FAA Requirements Engineering Management Handbook

8. Develop the Detailed Behavior and Performance Requirements

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Steps in the REMH

1. Develop the System Overview
2. Identify the System Boundary
3. Develop the Operational Concepts
4. Identify the Environmental Assumptions
5. Develop the Functional Architecture
6. Revise the Architecture to Meet Implementation Constraints
7. Identify System Modes
8. **Develop the Detailed Behavior and Performance Requirements**
9. Define the Software Requirements
10. Allocate System Requirements to Subsystems
11. Provide Rationale

Detailed Requirements: Goals

- Produce a complete and consistent set of detailed system behavioral and performance requirements.
- Firm up earlier non-software requirements into near-final version

Architecture Revision: Artifacts

- Set of system behavior goals
- Set of system performance goals

6 Revise the Architecture to Meet Implementation Constraints

8 Develop the Detailed Behavior and Performance Requirements:

The behavioral and performance requirements define how the system must change the controlled variables in response to changes in the monitored variables. This includes specifying the assigned value of the controlled variable for each system state and inputs, the allowed tolerance about this value, and performance characteristics such as the allowed latency. This practice provides guidelines on how to produce a complete and consistent set of detailed system behavioral and performance requirements.

8.1 Use the names of the monitored and controlled **variables,** the system **modes,** and the internal variables when writing the detailed system requirements

8.2 For each requirement, **specify the system modes** and the conditions **under which the requirement will apply**, followed by the change in the affected variable.

8.3 Ensure the detailed requirements are complete, i.e., an ideal value is assigned to each controlled variable and internal variable for every system state. Use a value of UNSPECIFIED when no meaningful assignment exists for a system state.

8.4 Ensure the detailed requirements are consistent, i.e., that only one ideal value is assigned to each controlled variable and each internal variable for every possible system state.

8.5 Ensure no two detailed requirements duplicate each other, i.e., specify the same outcome for overlapping modes and conditions.

8.6 Present the detailed system **requirements in the function that produces the variable** being specified. This creates an organization in which the definition of each variable is directly traceable to its parent function

8.7 Define the acceptable latency for each controlled variable along with the rationale for its value as part of the detailed system requirements.

8.8 Define the acceptable tolerance for each numerical controlled variable.

8.9 Do not define latency and tolerance for internal variables.

Main Points

- The detailed requirements define what behavior the system will impose on its environment
  - E.g., How the Isolette thermostat will effect the heating element, and (indirectly), the air temperature in the Isolette.
- Generally, embedded system requirements can be specified as another mathematical relationship between the monitored and controlled variables
- Due to the size and complexity of most systems, this is done by first defining, at the lowest level of functional architecture, what the value of each controlled and internal variable would be for a perfect system (referred to as the *ideal value function* in the core methodology).
- The ideal values are generally too restrictive, so we need to define tolerances for each controlled value.
- System performance aspects need to be specified by specifying *latencies*, i.e., a period of time, by which each controlled variable must complete its response.

8.1 Specify the Behavior of each Controlled Variable

- Defining the behavior of controlled variables makes for an easy starting point
- Use the names of the monitored, controlled and internal variables, as well as those of the system modes.
  - This helps tie the requirements to the framework created in previous steps.
  - *Traceability!*

8.2 Specify the Requirement as a Condition and an Assigned Value

- A requirement can be broken into two parts:
  - A condition under which the requirement holds, and
  - An assignment to a controlled variable
- The condition under which the requirement holds can be broken down further into:
  - The system mode
  - Other conditions based on monitored and internal variables

Example Requirements

1. If the Regulator Mode is NORMAL and the Current Temperature is less than the Lower Desired Temperature, the Heat Control shall be set to On.

2. If the Regulator mode is NORMAL and the Current Temperature is greater than the Upper Desired Temperature, the Heat Control shall be set to Off.

8.3-1 Ensure that Detailed Requirements are Complete

- Ideally, the value of every controlled variable and every internal variable should be specified for every possible condition within every possible mode.

- For example, the value of Heat Control can be completely specified with three additional requirements:

4. If the Regulator Mode is INIT, the Heat Control shall be set to Off.
5. If the Regulator Mode is NORMAL and the Current Temperature is greater than or equal to the Lower Desired Temperature and less than or equal to the Upper Desired Temperature, the value of the Heat Control shall not be changed.
6. If the Regulator Mode is FAILED, the Heat Control shall be set to Off.

8.3-2 Ensure that Detailed Requirements are Complete

- Sometimes it is not important to make an assignment to a variable in a particular mode or condition
  - It is, however, important to document this so users of this information don't rely on bad information

6. If the Regulator Mode is not NORMAL, the value of the Display Temperature is UNSPECIFIED.

8.4 Ensure that Detailed Requirements are Consistent

- Make sure requirements do not conflict with one another.

- Example: If the first requirement had been written

  "If the Regulator Mode is NORMAL and the Current Temperature is less than or equal to the Lower Desired Temperature, the Heat Control shall be set to On."

  it would conflict with the fourth requirement.

8.5 Ensure that Detailed Requirements are not Duplicated

- Requirements should also be checked to ensure that no requirement is stated more than once.

8.6 Organize the Requirements

- Requirements for each controlled and internal variable are presented in the function that defines that variable.
- Dependency diagrams can serve as visual “Table of Contents” for detailed requirements.

8.7 Define Acceptable Latency for each Controlled Variable

- Latency specifies the maximum lag between the time one or more monitored variables change value and an affected controlled variable must change its value.
- The latency can be a constant length of time or it can be an arbitrary function.
- Latencies can be defined once and shared in multiple places.
- Latencies should have a rationale provided.

8.8 Define Acceptable Tolerance for each Controlled Variable

- Tolerances should also be specified as a range from the ideal value.
  - Note that some (e.g. boolean and enumerated) types may not have a relevant tolerance

8.9 Do not Define Latency or Tolerance for Internal Variables

- Internal variables are only aids to break controlled variables' ideal value function into manageable pieces
  - Thus, they don't need latency or tolerance ranges.

8.10 Alternate Ways to Specify Requirements

- Shall statements are the most common, but not only, way to specify requirements.
  - Graphical models (with annotations) can be used
  - Tables can also be used
- Regardless of method used, the requirements should be stated:
  - Completely,
  - Consistently,
  - Unambiguously, and
  - Testably

Example Table Format

Specifying the *ideal value* for the Heat Control

Consider the following requirement -- *"If the Regulator Mode is NORMAL and the Current Temperature is less than the Lower Desired Temperature, the Heat Control shall be set to On."*

Table 15. Tabular Specification of Requirements

Regulator Mode	Condition		
INIT			REQ-MT1 ALWAYS
NORMAL	REQ-MT2 Current Temperature < Lower Desired Temperature	REQ-MT4 Lower Desired Temperature ≤ Current Temperature ≤ Upper Desired Temperature	REQ-MT3 Current Temperature > Upper Desired Temperature
FAILED			REQ-MT5 ALWAYS
Heat Control =	On	Previous Value	Off

MT = Monitor Temperature

If the Regulator Mode is NORMAL…

…and the Current Temperature is less than the Lower Desired Temperature…

…the Heat Control shall be set to On.

Summary

- Begin by completely specifying the behavior of all controlled variables as functions based on monitored variables.
- Ensure that the requirements are complete, consistent, organized, and non-duplicitous.
- Define acceptable latencies and tolerances for the controlled variables.
- Specify the requirements in a complete, consistent, unambiguous, and testable format.

For You To Do

Acknowledgements

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  - *FAA* DOT/FAA/AR-08/32*, Requirements Engineering Management Handbook.* David L. Lempia & Steven P. Miller.