Module Requirements

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Abstract

This module addresses requirements: What are requirements? How to find, select, and consolidate requirements?
Abstract

Requirements engineering is one of the systems engineering pillars. In this document we discuss the fundamentals of systems engineering, such as the transformation of needs into specification, the need to prescribe what rather than how, and the requirements when writing requirements.
## Definition of “Requirement”

<table>
<thead>
<tr>
<th>Requirements describing the needs of the customer:</th>
<th>Customer Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements describing the characteristics of the final resulting product:</td>
<td>Product Specification</td>
</tr>
<tr>
<td>The requirements management process recursively applies definition 2 for every level of decomposition.</td>
<td></td>
</tr>
<tr>
<td>Requirements describing the needs of the company itself over the life cycle:</td>
<td>Life Cycle Needs</td>
</tr>
</tbody>
</table>

Fundamentals of Requirements Engineering
Gerrit Muller
version: 0.1
September 25, 2014
REQdefinition
Flow of Requirements

**What**
- customer needs: What is needed by the customer?
- product specification: What are we going to realize?
- system design: How are we going to realize the product?

**How**
- What are the subsystems we will realize?
- How will the subsystems be realized?
- up to "atomic" components

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- choices
- trade-offs
- negotiations

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September 25, 2014
REQwhatWhatHow
System as a Black Box

system seen as black box

inputs → functions → outputs

quantified characteristics

restrictions, prerequisites

boundaries, exceptions

standards, regulations

interfaces
Stakeholders w.r.t. Requirements

- **Customer**
  - (purchaser, decision maker, user, operator, maintainer)

- **Company**
  - Policy and Planning
    - (business, marketing, operational managers)
  - Customer-Oriented Process
    - (sales, service, production, logistics)
  - Product Creation Process
    - (project leader, product manager, engineers, suppliers)
  - People, Process, and Technology management process
    - (capability managers, technology suppliers)
The “Formal” Requirements for Requirements

Specific
Unambiguous
Verifiable
Quantifiable
Measurable
Complete
Traceable
The Requirements to Enable Human Use

Accessible
Understandable
Low threshold
Abstract

The basic “CAFCR” reference model is described, which is used to describe a system in relation to its context. The main stakeholder in the context is the customer. The question “Who is the customer?” is addressed.
The “CAFCR” model

What does Customer need in Product and Why?

Customer What

Customer How

Product What

Application

Functional

Conceptual

Realization

drives, justifies, needs

enables, supports

Customer objectives

Product How
Integrating CAFCR

What does Customer need in Product and Why?

Customer What

C: Customer objectives

Product What

F: Functional

C: Conceptual

R: Realization

Product How

A: Application

intention

objective driven

context understanding

opportunity

constraint awareness

knowledge based

What does Customer need in Product and Why?
CAFCR can be applied recursively

- Consumer
  - Drives
  - Enables
  - Customer's Business
    - Drives
    - Enables
    - Value Chain
      - larger scope has smaller influence on architecture
- Customer Business
  - Drives
  - Enables
- System (producer)
  - Drives
  - Enables
## Market segmentation

<table>
<thead>
<tr>
<th>segmentation axis</th>
<th>examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>geographical</td>
<td>USA, UK, Germany, Japan, China</td>
</tr>
<tr>
<td>business model</td>
<td>profit, non profit</td>
</tr>
<tr>
<td>economics</td>
<td>high end versus cost constrained</td>
</tr>
<tr>
<td>consumers</td>
<td>youth, elderly</td>
</tr>
<tr>
<td>outlet</td>
<td>retailer, provider, OEM, consumer direct</td>
</tr>
</tbody>
</table>
Example of a small buying organization

Who is the customer?

- CFO: Chief Financial Officer
- CIO: Chief Information Officer
- CMO: Chief Marketing Officer
- CEO: Chief Executive Officer
- CTO: Chief Technology Officer

- purchaser
- operator
- maintainer
- user
- department head
- decision maker(s)
CAFCR+ model; Life Cycle View

Customer objectives
Application
Functional
Conceptual
Realization

Life cycle operations
- maintenance
- upgrades

Life cycle development
- manufacturing
- installation

Sales, service, logistics, production, R&D

Short introduction to basic “CAFCR” model
version: 0.4
September 25, 2014
BCAFCRplusLifeCycle
Abstract

The notion of "business key drivers" is introduced and a method is described to link these key drivers to the product specification.
Example Motorway Management Analysis

Key-drivers
- Safety
  - Reduce accident rates
  - Enforce law
  - Improve emergency response
- Effective Flow
  - Reduce delay due to accident
  - Improve average speed
  - Improve total network throughput
  - Optimize road surface
  - Speed up target groups
  - Anticipate on future traffic condition
- Smooth Operation
  - Ensure traceability
  - Ensure proper alarm handling
  - Ensure system health and fault indication
- Environment
  - Reduce emissions

Derived application drivers
- Early hazard detection with warning and signaling
- Maintain safe road condition
- Classify and track dangerous goods vehicles
- Detect and warn noncompliant vehicles
- Enforce speed compliance
- Enforce red light compliance
- Enforce weight compliance
- Deicing
- Traffic condition dependent speed control

Requirements
- Automatic upstream accident detection
- Weather condition dependent control
- Traffic speed and density measurement
- Cameras

Note: the graph is only partially elaborated for application drivers and requirements
### Method to create Key Driver Graph

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Define the scope specific. in terms of <strong>stakeholder</strong> or <strong>market segments</strong></td>
</tr>
<tr>
<td>2.</td>
<td>Acquire and analyze facts extract <strong>facts</strong> from the <strong>product specification</strong> and ask <strong>why questions</strong> about the <strong>specification</strong> of existing products.</td>
</tr>
<tr>
<td>3.</td>
<td>Build a graph of relations between drivers and requirements where <strong>requirements</strong> may have <strong>multiple drivers</strong> by means of brainstorming and discussions</td>
</tr>
<tr>
<td>4.</td>
<td>Obtain feedback discuss with <strong>customers</strong>, observe their <strong>reactions</strong></td>
</tr>
<tr>
<td>5.</td>
<td>Iterate many times increased understanding often triggers the move of issues from <strong>driver</strong> to <strong>requirement</strong> or vice versa and rephrasing</td>
</tr>
</tbody>
</table>

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Key Drivers How To

18  Gerrit Muller

version: 0.2

September 25, 2014

TCAFkeyDriverSubmethod
Recommendation for the Definition of Key Drivers

- Limit the number of key-drivers
  - minimal 3, maximal 6

- Don’t leave out the obvious key-drivers
  - for instance the well-known main function of the product

- Use short names, recognized by the customer.

- Use market-/customer- specific names, no generic names
  - for instance replace “ease of use” by “minimal number of actions for experienced users”, or “efficiency” by “integral cost per patient”

- Do not worry about the exact boundary between Customer Objective and Application
  - create clear goal means relations
Transformation of Key Drivers into Requirements

Key Drivers (Customer) -> Derived Application Drivers -> Requirements

Customer What
- Customer objectives

Customer How
- Application

Product What
- Functional

Key (Customer) Drivers

Customer means
- may be skipped or
- articulated by several intermediate steps

Derived Application Drivers

Product functions
- interfaces
- performance figures
Abstract

An elicitation method for needs is described using many different viewpoints. A selection process with a coarse and a fine selection is described to reduce the specification to an acceptable and feasible subset.
Complementary Viewpoints to Capture Requirements

- **Top-down**
  - Key-drivers (customer, business)
  - Operational drivers (logistics, production, etc.)
  - Roadmap (positioning and trends in time)
  - Competition (positioning in the market)

- **Bottom-up**
  - Regulations
  - "Ideal" reference design
  - Prototyping, simulation (learning vehicle)
  - Existing systems

Needs

Continuous Product Creation Process

Feedback
Requirement Selection Process

- strategy
- roadmap
- competition
- product specification
- need characterization
- requirement phasing
- Technology, People, Process
costs and constraints

- customer needs
- operational needs
Simple Qualification Method

- Important
  - Discuss
  - Don't discuss
- Urgent
  - Discuss
  - Don't discuss

- Effort
  - Don't discuss
  - Discuss
- Value
  - Discuss
  - Do
Examples of Quantifiable Aspects

- Value for the customer
- (dis)satisfaction level for the customer
- Selling value (How much is the customer willing to pay?)
- Level of differentiation w.r.t. the competition
- Impact on the market share
- Impact on the profit margin

Use relative scale, e.g. 1..5 1=low value, 5-high value

Ask several knowledgeable people to score

Discussion provides insight (don't fall in spreadsheet trap)
- Determine the key drivers for one particular product family.
- Translate these drivers into application drivers and derive from them the requirements.
Needs and Requirements

Needs, Specification, Requirements

Requirements describing the needs of the customer: *Customer Needs*

Requirements describing the characteristics of the final resulting product: *Product Specification*

The requirements management process recursively applies definition 2 for every level of decomposition.

Requirements describing the needs of the company itself over the life cycle: *Life Cycle Needs*

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Flow of Requirements

- **What**
  - What is needed by the customer?
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  - How will the subsystems be realized?

- **up to "atomic" components**

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Enable Human Use

- Accessible
- Understandable
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CAFCR, Customer Key Driver Graph

CAFCR+ Model

Customer objectives
Application
Functional
Conceptual
Realization

Life cycle
operations
maintenance
upgrades

sales, service, logistics, production, R&D

Example Key Driver Graph

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Safety
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Smooth Operation
Environment
Derived application drivers
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Reduce emissions

Early hazard detection
Enforce regulation
Maintain safe road condition
Clarity and track dangerous goods vehicles
Detect and warn dangerous vehicles
Enforce speed compliance
Ensure speed control
Monitor traffic

Requirements
Automatic upstream accident detection
Weather condition dependent control
Traffic speed and density measurement
Cameras

Complementary Viewpoints

top-down
key-drivers
(customer, business)
operational drivers
(logistics, production, etc.)
roadmap
(positioning and trends in time)
competition
(positioning in the market)
regulations
“ideal” reference design
prototyping, simulation
(learning vehicle)
bottom-up
(technological opportunities)
existing systems

Needs
Continued Product Creation Process
Feedback

Note: the graph is only partially elaborated for application drivers and requirements