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SYSTEM REQUIREMENTS SPECIFICATION

Autonomous Floor Cleaning Robot

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Generated from the SysML v2 model of the product with Doc42. Tables, values and diagrams are read from the model at this revision; change the model, not this document.

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1 Introduction

1.1 Purpose

This specification states what the robot shall do and how well, as verifiable requirements on the robot as a whole. It refines the customer requirements of RVC-CRS-001 and is the baseline for the design (RVC-SDS-001) and for verification (RVC-VVP-001). It contains no design.

1.2 Scope

The system of interest is the robot: its mechanics, electronics and firmware. The requirements apply to the robot as delivered, operating in the conditions of use stated in RVC-CRS-001.

The docking station, the mobile application and the home are external to the system. They appear in this specification only through the interfaces the robot has with them. Requirements on those external systems are not part of this document.

1.3 Document conventions

This document is generated from the SysML v2 model of the robot. Tables, values and diagrams are read from the model at the revision stated on the title page, so they agree with it by construction; the surrounding text is written by the engineering team.

Requirements are identified by a stable number. The word *shall* marks a binding requirement.

Prefix	Identifies	Specified in
USR	Customer requirement	RVC-CRS-001
SYS	System requirement	RVC-SRS-001
BASE, PCB, FW, TOP, BIN, HAR	Module requirement	RVC-SDS-001
VER	Verification case	RVC-VVP-001
VAL	Validation case	RVC-VVP-001

1.4 Applicable and reference documents

The four documents of the robot form one set. Each holds one kind of information and refers to the others for the rest.

Number	Document	Answers
RVC-CRS-001	Customer Requirements Specification	What does the household need?
RVC-SRS-001	System Requirements Specification	What shall the robot do, and how well?
RVC-SDS-001	System Design Specification	How is the robot built to do it?
RVC-VVP-001	Verification and Validation Plan	How will we know that it does?

The structure and content of the set follow these guides, tailored to a product of this size:

- ISO/IEC/IEEE 29148:2018, *Systems and software engineering — Life cycle processes — Requirements engineering*, for the stakeholder and system requirements specifications.
- NASA/SP-2016-6105 Rev 2, *NASA Systems Engineering Handbook*, for the verification and validation plan and the requirements verification matrix.
- INCOSE, *Systems Engineering Handbook*, fifth edition, and INCOSE, *Guide to Writing Requirements*, for the separation of needs, requirements, design and verification, and for the wording of requirements.

2 System overview

The robot performs nine functions, which together form its operating behaviour (*OperateCleaningRobot*):

- **locomotion**, driving and steering the robot;

- **cleaning**, brushing and vacuuming the floor;
- **perception**, sensing obstacles, drops and the surrounding space;
- **navigation**, mapping the home, locating the robot in it and planning its path;
- **power management**, supplying the robot and charging its battery;
- **docking**, finding the docking station and connecting to it;
- **mission control**, sequencing a cleaning mission from start to finish;
- **safety supervision**, stopping the robot when a hazard is detected;
- **user interaction**, accepting commands and reporting status.

These functions describe what the robot does as seen from outside. The operating modes a user can observe are a requirement of this specification; the states the robot moves through internally are design. They say nothing about which hardware or firmware performs them; that allocation is a design decision and is described in RVC-SDS-001.

2.1 System context

The system of interest is the robot. The user, the mobile application, the docking station and the home are outside it; the requirements constrain the robot's behaviour at these interfaces.

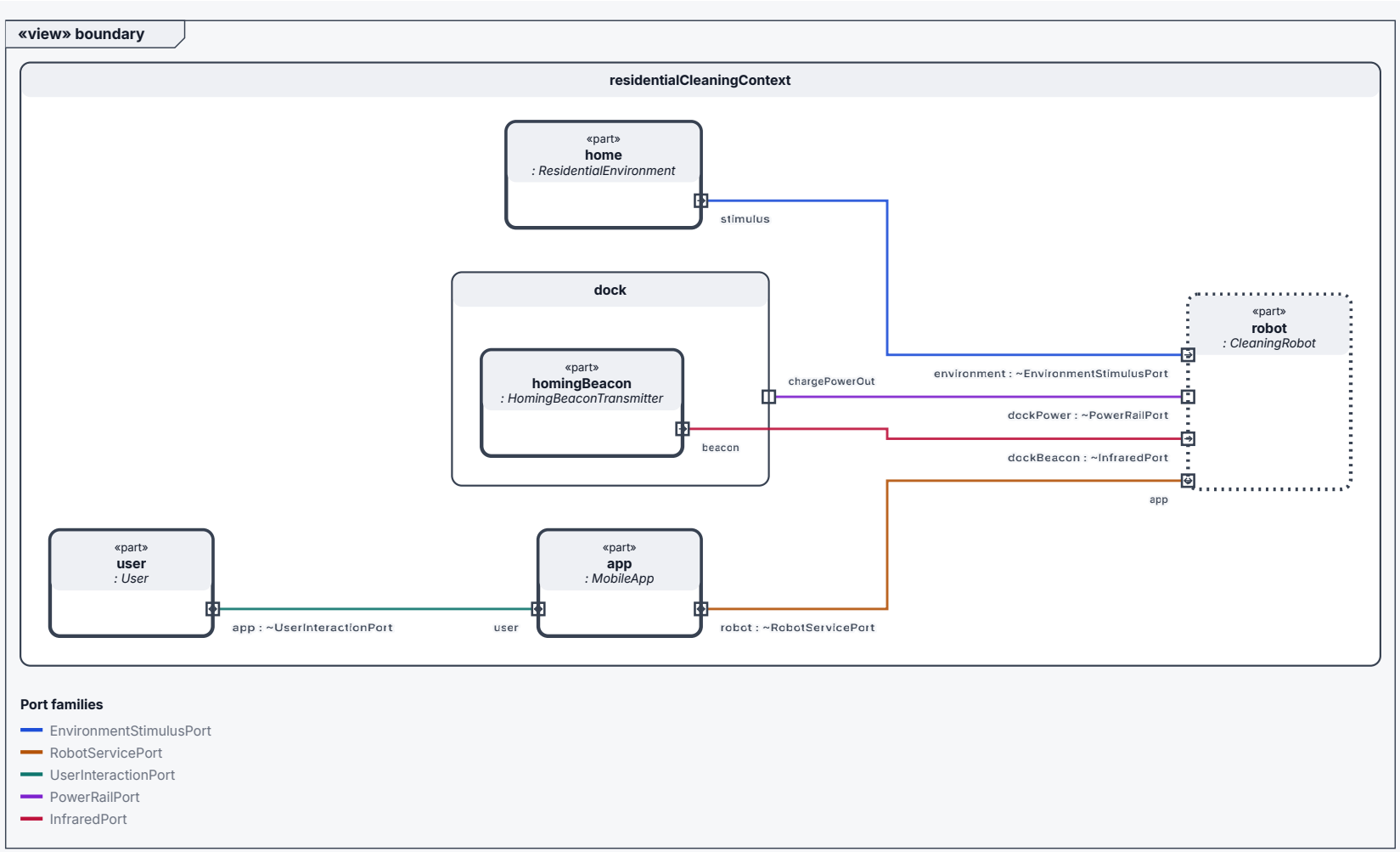


Figure 1: System context

3 System requirements

Each requirement constrains one measurable property of the robot and states its limit, and names the customer requirement it was derived from. The limits are read from the model, where the analyses and budgets use the same values. A requirement states what the robot shall do or be, not how: the design that meets it is in RVC-SDS-001, and how it is verified is in RVC-VVP-001.

3.1 Functional requirements

ID	Requirement	Text	Derived from
SYS-005	Coverage map maintenance	The robot shall maintain a map of cleaned, unreachable and unknown floor cells throughout a mission.	USR-003
SYS-006	Wheel stall detection and recovery	The robot shall detect a stalled drive wheel within 2 s and enter a bounded recovery.	USR-SAFE-001
SYS-007	Return to dock on low battery	The robot shall return to its dock when the state of charge falls below 15 percent.	USR-002
SYS-013	Dust bin capacity	The robot shall hold at least 400 mL of debris in a dust bin that is removed and emptied without tools.	USR-008
SYS-017	Operating modes	The robot shall at any time be in exactly one of the operating modes idle, cleaning, paused, returning to the dock, charging, safe stop and fault, and shall report a change of mode to the local application.	USR-004

3.2 Performance requirements

ID	Requirement	Text	Derived from
SYS-001	Cleaning area per charge	The robot shall clean at least 80 m² of floor on one battery charge in the reference home.	USR-001
SYS-002	Floor coverage	The robot shall cover at least 90 percent of the reachable floor area in one mission.	USR-001
SYS-004	Localization accuracy	The robot shall keep its localization error below 150 mm throughout the reference mission.	USR-003
SYS-012	Acoustic noise	The robot shall emit a sound pressure level of at most 65 dB(A) at 1 m while cleaning a hard floor at the default suction setting.	USR-007
SYS-014	Threshold climbing	The robot shall cross a rigid threshold at least 20 mm high in both directions.	USR-009
SYS-016	Recharge time	The robot shall recharge from the low-battery return threshold to full charge within 4 h on its dock.	USR-002

3.3 Interface requirements

ID	Requirement	Text	Derived from
SYS-009	Mission status reporting	The robot shall report mission progress and faults to the local application during a mission.	USR-004

3.4 Physical characteristics

ID	Requirement	Text	Derived from
SYS-011	Overall height	The robot shall be no higher than 95 mm, including the laser scanner turret.	USR-006
SYS-015	Robot mass	The robot shall have a mass of at most 4 kg with an empty dust bin.	USR-010

3.5 Safety requirements

ID	Requirement	Text	Derived from
SYS-003	Obstacle avoidance	The robot shall avoid collision with household obstacles that are at least 30 mm high.	USR-SAFE-001
SYS-008	Charging within the battery safe operating area	The robot shall keep charge current and cell temperature inside the safe operating area of the battery.	USR-002
SYS-SAFE-010	Cliff detection	The robot shall detect a drop of at least 50 mm before a wheel crosses its edge.	USR-SAFE-001
SYS-SAFE-011	Safe stop on hazard	The robot shall command a safe stop within 100 ms of a cliff, lift, collision, over-current or over-temperature hazard.	USR-SAFE-001
SYS-SAFE-012	Battery protection independent of firmware	The robot shall disconnect the battery on over-current, over-voltage, under-voltage and over-temperature by hardware that works without the application firmware.	USR-SAFE-001
SYS-SAFE-013	Safe stop held until cleared	The robot shall remain stationary in safe stop, with drive and cleaning motors off, until the hazard is no longer present and the user has confirmed that the robot may continue.	USR-SAFE-001

3.6 Security and privacy requirements

ID	Requirement	Text	Derived from
SYS-010	Local storage of map data	The robot shall keep raw home-map data on the robot and the local network unless the user has explicitly consented to transfer.	USR-005

4 Traceability to customer requirements

Every customer requirement of RVC-CRS-001 has one derivation in the model. The derivation names all system requirements derived from the customer requirement and records why that set is complete: meeting all of them leaves nothing of the customer requirement unmet.

The table shows those derivations as they are in the model. The build of the model fails when a customer requirement has no derivation or when a system requirement is named by none, so a row cannot be missing.

Customer requirement	Derived system requirements	Why this set is complete
USR-001 Whole-home cleaning in one run	*SYS-001 Cleaning area per charge* *SYS-002 Floor coverage*	Cleaning the whole home in one run needs enough energy for the area and a path that actually reaches the floor. Area per charge bounds the first, coverage of the reachable floor the second.
USR-002 Unattended docking and charging	*SYS-007 Return to dock on low battery* *SYS-008 Charging within the battery safe operating area* *SYS-016 Recharge time*	Being ready the next day without help needs the robot to leave for the dock early enough, to charge safely once there, and to finish charging overnight.
USR-003 Reliable navigation at home	*SYS-004 Localization accuracy* *SYS-005 Coverage map maintenance*	Knowing where it is becomes a bound on localization error. Knowing where it has cleaned becomes a maintained coverage map.
USR-004 Mission progress and fault feedback	*SYS-009 Mission status reporting* *SYS-017 Operating modes*	Progress and faults are carried by the mission status the robot reports to the application. The household also needs to know what the robot is doing at any moment, which is its operating mode.
USR-005 Privacy of the home map	*SYS-010 Local storage of map data*	The map is the only personal data the robot creates. Keeping it local by default, with transfer only after explicit consent, is the whole need.
USR-006 Cleaning under furniture	*SYS-011 Overall height*	Fitting under furniture with about 10 cm of clearance is one dimension, the overall height including the LiDAR turret, with margin for carpet pile.
USR-007 Quiet operation	*SYS-012 Acoustic noise*	A conversation in the same room is possible below about 65 dB(A), so the need becomes one sound pressure limit with a stated distance, floor and mode.
USR-008 Easy routine maintenance	*SYS-013 Dust bin capacity*	Emptying at most once per run needs a bin that holds the debris of one run of the reference home; doing it without tools is part of the same requirement.
USR-009 Thresholds between rooms	*SYS-014 Threshold climbing*	Door thresholds and rug edges in the target homes are up to 20 mm high; crossing them in both directions is one capability.
USR-010 Carrying between floors	*SYS-015 Robot mass*	Carrying in one hand is bounded by mass. The grip is a detail of the enclosure design under that limit.

Customer requirement	Derived system requirements	Why this set is complete
USR-SAFE-001 Safe operation in the household	*SYS-003 Obstacle avoidance* *SYS-SAFE-010 Cliff detection* *SYS-SAFE-011 Safe stop on hazard* *SYS-006 Wheel stall detection and recovery* *SYS-SAFE-012 Battery protection independent of firmware* *SYS-SAFE-013 Safe stop held until cleared*	The household hazards are falling, collision, entanglement and the battery. Each has a detection requirement, and all of them lead to one supervised safe stop, which holds until the hazard is gone and the user has confirmed. The battery additionally has protection that does not depend on firmware, because a firmware fault must not become a fire risk.

5 Verification

Every requirement of this specification is verified by at least one verification case. The methods, the cases with their pass criteria and the requirements verification matrix are in the Verification and Validation Plan, RVC-VVP-001. This specification states what is required; it claims nothing about whether the design meets it.