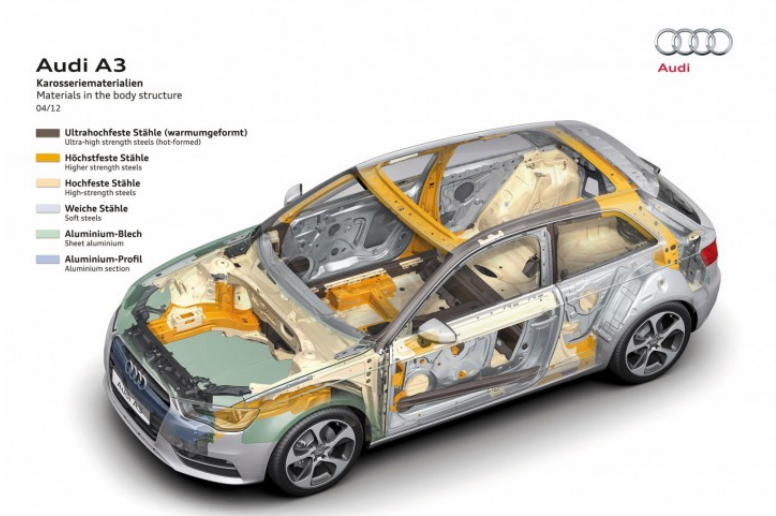
Functional boundaries

- Assignment of functional requirements to configuration items creates a natural modularity along the functional boundaries.
- ***However***, the boundaries of the modules do not need to follow the logical and functional boundaries of that system.



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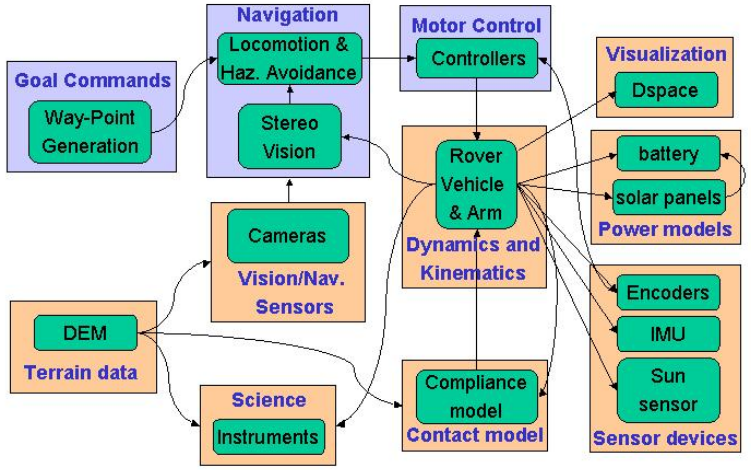

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The power of Modularity

- Anything and everything is decomposable, and has components, parts, atoms etc.
- The ease of decomposability is different for different systems.
- Modularity makes it easier to maintain and evolve the system.
- ***However,*** there are limits to evolvablity benefit of modularity (e.g. system's dynamic and lifecycle).

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http://www.thocp.net/hardware/pictures/storage/cdrom.jpg

https://upload.wikimedia.org/wikipedia/commons/8/86/SanDisk_Cruzer_Micro.png

Benefits of modularity

- The benefits of modularity include nonfunctional properties:
  - Evolvability, or technology push.
  - Manufacturability, assembility, ease of production planning.
  - Testability, verifiability (better test and verification).
  - Style creation, customization, and modifiability.
  - Reusability.
  - Quality control.
  - Better supplier management.
  - Serviceability and maintainability.
  - Upgradability.
  - Recyclability.

Modularity and functionality

- Modularity and functionality have no positive relationship.
- Modularization can have adverse immediate effects on functionality.
- Non-functional requirements have utilities for a specific system lifecycle, or a specific system stakeholder.
- Modularity should not be regarded as a driver for functionality.
- ***However***, in longer term it can improve functionality indirectly through facilitation of evolvability attribute.

Paradigms of systemic objects

Object	Main paradigm
System of systems	-Goal sharing -Loose coordination
System	-Function sharing -Functional synchronization -Integration -Delivery of complex functionality
Subsystem	-Simple function delivery -Tight coordination -High level of integrality
Component	-Single function delivery -Finds value in system context
Module	-Delivery of system attributes/non-functional requirements

Stakeholders of systemic objects

Object	Main stakeholders
System of systems	-Government -Enterprise
System	-User -Developer/manufacturer -Engineer/system engineer -Enterprise
Subsystem	-Developer/manufacturer -Engineer -System engineer -Supplier -User
Component	-Supplier -Developer/manufacturer -Engineer
Module	-User -Enterprise -Supplier -Developer/manufacturer -Engineer

Decision parameters for boundary creation

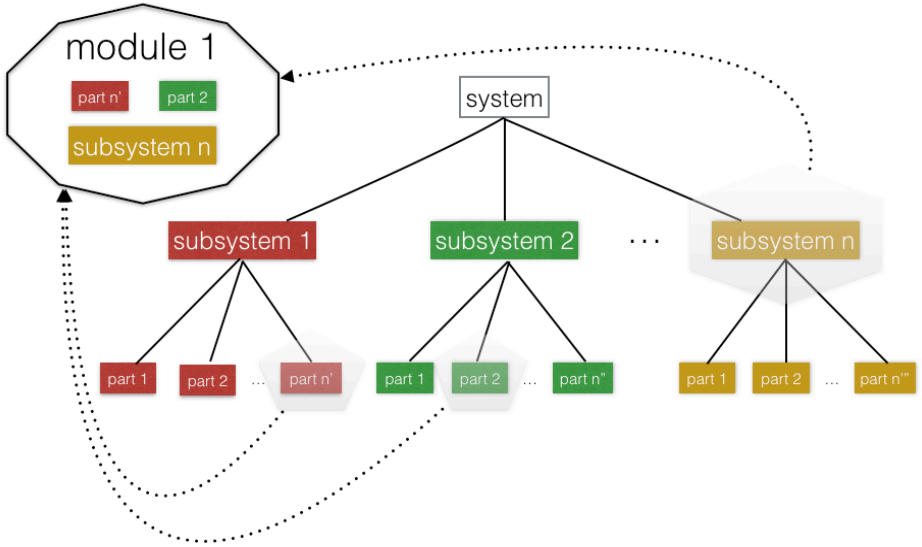
Object	Main design parameters
System of systems	-Strategies for information sharing
System	-Types of technologies -Developer/manufacturer -Engineer/system engineer -Configuration parameters
Subsystem	-Developer/manufacturer -Engineer -System engineer -Supplier -User
Component	-Choice of supplier -Developer -Engineer
Module	-Delivered dollar value of modularization against its cost, including the risk it might bear for functional capabilities.

What is a module?

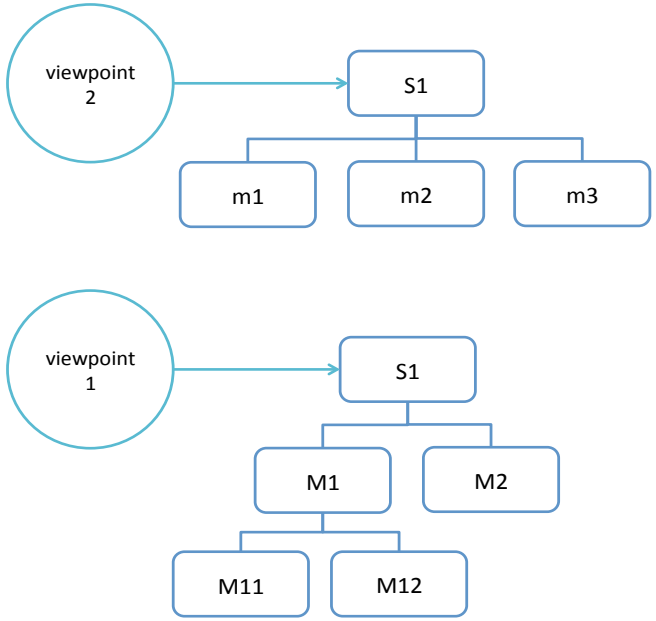
A module is composed of some system parts, and is a detachable unit of a system that has a non-functional utility for a particular system stakeholder.

- Similar to way the functional requirements are mapped into subsystems, non-functional requirements are mapped into modules.
- **The boundaries of the modules and subsystems are not necessarily identical.**

Module boundaries and viewpoints



Modules' boundaries are not necessarily common with functional boundaries



Modular views of a system depend on the viewpoint and the viewer

Summary

- A module should not necessarily have a unique function.
- The primary goal of modularization is non-functional.
- Subsystems, and components only have functional purposes attached to them.
- Every subsystem is a module. However a module is not a subsystem.
- Modules' boundaries are not necessarily common with functional boundaries.
- Modular views of a system depend on the viewpoint and the viewer
- A module does not necessarily have standard interface.

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