D1.1 MARIO System Specification for Pilot 1

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D1.1

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Executive Summary

This report details the hardware and software architecture required at Pilot 1 to achieve the baseline of functions required. This document will guide the development of the system especially the development of interfaces between major components and thus the process of system integration.

The detailed design set out in this report is the result of extensive consultation both technical and with end users at the three test sites. A user led requirements capture process has led to the complete requirements set presented in Appendix A.

This report also contains a functional overview of what will be achieved at Pilot 1 and acts as a reference point for defining the function and deployment of MARIO into the three Pilot 1 test sites.

This report has been updated (2v0) to reflect comments made by the reviewers at the first review and addresses a number of key additional points:

- An assessment of the user interface design with regard to interactions with people with dementia (PwD). (See Section: 5.4)
- The process for development used in conjunction with feedback from the trials. (See Section: 5.5)
- The addition of details surrounding the development of the technical requirements in Appendix A through consultation with pilot stakeholders including PwD. (See Section 2.1.2)
- An assessment of the technology differences between the existing Kompaï platform and the MARIO platform.(See Section 2.1.1)
- The integration of a description of data management derived from Task 1.3 .(See Section 6)

It is intended that the design details in this deliverable will be updated prior to development taking place in Trail 2 where additional coverage of functions will be reviewed based on the results from Trail 1. Trial 3 is not expected to further change the design but to concentrate on greater robustness and appropriate interactions all of which should take place within the defined architecture.

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1. Introduction

The key objective of this work is to provide a detailed high level specification for the MARIO platform in terms of both its functional competence and underlying software and hardware architecture. The work necessarily concentrates on the requirements for the first functional stage of the project that will result in the first Pilot trials. The work sets out the functional goals of Pilot 1 setting them in the context of both project and user requirements and details the architectural elements needed to achieve these functional goals.

The key outcome of the work falls into two parts. Firstly the distillation and refinement of the requirements capture process into both a set of formal requirements and a set of implementation Use Cases. Secondly a detailed breakdown of those requirements and Use Cases into packages for implementation both in terms of hardware architecture and software.

1.1 Work Package 1 Objectives

The overall WP1 objectives are:

- To introduce MARIO to the pilots settings
- To engage stakeholders of various types across different settings to attain the best possible additions to user specifications
- Using the user specifications, to document the final and best-fit MARIO functionalities
- To develop the data management plan and system architecture to support the intended functionalities
- To develop and document the MARIO Ethical Framework that makes clear the privacy, security and ethical expectations right at the beginning of the project.
- To develop an assessment methodology for the assessment of the benefits of MARIO solutions

The specific objectives addressed within this report are the utilisation and amalgamation of user derived specifications into a set of functionalities and the development of a system architecture to support the delivery of those functions.

1.2 Purpose and Target Group of the Deliverable

The purpose of this deliverable is to set out the high level system architecture such that more detailed design of the software system can proceed within a defined framework and to detail the functions that will be implemented on the MARIO platform to support the key objectives of the project.

This report is primarily a point of reference aimed at the technical implementation team within the project, but it should also be accessible to management and in particular staff engaged in the trialling process to assess and plan technically related tasks prior to trials starting and to assess functional expectations during the trial.

1.3 Relations to other Activities in the Project

The functional specification in this report is derived form the following sources:

- The description of work for the MARIO project
- Interviews and assessments of both Users and Care Staff in Task 1.1.
- Technical reviews undertaken as a part of WP1 Task 1.2.

Requirements from these sources were combined and reviewed. The functional specification and the system architecture were then derived from the requirements.

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The report also draws on the Ethical Framework set out in D 1.2 and the Data Management plan in D10.5.

1.4 Document Outline

The document is divided into a number of sections. The main body of the document first details the high level functions that MARIO must perform as sets of Use Cases. The second part then details the software and hardware architectures providing key detail on functional boundaries and interfaces between major components. The Appendix to the document presents the formal requirements specification derived during Task 1.2.

1.5 About MARIO

MARIO addresses the difficult challenges of loneliness, isolation and dementia in older persons through innovative and multi-faceted inventions delivered by service robots. The effects of these conditions are severe and life-limiting. They burden individuals and societal support systems. Human intervention is costly but the severity can be prevented and/or mitigated by simple changes in self-perception and brain stimulation mediated by robots.

From this unique combination, clear advances are made in the use of semantic data analytics, personal interaction, and unique applications tailored to better connect older persons to their care providers, community, own social circle and also to their personal interests. Each objective is developed with a focus on loneliness, isolation and dementia. The impact centres on deep progress toward EU scientific and market leadership in service robots and a user driven solution for this major societal challenge. The competitive advantage is the ability to treat tough challenges appropriately. In addition, a clear path has been developed on how to bring MARIO solutions to the end users through market deployment.

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2 MARIO System Overview

High level overview of the system detailing major hardware and software components, user interface and external connectivity. Overview of the operating environment and the user benefit.

2.1 System description

2.1.1 Brief system introduction

Short description of complete system and its function, images of system.

The MARIO system consists of a mobile robot based on the Kompai platform from Robosoft. The system is able to navigate around an environment that it has pre-mapped. It has capability for speech and touch screen interfaces for the user and is able to produce audio output as well as having a display screen.

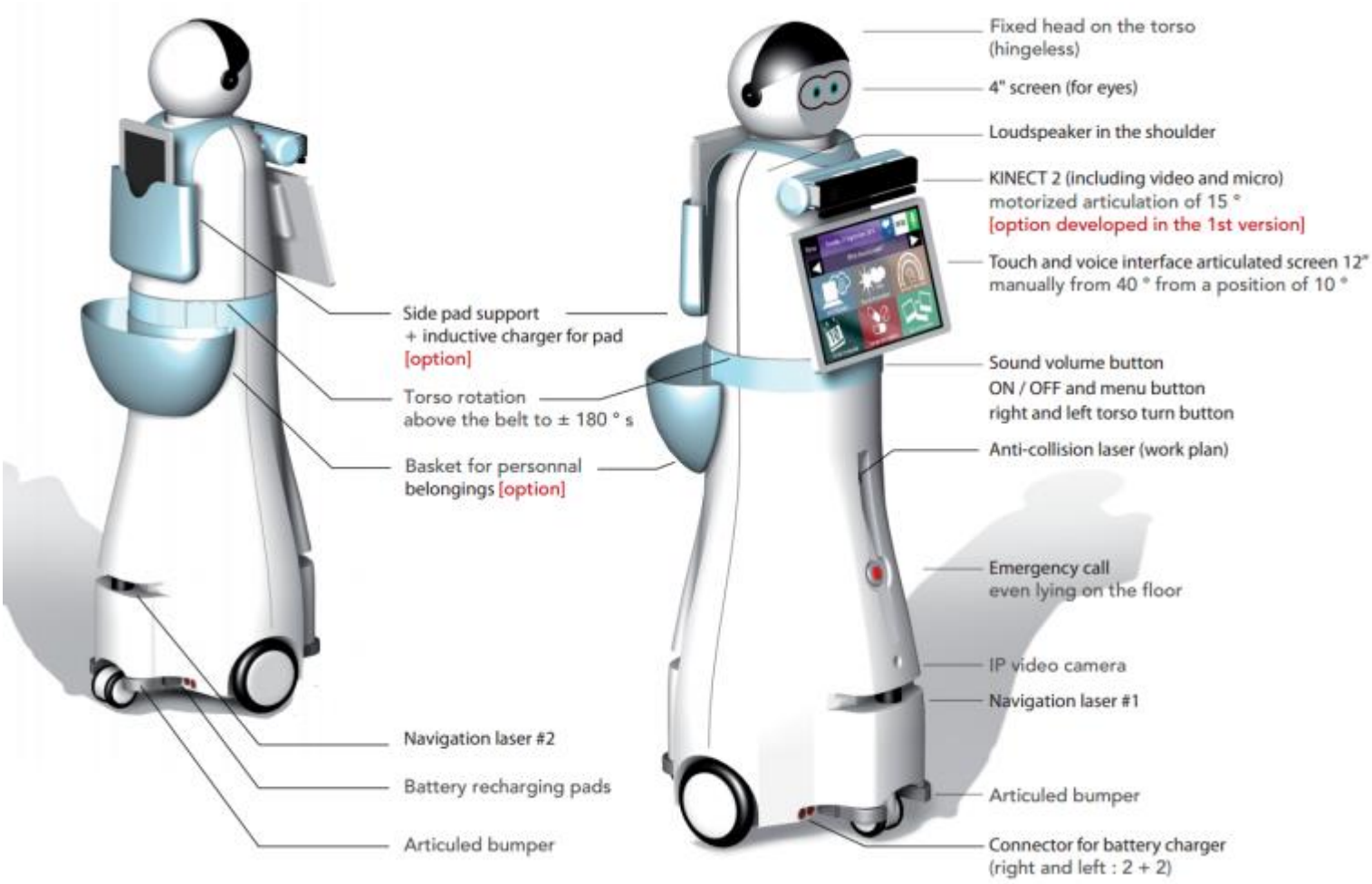

Figure 1: MARIO platform schematic[1]

[1] http://www.robosoft.com/robotic-solutions/healthcare/kompai/index.html

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The following tables highlight the similarities and differences between the original Kompai robot and the MARIO robot.

Item	Kompai 1	MARIO
Traction	Differential wheel	Differential wheel
Low level control	PURE	PURE
Obstacle detection	Only one horizontal front laser used for navigation and obstacles avoidance	One horizontal in the front for navigation and front obstacles avoidance, one in the back and one vertical in front for obstacles detection
3D sensor	Fixed Kinect 1	Kinect 2 with motorized tilt +-20°
Torso	Fixed	Motorized
Computing	One tablet PC running navigation and robot application	2 power full computer one running Windows OS for navigation and standard functions provided with Kompai robot. The second running any other OS for additional functions developed by partners.
Head	Fixed head	Animated head and removable for the possibility to replace it by Jibo head (MARIO project requirement)
Autonomy	Depending on the scenario it is about 3h	Double
Quality of sound	Normal	Additional amplifier to adjust the quality of sound
High level software interface	Under MRDS based programming environment	Web based programming technology

Item	Requirements in MARIO use cases	Link to project requirements (D1.1)	Required hardware customization with regard to standard Kompaï 1 robot	Remarks
	Guiding the user towards a place (Follow-me)	2.4	Additional sensor in the rear of the robot to track the movement of the user	A 2D laser was added in the rear to answer this requirement. Lower part of the robot need to be re-designed to integrate it
	Tables and vertical objects detection and avoidance	2.4	Additional sensor to cover to complete volume of the robot	A vertical laser was added to answer this requirement. Lower part of the robot need to be re-designed to integrate it
	behavioural skills	1.1 & 2.4	Kinect 2 with additional tilt capabilities to extend its field of view.	Re-design of the upper part to integrate Kinect 2 and tilt mechanism. On the Kompai 1 only a fixed Kinect 1 was available
			Additional chest rotation to continue to track the patient when the robot execute a curve path (avoiding obstacles)	Deep change because the interface between the upper and top parts need to be re-designed

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			Additional powerful computer to interface Kinect 2 and a second user computer to run behavioural module and other partner's software	More volume needed in the lower part of the robot
	Emotion expression by the robot	2.11	Additional emotion expression on the robot head	Re-design of the head to integrate Eyes expression on it
	Option to integrate JIBO into the MARIO system	Page 15 & 16	Provide mechanical interface to replace the standard robot head by Jibo.	Deep change because of the re-design of the interface between the upper part and the head.
	Increase the autonomy of the robot	2.3	Additional batteries	More volume needed in the lower part of the robot
	Identification of person and objects	3.3 & 5.6	Additional RFID sensor on the robot	
	Quality of sound		Additional amplifier to adjust the quality of sound	

Table 1: Kompaï and MARIO comparison

2.1.2 Requirements Analysis

The functional specification in this report is derived from the following sources:

- The description of work for the MARIO project
- Interviews and assessments with a range of both Users and Care Staff at each of the three trial sites.
- Reviews with both the whole MARIO project team and detailed technical reviews both undertaken as a part of WP1.

Requirements from these sources were combined and reviewed by the project team. The functional specification and the system architecture are derived in turn from the requirements. Appendix A to this document presents the requirements.

The derivation of requirements took place in three stages first the Description of Work was systematically analysed for all references to functional features of the proposed system. Each relevant section was then captured and stored in a Mind Map. Each section text was then analysed for functional intent or indications of hardware or software requirements. From this individual requirement statements were constructed. These were then clustered and grouped according to a basic functional scheme relating to hardware, software and interaction requirements. This provided a hierarchy of requirements.

The second stage cantered around gathering User derived input to requirements. Sets of interviews were carried out at the three pilot sites one set with staff and one with PwD participants. The concept of MARIO was explained at the start of each meeting and a short video used to show what MARIO might look like and how it might operate. Both staff and PwD were asked a set of key questions about their views on MARIO and were also asked to identify things they would like MARIO to do for them. This was done without any attempt to constrain answers to technically feasible outcomes. Staff and PwD were also asked about how they thought MARIO looked and how they thought they might interact with MARIO.

The outcomes from these interviews were documented by staff at the pilot sites and transcripts of the interviews were captured. This material was then used to identify functional characteristics

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requested by users that might augment MARIOs requirement. These were then captured within the Mind Maps and clustered with the requirements derived from the description of work.

From the detailed Mind Maps a distillation of the full set of requirements was created as a word document. This was circulated to the WP1 team for discussion. This resulted in further consolidation of the requirements and in the addition of cascaded technical requirements.

In the final step these sets of requirements were then reviewed by the MARIO technical team and entered into the UML tool used to capture the design. These captured requirements were then utilised within the UML tool to ensure that software components aligned with each requirement hierarchy. At each stage of the development of the technical design, as provided in this document, cross checks were made with the higher level sets of requirements to ensure that key features captured in the requirements process had not been missed. This cross checking used the implementation model structure within UML where Use Cases and Packages are linked to Requirements to ensure each Requirement is linked to either a Use Case or Package. For the sake of brevity these diagrams have not been include in this document.

It is the intention that at Trial 1 and at the start of Trial 2 (M24) a review of the full set of requirements against the trial delivery will be carried out to assess the requirement/function delivery mapping. The expectation is that a number of requirements may be downgraded to “may” from “should” status, as is normal at this point in product development.

For reference all of the Mind Maps referred to above are included as separate a PDF Annex to this document.

2.1.3 Functional overview

Description of the major functions carried out by the system.

The following Use Case diagram shows the major functions that will be carried out by MARIO both for the user and for associated care staff.

The purpose of these functions is to provide the following benefits to the user:

- Decrease loneliness
- Assist in daily living tasks
- Capture and analyse heath data about the user

While the MARIO robot cannot physically help the user it can provide cognitive assistance and social interaction.

The functions that MARIO will carry out for the user are illustrated in the following diagram.

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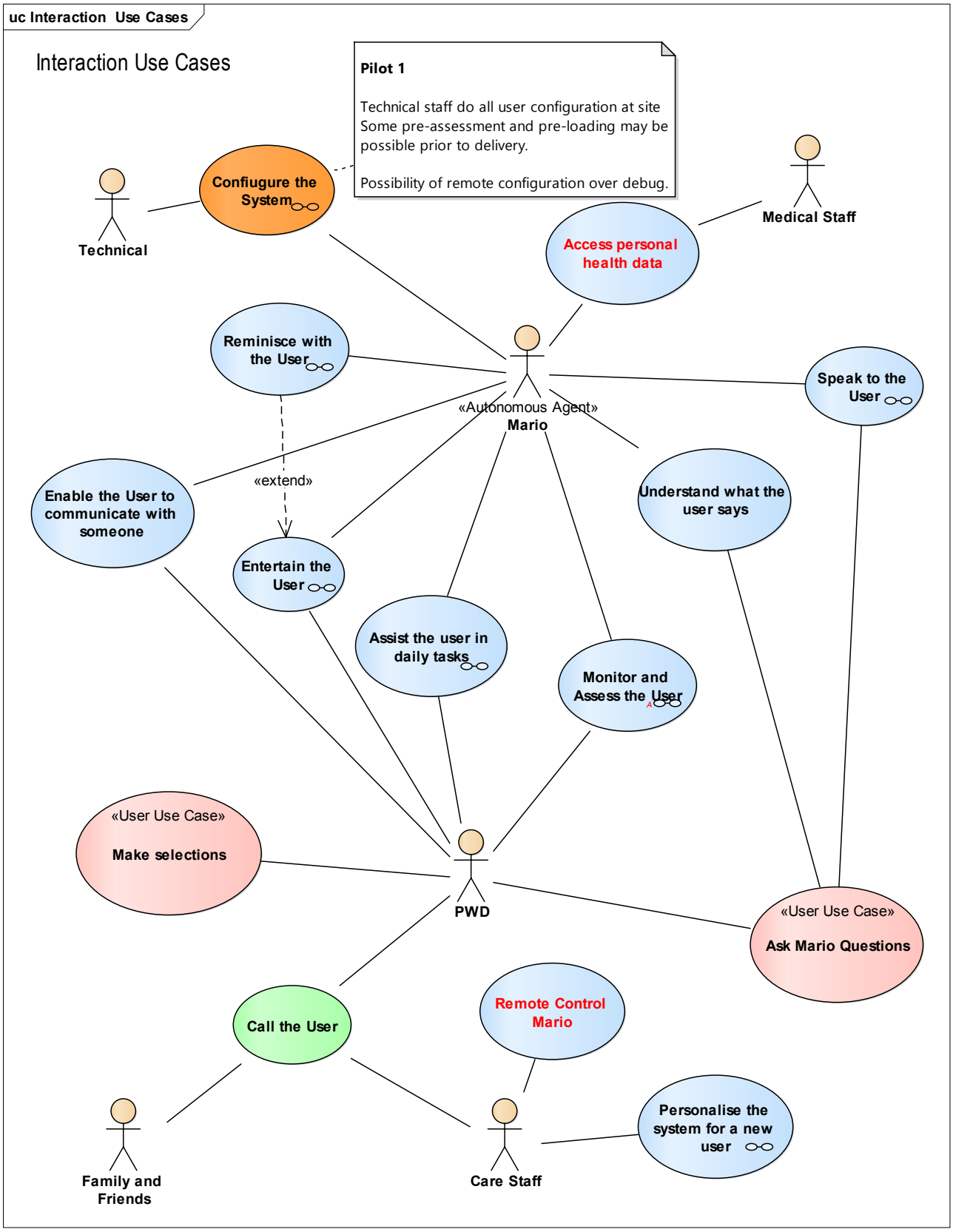

Figure 2 Main User Interaction Use Cases

The diagram shows all of the major functions and their interaction with the different people (Actors) that will use MARIO.

2.1.3.1 User interaction in Pilot 1

In Pilot 1 each MARIO robot will be associated with one specific Person With Dementia (PWD) and their care staff. The three trial sites represent three different modes of use; a care home, a user's house and a hospital environment. In each of these three settings MARIO will need to interact with different people. In the Home and Hospital environments MARIO will encounter people, both carers and friends and family who are not familiar with MARIO. In the Care environment most of the staff can be given some level of information and even training about MARIO. In each of these environments there are different requirements, both in terms of the physical environment and in terms of the functional interaction with the PWD and their carers. For example in the home environment there may be small steps or thresholds at doorways and different floor coverings, and in the Hospital environment MARIO may be allocated to a PWD without having any pre-loaded information about them.

In the Care and Home environments MARIO will be pre-loaded with personal information about the user, entertainment preferences a diary of events and basic personal information. However it should be noted that MARIO will not be given any data about medication or be used to remind the user about taking medication as this would cross a boundary between different types of medical device and necessitate a higher level of product approval as well as present data integrity and privacy concerns.

For functions such as performing the CGA assessment and accessing this health data MARIO must be able to identify the specific user, to ensure that data collected from the user, and must be able to identify care staff who can access the health data and add new personal information for the user. Identifying the user is also important for a number of the personalised functions such as entertaining the user, in reminiscence activities, and in functions that need access to the user's personal contacts and family data (e.g. the name of a specific relative). The intention is to achieve this using RFID tags although there are a number of implementation issues that must be resolved during the initial part of the Pilot.

The individual functions delivered in Pilot 1 are detailed in the following sections.

2.1.3.2 Colour Key

The diagrams use a simple colour key to indicate the status of each Use Case:

- Not implemented in Pilot 1 (Future Use Case)
- Use Case to be delivered in Pilot 1
- Component that may be delivered in Pilot 1
- Configuration Use Case requiring external work prior to delivery.
- Use Case identified in requirements but considered too technically difficult within the MARIO project.

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2.2 Hardware overview

2.2.1 Hardware block diagram

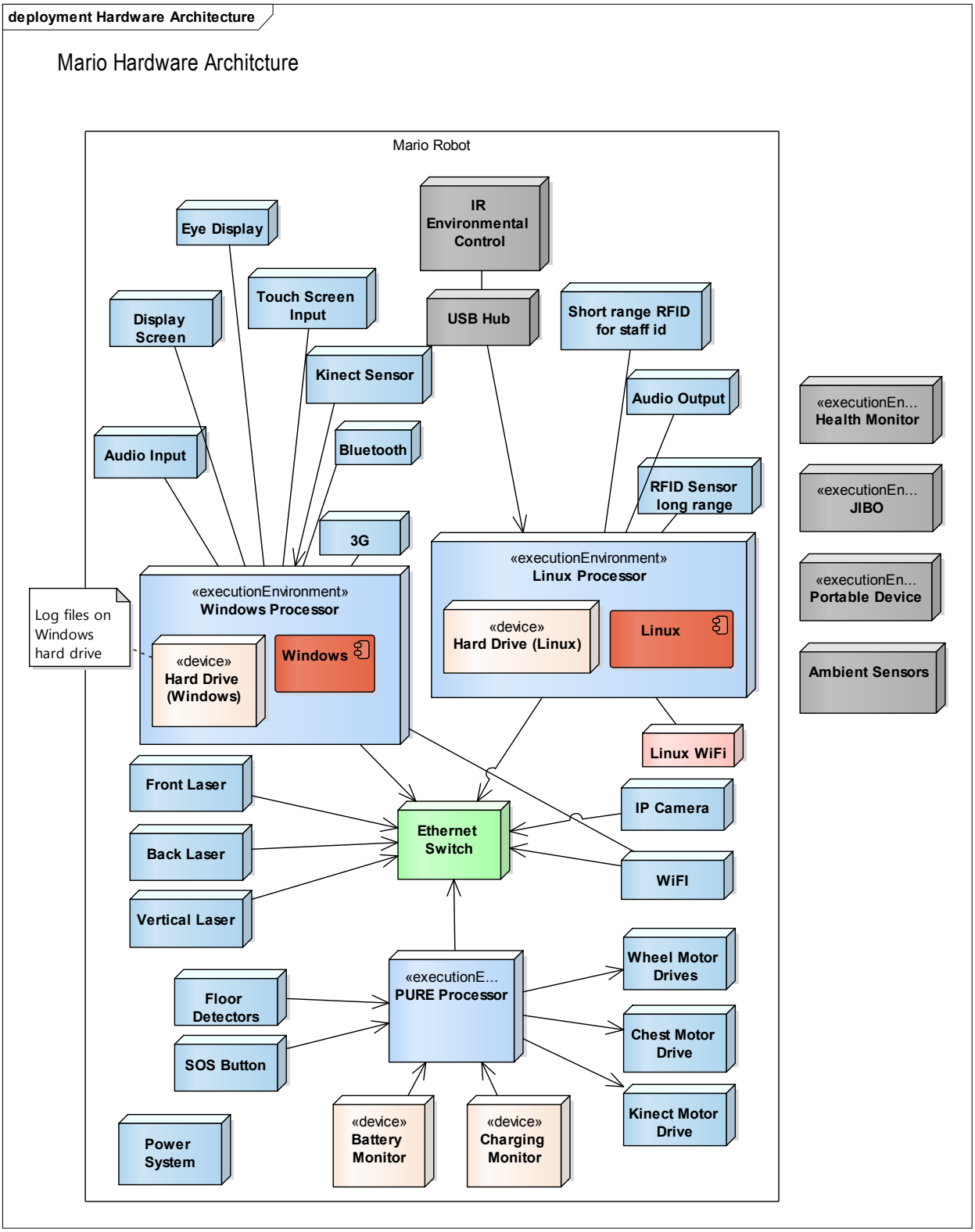

Figure 3:High level hardware block diagram showing major sub-systems and internal and external hardware connectivity.

Note: The above diagram shows that the JIBO[2] personal platform may become part of the later stages of the MARIO project. There is an option to integrate JIBO into the MARIO system by replacing the head assembly with a JIBO. However the practicality of this cannot be assessed until JIBO is available some time in 2016/17.

2.2.2 Major hardware components

List of major hardware components each with a description of function and information about supplier and developer.

The following are the major hardware components that will be delivered as part of the MARIO robot package:

Item	Supplier	Function
Robot	Robosoft	Platform that will move around the operating environment.
Charging station	Robosoft	Static charging station located on flat wall. Robot can return to the charging station to recharge.
Health monitor	e.g. FitBit	Wrist band able to communicate via Bluetooth to PC to upload basic health data on movement and heart rate.
Long range RFID	Feig Electronics	Able to scan tags at a distance to recognise objects important to the user.
Short range RFID		Worn by user to identify them to MARIO

Table 2: MARIO's main hardware components.

2.2.3 Sensing Overview

List of sensors with a description of function and information about supplier and developer.

Nearly all of the sensing used within MARIO is supplied with the platform the following are the exceptions to this:

- Sensors of various kinds including Infra Red Detectors, pressure mats, door switches etc. are placed within the user's environment to monitor the location of the user when it is impossible for MARIO to follow the user. For example in a toilet or bathroom. These sensors can be accessed by MARIO to gather and add to the data it captures about the location and daily activity of the user. Typically such sensors will utilise Internet of Things technology to communicate with the local data network where one exists, or directly with MARIO. (Not included in Pilot 1)
- Health monitoring sensing is carried out using a commercial health sensor worn by the user. For Pilot 1 this will provide basic health information, in later trials more advanced sensors will be considered able to add to the health data that is captured.
- RFID tags will be used to identify a small number of personal objects that are important to the user. MARIO will be equipped with an RFID reader that is able to detect and identify these objects and provide basic location information for each object that is tagged.
- A second set of close proximity RFID tags can optionally be used to identify users within the environment. This will require the user to be close to the robot platform before their RFID tag can be read.

[2] https://www.jibo.com

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The sensing systems on the robot that sense the environment around the robot consist of a set of laser scanners able to scan and measure the distance to objects within their field of view. As a part of the initial installation of MARIO in each user environment the robot platform is able to use these sensors and a navigation process to create a map of its environment. During operation MARIO will use this map, in conjunction with the laser scanners, to identify its own location within the map and as a result navigate to any location. Over time this map is likely to degrade as furniture is moved, the extent and scale of this degradation will be examined within the Pilot. Once a map has degraded to the point where this impacts on MARIO's functions it will be necessary to rebuild the map with a new scan of the environment.

In addition to these navigation sensors the platform is equipped with a 3D vision system able to tilt and pan with the robot as it rotates its upper torso. This sensor is used during interaction with the user.

2.2.4 Communications overview

Overview of the external communication specification.

The system contains the following communication connections:

Wireless LAN (Windows)	Data connection to servers and the internet	Used to upgrade the system and provide remote interaction. Also provides access to MARIO from staff or carer PC for health data download.
	Provides Skype style video communication for the user.	User can connect and receive calls.
	Provides access to the internet for the user applications.	Download of news items, music, videos etc.
Wireless LAN (Linux) ***(Optional)***	Data connection to servers and the internet	Used to support remote data access for systems running on the Linux PC.
Bluetooth	Connection to the health monitor.	Health monitor periodically uploads data from the wearable monitor to the internet.
3G/4G Mobile	Mobile phone access for data and voice.	Remote communication for the User and for service functions.

Table 3: MARIO Communication channels.

2.3 Software Overview

The software within MARIO can be divided into a three layer hierarchy of packages, each package composed of components. The following section details these components and their interfaces and dependencies.

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The heart of the system is an event driven decision manager that distributes control between the applications. Underlying this event system are a number of system service functions that monitor and execute actions triggered by events.

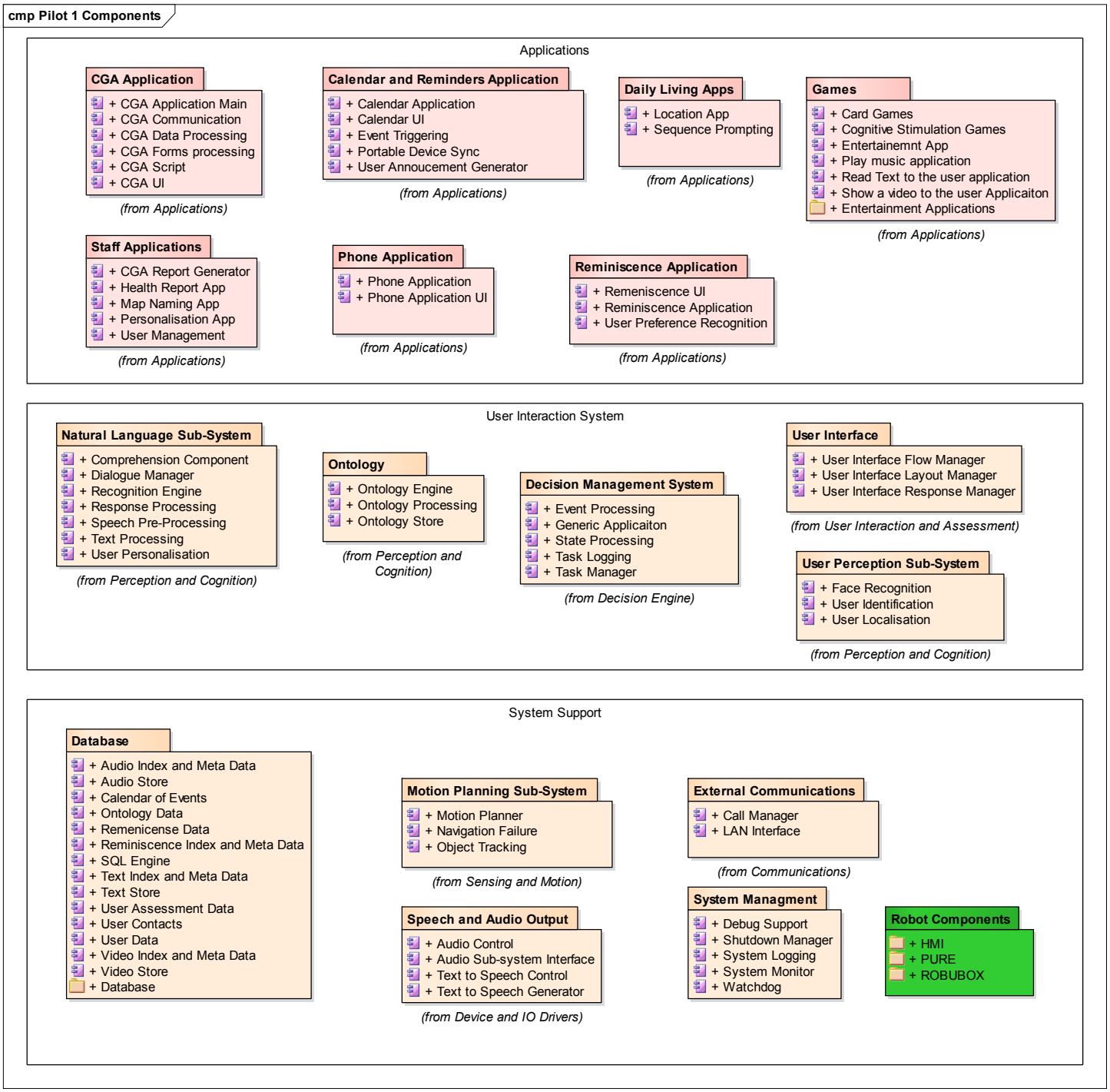

Figure 4: Pilot 1 package hierarchy

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2.4 Implementation phase plan overview

2.4.1 The UML Model

This report extracts key diagrams from the Universal Modelling Language (UML) model that has been created during the requirements analysis and architecture development process. The key technical elements of UML are used within the diagrams extracted from this model and used within this report. At this high level stage of function description and architecture design only Use Case and Component diagrams have been used. At the next stage Object and Sequence diagrams will be used to define data, object and execution flows between the major components in the system so as to pre-empt the integration process.

2.4.1.1 UML element descriptions

The following UML element descriptions are edited from the OMG UML specification (UML Superstructure Specification, v2.1.1). These have been paraphrased in the context of this report in order to provide some explanation of their use within the text and diagrams in the report to illustrate the functional and package architecture.

Component : *"A component represents a modular part of a system that encapsulates its contents …. A component defines its behavior in terms of provided and required interfaces. … (encompassing both their static as well as dynamic semantics)."*

Actor: *"An actor models a type of role played by an entity that interacts with the subject (e.g. by exchanging signals and data), but which is external to the subject. ... Actors may represent roles played by human users, external hardware, or other subjects. Note that an actor does not necessarily represent a specific physical entity but merely a particular facet (i.e., "role") of some entity that is relevant to the specification of its associated Use Cases. Thus, a single physical instance may play the role of several different actors and, conversely, a given actor may be played by multiple different instances."*

Use Case: *"A UseCase is a kind of behaviored classifier that represents a declaration of an offered behavior. Each Use Case specifies some behavior, possibly including variants, that the subject can perform in collaboration with one or more actors."*

Package: *"A package is a namespace for its members, and may contain other packages. Only packageable elements can be owned members of a package. By virtue of being a namespace, a package can import either individual members of other packages, or all the members of other packages. In addition a package can be merged with other packages."*

Interface: *"An interface is a kind of classifier that represents a declaration of a set of coherent public features and obligations. An interface specifies a contract; any instance of a classifier that realizes the interface must fulfill that contract."*

Node: *"…a Node .. is associated with a Deployment of an Artifact. It is also associated with a set of Elements that are deployed on it…. Nodes may have an internal structure defined in terms of parts and connectors associated with them for advanced modeling applications."*

Dependency Link: *"A dependency is a relationship that signifies that a single or a set of model elements requires other model elements for their specification or implementation. This means that the complete semantics of the depending elements is either semantically or structurally dependent on the definition of the supplier element(s)."*

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Extend Link: *"This relationship specifies that the behavior of a Use Case may be extended by the behavior of another (usually supplementary) Use Case."*

Association Link: *"An association specifies a semantic relationship that can occur between typed instances."*

2.4.2 Description of Pilot 1

This document illustrates the full system that is proposed to fulfil the requirements and details the Pilot 1 phase of development. The underlying UML model used to define the system will continue to be developed through the implementation phases of the project. This document is therefore a high level overview of the full system taken as a snapshot suitable for completion of the current deliverable. Once Pilot 1 is complete further milestone based snapshots will be derived to aid in checking functional progress and to develop functional descriptions in subsequent phases.

2.4.3 Testing overview

Description of testing (functional and compliance) at Pilot1.

As this report specifically relates to the functional implementation at Pilot 1 the testing overview will only detail the system tests that form the basic functional stage gate for technical acceptance prior to deployment in Pilot 1 trials. The details of each functional stage gate will need to be specifically related to the execution of the defined functions within the three different trial sites. For example navigation through the environment may have varying degrees of success depending on the details of the trial site. Thus stage gate acceptance may occur for one site and not another.

2.4.4 Pilot 1 Stage Gate

The following are a set of key system abilities for MARIO that it must be able to achieve before a trial can take place. These must be tested in the specific environment of the trial, for example the house or rooms of the PWD who will use MARIO. Similarly the User Interaction tests must be carried out with the PWD who will use MARIO in order to assess the communication quality and likely success of the interactions. These tests act as a Critical Stage Gate for Pilot 1.

2.4.4.1 Motion Ability

a) MARIO can navigate through the real environment without getting lost and without colliding with any objects. It can communicate its position in human terms by naming where it is. It can recognise that it has been trapped, e.g. in a room where the door is closed.

b) MARIO can locate people in the room that it is located. It can approach a standing person and verify if that is their user.

c) It can move to named locations.

d) MARIO can lead the user to a location

2.4.4.2 Interaction Ability

a) MARIO can interact in limited ways with the user. Through the touch screen or through simple voice commands.

b) The user can select by voice or touch from choices offered on the Touch Screen or spoken to the user.

c) The user can interact with various applications presented on the Touch Screen.

d) MARIO can understand and respond to a limited number of pre-defined requests from the user.

e) MARIO can prompt and remind the user of events.

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f) MARIO can greet the user and ask questions of the user based on pre-defined responses.

2.4.4.3 Cognitive Ability

a) MARIO can stop in front of a person or orient itself to a person in order to speak to them.

b) MARIO can say “Good morning Mary”, or “Good afternoon Mary” appropriately.

c) MARIO can understand when the user uses different names that relate to the same physical location.

2.4.4.4 Perception Ability

a) MARIO can detect people within a scene.

b) MARIO can recognise its location on a map and name it.

c) MARIO can recognise the user by their face if they are facing MARIO.

2.4.4.5 Configurability

a) MARIO can be configured prior to delivery by ROBOSOFT with the preferred settings for applications for the user as communicated in the Delivery Plan.

b) MARIO can be configured by Care Staff at the test site with details of the test site and of the user (e.g. place names, personal information about the user etc.).

2.4.4.6 Adaptability

a) MARIO has a limited understanding of the preferences of the user based on prior choices made by the user.

2.4.4.7 Decisional Autonomy

a) MARIO must be able make a decision about which room to visit next

b) MARIO must be able to decide to approach a user and speak to them.

c) MARIO must decide to respond to a user.

2.4.4.8 Technical Risks

Risk	Mitigation
MARIO fails to recognise spoken words or fails to understand regional accents.	MARIO can ask the user to repeat the words or can use the Touch Screen to confirm what has been requested.
Fails to recognise user’s language patterns	MARIO will ask the user to select between alternatives presented on the Touch Screen rather than rely on free form speech.
Fails to recognise location	MARIO can navigate until it recognises its location or can call for help. Failure in the Laser scanners or in the SLAM mapping and localisation processes may only be temporary and the result of abnormally low feature levels at the current location.
Fails to recognise user	MARIO can offer to carry out tasks that do not require User Identification such as playing

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	games etc.
Lack of Internet connection	MARIO will restrict its functions to those that do not require internet access. If data is to be transferred MARIO will wait until an Internet connection is available.
Lack of Mobile Phone Signal	MARIO will restrict its functions to those that do not require mobile phone access. In particular this may affect the Phone Application. MARIO will make it clear to the user that there is no signal
MARIO fails in one or more trial environments to pass the Stage Gate tests.	Trials can continue at those sites where the Stage Gate tests are complete. MARIO may be able to operate in a subset of the environment or with limitations on the functions offered (for example the location application may have to be removed).
MARIO may run out of power before being able to return to its charging location.	MARIO will signal to Care staff that it is in difficulty if its battery runs below a fixed threshold. MARIO may calculate that it cannot reach the charger (for example because of a closed door) and may choose to park itself in a safe way.

Table 4: Technical risk table

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3 Functional Description

Use Case descriptions of the functional characteristics proposed for MARIO.

3.1 Use Cases

Detail of each use case and their interconnections and dependences.

The following sections detail the main Use Case groups within MARIO and highlight the functional delivery at Pilot 1. Each Use Case characterises a specific behaviour of the system and will be implemented through the interaction of user interface, software and hardware components in the system. The full UML model details the linkage between Use Cases and Packages but these relationships are difficult to visualise meaningfully due to their inherent complexity. The full UML model also links the individual requirements detailed in Appendix A to the Use Cases and packages of components.

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3.1.1 Use Cases: Configuring MARIO

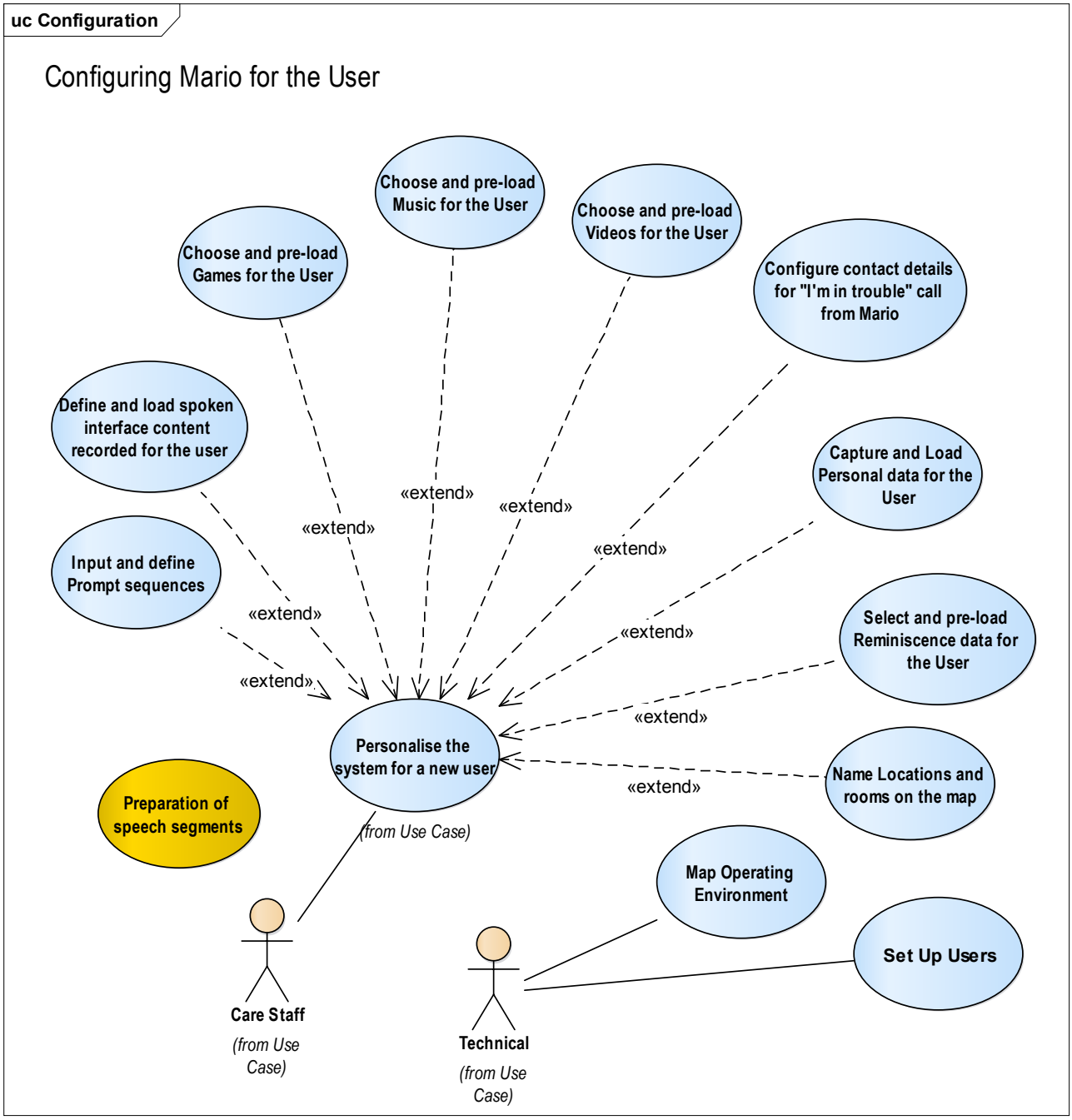

Figure 5: Configuring MARIO Use Case

The following table details the functional delivery at Pilot 1 for each component Use Case

3.1.1.1 Choose and pre-load Games for the User

Pilot 1	*Dependency*	*Responsibility*
A range of games are to be provided with MARIO.	Pre-existing Games	Robosoft
Chose a subset of games that are appropriate for the user.	User preference data	Pre-selection by Care staff Loaded by Robosoft.

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User can select and play games on MARIO screen.		Games App

3.1.1.2 Choose and pre-load Music for the User

Pilot 1	*Dependency*	*Responsibility*
Music files can be loaded, subject to copyright	Music selection appropriate to user	Robosoft
Choose music that is appropriate for the user.	Selection of music by the user or family.	Care Staff
User can select and play Music through MARIO speakers.		Music App

3.1.1.3 Choose and pre-load Videos for the User

Pilot 1	*Dependency*	*Responsibility*
Videos can be loaded for the User to watch, subject to copyright.	Selection of videos that can be used.	Robosoft
Chose videos that are appropriate for the user.	Selection of videos by the user or family.	Care staff
User can select and show videos on MARIO screen.		Video App

These may be personal videos or DVDs or TV programmes the user selects that are then loaded onto the system for the user to watch.

3.1.1.4 Configure contact details for "I'm in trouble" call from MARIO

Pilot 1	*Dependency*	*Responsibility*
MARIO can call a help line or send an SMS message or email when it is stuck.	Defined number to call, and an account/phone to email or text. Recipient of audio call must be aware that this is an automatic call.	Care Staff
Predefined phrase spoken over audio communication channel	Defined or recorded phrase	Deployment process
Configure Text message to be sent to Mobile Phone, or emailed.	Defined number or email to use.	Care Staff

3.1.1.5 Capture and load personal data for the user

Personal data allows the User Interface to become more personable and friendly. Such data as the user's name, birthday and data about friends and family including contact details can all be used to configure the system.

Pilot 1	*Dependency*	*Responsibility*

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Capture data for the User	Identification of data needed within the User Interface	Care Staff, UI Design
Provision of Staff interface to load and edit data.	Staff identification	Care Staff, Staff App
Loading and editing of User Data.	Staff App	Care Staff

3.1.1.6 Define and load spoken interface content recorded for the user

These audio files are speech fragments used in user communication. They are different from the entertainment audio files.

Pilot 1	*Dependency*	*Responsibility*
Load audio files for the user	Capture of audio files and meta data	Deployment process
Recorded in advance and read by family and friends or other people familiar to the user	Phrase set for recording	Care Staff

3.1.1.7 Input and define Prompt sequences

The prompt sequences used by each person will be different and the tasks that need prompting will be different for each user.

Pilot 1	*Dependency*	*Responsibility*
Selection and construction of sets of daily living task prompts for each user.	Identification of User needs	Care Staff
Load prompt sequences into MARIO.	Prompt sequence setting App	Care Staff
User can choose a daily task for prompting		Daily Living App
User can sequence a set of prompts for a daily task		Sequence App

3.1.1.8 Name Locations and rooms on the map

Once MARIO has generated its map of the operating environment, it is necessary to name regions and places on the map so that these can be referred to by name for navigation and location identification.

Pilot 1	*Dependency*	*Responsibility*
Identify room names and location names with user	Knowledge of operating environment Naming conventions. Knowledge of multiple names for a place.	Care staff

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Load names into MARIO	Place naming App	Robosoft
	Ontology mapping for place names	Ontology System

3.1.1.9 Preparation of speech segments

Within the user interface there is an option to utilise spoken text segments rather than text to speech conversion to generate speech. It is known that PWD sometimes respond more positively to familiar voices, those of friends or family and so for some parts of the user interface it may be appropriate to make use of this using re-recorded segments.

Pilot 1	*Dependency*	*Responsibility*
Identification of required speech segments	UI Design has highlighted where this can be used.	Care Staff
Recording of Speech Segments and provision of meta data.	Identification of familiar voices for the User	Care Staff
Loading of Speech segments.		Robosoft

3.1.1.10 Select and pre-load Reminiscence data for the User

Some success in stimulating communications with PWD has been achieved by using photographs or recordings taken either from their own personal history or from local or national archives. For example images of cultural, sporting or political events or personal family events such as birthday parties or weddings. The system supports both specific and generic “reminiscence” data of this kind but it needs to be curated and stored in the system prior to use.

Pilot 1	*Dependency*	*Responsibility*
Select reminiscence data from sources personal to the user	Knowledge of user preferences	Care Staff
Generate generic reminiscence data for age and place.	Generation of generic parameters for selection. (Culture, Sport, News etc.)	Deployment process

3.1.1.11 Map Operating Environment

Pilot 1	*Dependency*	*Responsibility*
Prior to use the operating environment must be cleared and MARIO allowed to move round the environment in order to map it.	Access to clear environment with no people and only static objects.	Deployment

One limitation in MARIO is that if this map data becomes out of date as a result of the movement of furniture or other semi-permanent structures then this process will need to be repeated as MARIO cannot adjust or reconfigure its map over time as the environment changes.

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3.1.1.12 Set up users

Pilot 1	*Dependency*	*Responsibility*
The different users must be set up on the system for example by association of RFID tags to roles, and through the recording of faces.	User ID mechanism.	Deployment

In particular the PWD user must be identifiable to the system and care staff who have access to medical data must be specifically identified.

3.1.2 Use Case: Entertaining the User

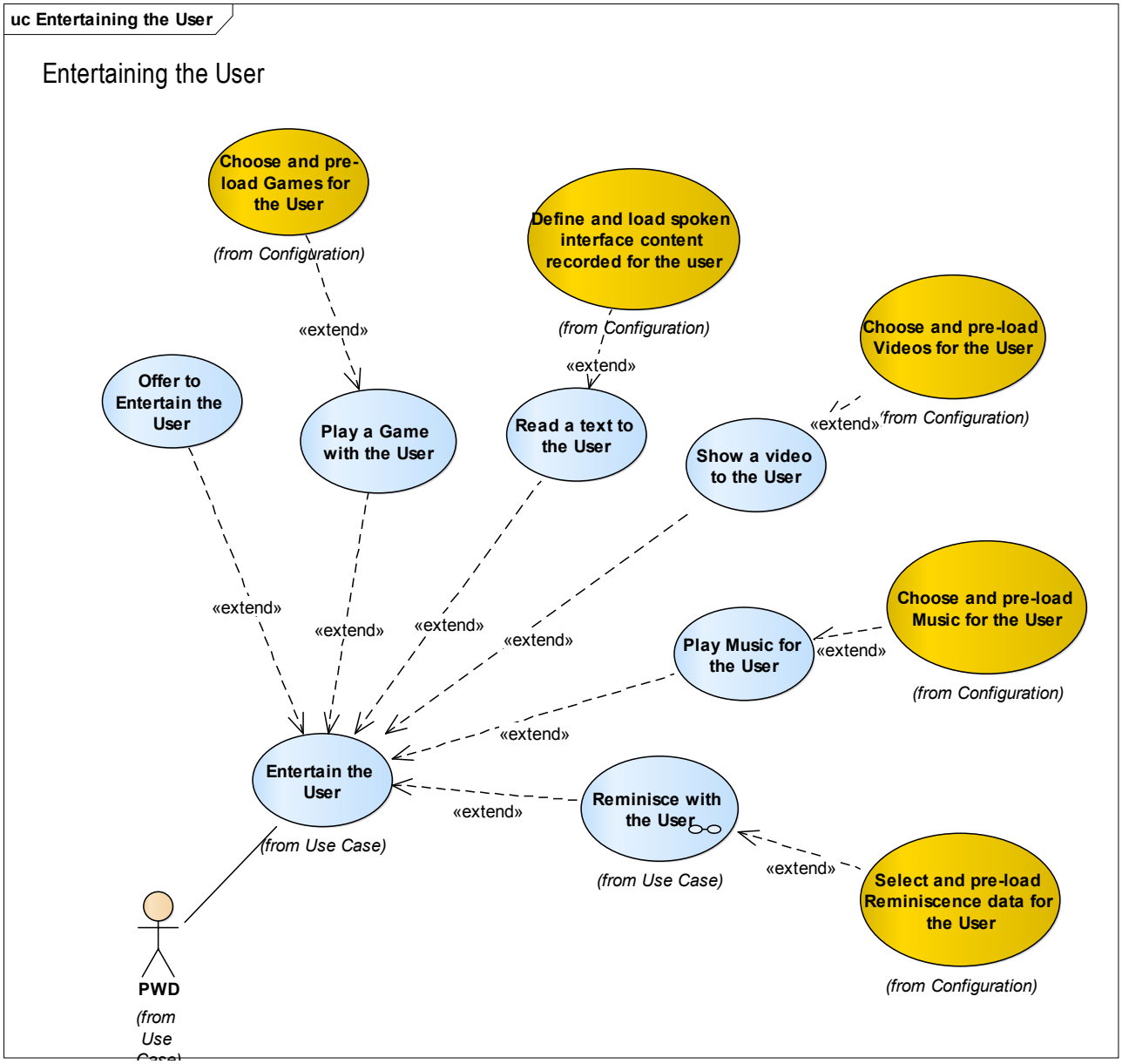

Figure 6:Entertain the User Use Cases

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3.1.2.1 Offer to Entertain the User

Pilot 1	*Dependency*	*Responsibility*
Limited prompting of user	Ability to detect socially appropriate moments to offer to entertain the user.	Social Awareness implementation
MARIO activation of appropriate Application.	Use interaction to select activity	Implementation

Simple solution to detecting the right moment to offer entertainment to the user is required. Possible to make offerings based on what the User has interacted with in the past. Such as:

- "Do you want to play a game?"
- "Do you want to see the pictures form your last birthday?"
- "Would you like to listen to some music?"

Open questions exist on the ability of MARIO to:

- Detect that user is idle
- Detect they are asleep? eyes open eyes closed?

Full solution will require detection of state of user.

3.1.2.2 Play Music for the User

Use Case is intended to reduce load on care staff and add to the independence of the user by offering a set of choices they can select from.

Pilot 1	*Dependency*	*Responsibility*
User can choose to play music.	Music has been loaded	Entertainment App
User can choose music to play	Music has been loaded	Music App
User can control the playing of music.		Music App
MARIO can stop the music if the user is no longer attending.	Able to spot the user is no longer paying attention for example by examining eye gaze.	Music App

Music may be audio files or videos flagged as music videos.

Needs to ensure copyright is OK.

3.1.2.3 Play a Game with the User

At least two games will be offered. Need to consider cognitive stimulation games in addition to entertainment games. Card games such as Sevens should be offered.

Pilot 1	*Dependency*	*Responsibility*
Games are available with a suitable UI for the user	Review of available games	Care Staff
User can choose to play a game.	Games have been loaded for the User	Entertainment App
User can select which	Games have been loaded	Game App

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game to play	for the User	
MARIO can finish the Game App if the User is no longer playing.	Able to detect that user is no longer playing the game.	Game App

3.1.2.4 Read a text to the User

Pilot 1	*Dependency*	*Responsibility*
Audio Books chosen for user		Care Staff
Audio Books loaded into system	Copyright checked	Deployment
Short texts recorded from people known to User		Care Staff
Recorded texts loaded into system.	Meta-tags applied	Deployment
User can select to hear a reading	Appropriate social context	Entertainment App
User can select which reading to hear		Entertainment App
User can control the reading		Entertainment App
MARIO can stop the reading if the user is not attending	Being able to spot the attention state of the user	Entertainment App

3.1.2.5 Show a video to the User

Pilot 1	*Dependency*	*Responsibility*
Videos selected for the user		Care Staff
Videos loaded into the system	Copyright checked Meta-tags added	Deployment
User can choose to watch a video	Appropriate social context	Entertainment App
User can select which video to watch		Entertainment App
User can control the playing of the video		Entertainment App
MARIO can stop the video if the user is no longer attending	Being able to spot the attention state of the user	Entertainment App

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3.1.3 Use Case: Assist the User

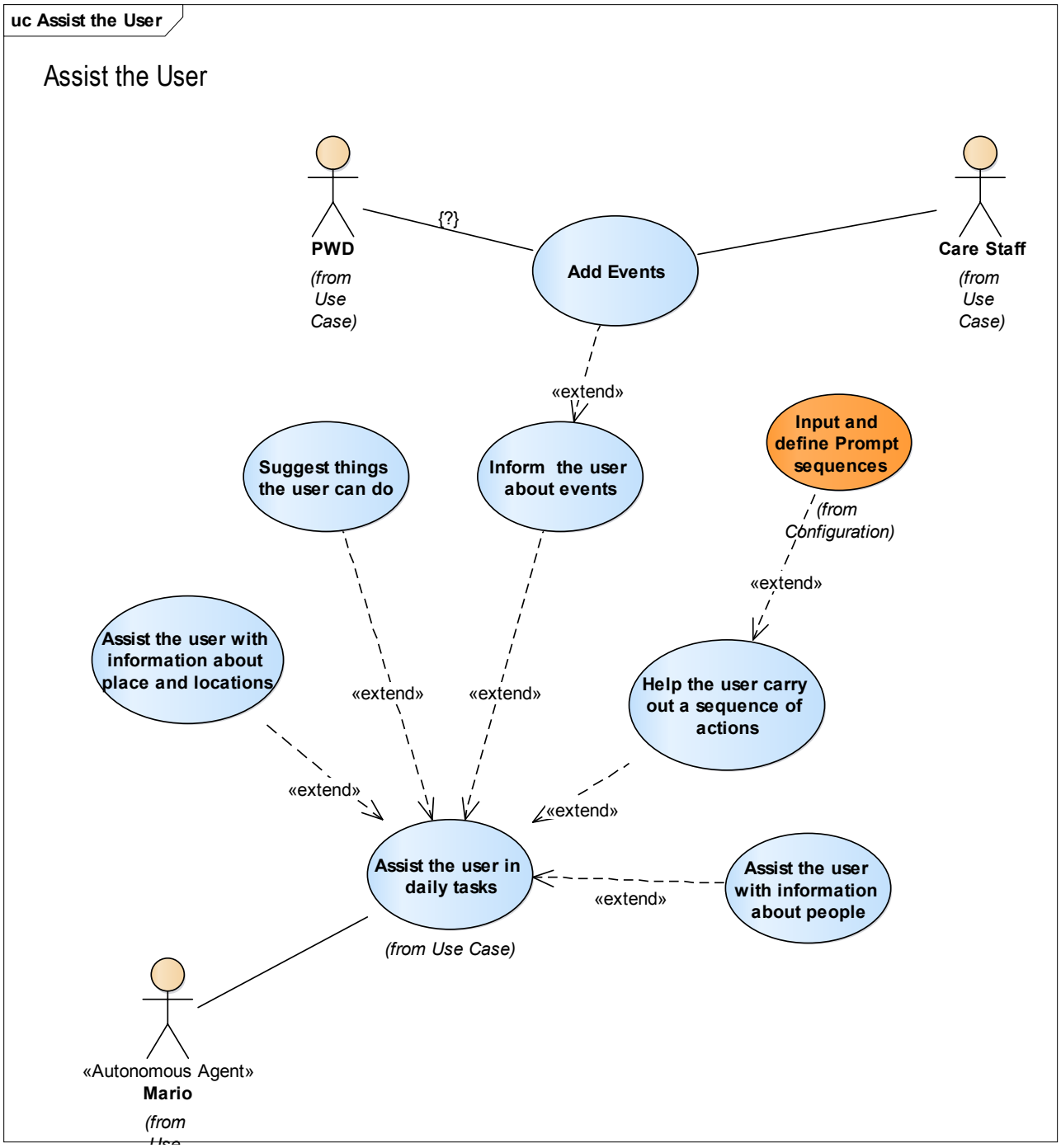

Figure 7: Assisting the User Use Cases

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3.1.3.1 Add Events

Pilot 1	*Dependency*	*Responsibility*
The Care staff can set up and add events to the calendar and the daily living schedule (e.g. meal times, bed time etc).	User's ability to respond to event prompts. Care staff identification and interface.	Calendar App
Configurable option to allow user to enter data.	Careful data scrutiny to avoid setting "wrong" events.	Calendar App

Care also needed in the design of the User based UI to avoid false entries and incomplete entries.

3.1.3.2 Assist the user with information about people

Pilot 1	*Dependency*	*Responsibility*
Can answer two simple questions of the form: • "Who am I?" • "Who are you?" (Addressed to MARIO)	Speech recognition and comprehension quality	Monitor the User App

Later stage intention is to be able to answer questions about the following:

- Who is in the room (Person-place questions)
- Who has the user seen or communicated with recently (Person-time questions)

3.1.3.3 Assist the user with information about place and locations

Pilot 1	*Dependency*	*Responsibility*
Care Staff can enter point of interest (PoI): names for places and regions on the internal map captured by MARIO. Then the robot will be able to reach any PoI using its autonomous navigation capabilities.	Care Staff interface with access to map naming application. Map generation during installation.	Robosoft/Implementation
Can answer two simple questions of the form: • "Where am I?" • "Take me to the *<named location>*"	Ontology to map location names the user uses to names tagged on the map. Ontology needed to assess if MARIO needs to move to the named location or simply direct the user.	Monitor the User App and Location App
Will lead the user to the named location.		Location App

There will need to be a re-mapping process when the user's environment changes as it is impossible to accumulate new information into an existing map

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3.1.3.4 Help the user carry out a sequence of actions

Pilot 1	*Dependency*	*Responsibility*
Pre-defined sequences established for each user	Definition and capture of suitable sequence steps, will involve speech and text.	Care Staff
User can select a particular stored sequence to use.	Sequences loaded	Sequence App
User can progress through sequence via interaction with MARIO. Can go back or repeat last step	Ability to recognise and interact around responses	Sequence App

Future

Eventually care staff will be able to use a generic script based mechanism to allow them to compose and up-load sequences that might be relevant for each user, and to edit existing ones.

3.1.3.5 Inform the user about events

Pilot 1	*Dependency*	*Responsibility*
Events stored in the diary are triggered and displayed to the user. MARIO will attempt to find the user to ensure the reminder is delivered appropriately.	MARIO can find and approach the user.	Calendar App
MARIO must construct a reminder text and speech based on the event type	Suitable meta-data stored with event.	Calendar App and Ontology Engine
MARIO may remember events to remind the user when the user is found.		Calendar App

3.1.3.6 Suggest things the user can do

Pilot 1	*Dependency*	*Responsibility*
Pre-loaded daily events.	Identification of events relevant to the user.	Care Staff
MARIO will prompt the user at specific times of the day about things they should do.		Calendar App

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3.1.4 Use Case: Locate the User

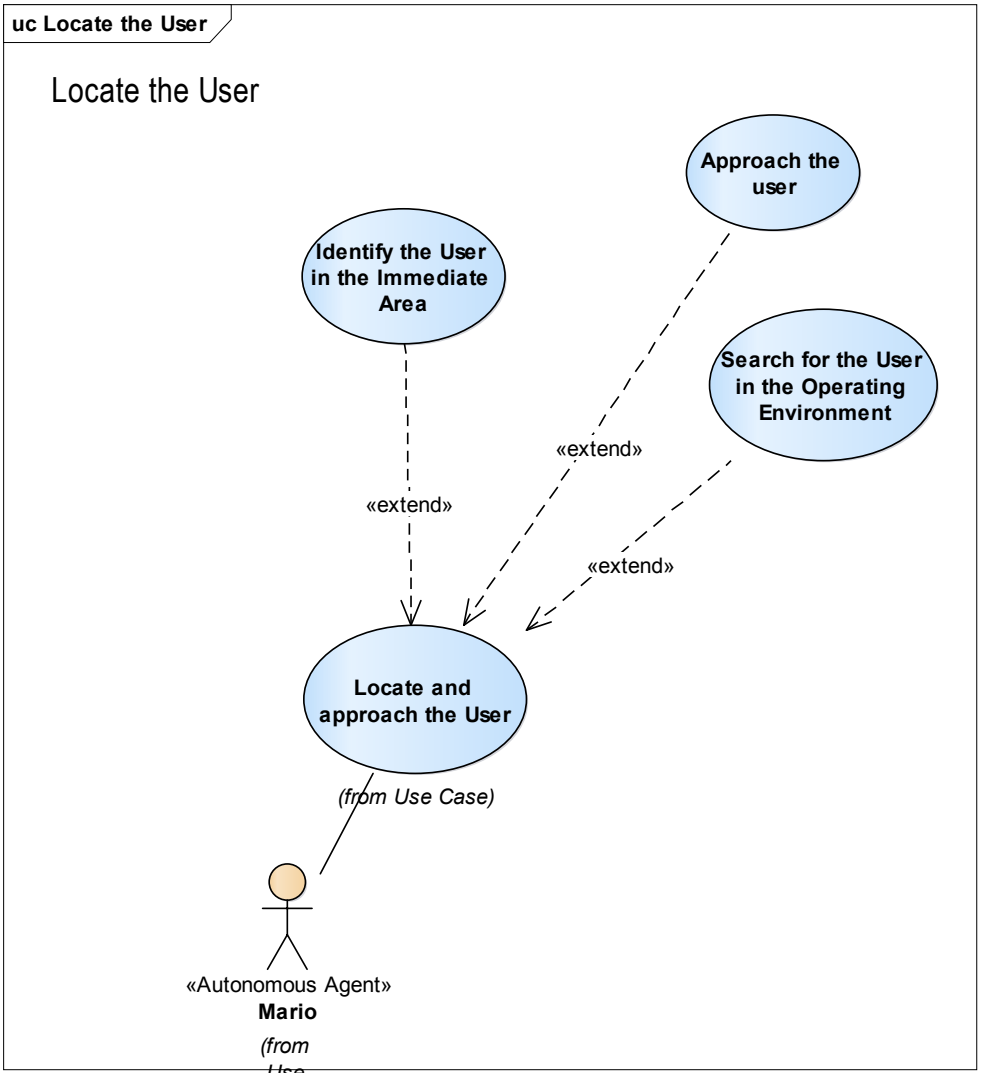

Figure 8: Locating the User Use Cases

3.1.4.1 Approach the user

Pilot 1	*Dependency*	*Responsibility*
MARIO can approach a standing person		**Robosoft** for navigation and **CNR** for the algorithm to approach the person

3.1.4.2 Identify the User in the Immediate Area

Pilot 1	*Dependency*	*Responsibility*
Identify single User via short range RFID tag, via health monitor sync, via face recognition.	User is wearing RFID tag, User is wearing health monitor	Monitor the User App

Issues

There are a series of open issues in terms of user identification:

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Face recognition may work with front views only.

Voice identification is not seen to be viable given the potential for background noise.

RFID tags are expected to be unreliable in the long term because the user will not always wear them.

It may be possible to identify staff based on QR badge codes. But this requires not only technical investigation but also processes at each test site that may make it impractical to implement, particularly in the home and hospital settings where a wider range of staff interact with the user.

3.1.4.3 Search for the User in the Operating Environment

Pilot 1	*Dependency*	*Responsibility*
Can scan current room to locate a person standing.		Locate User App

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3.1.5 Use Case: Monitoring the User

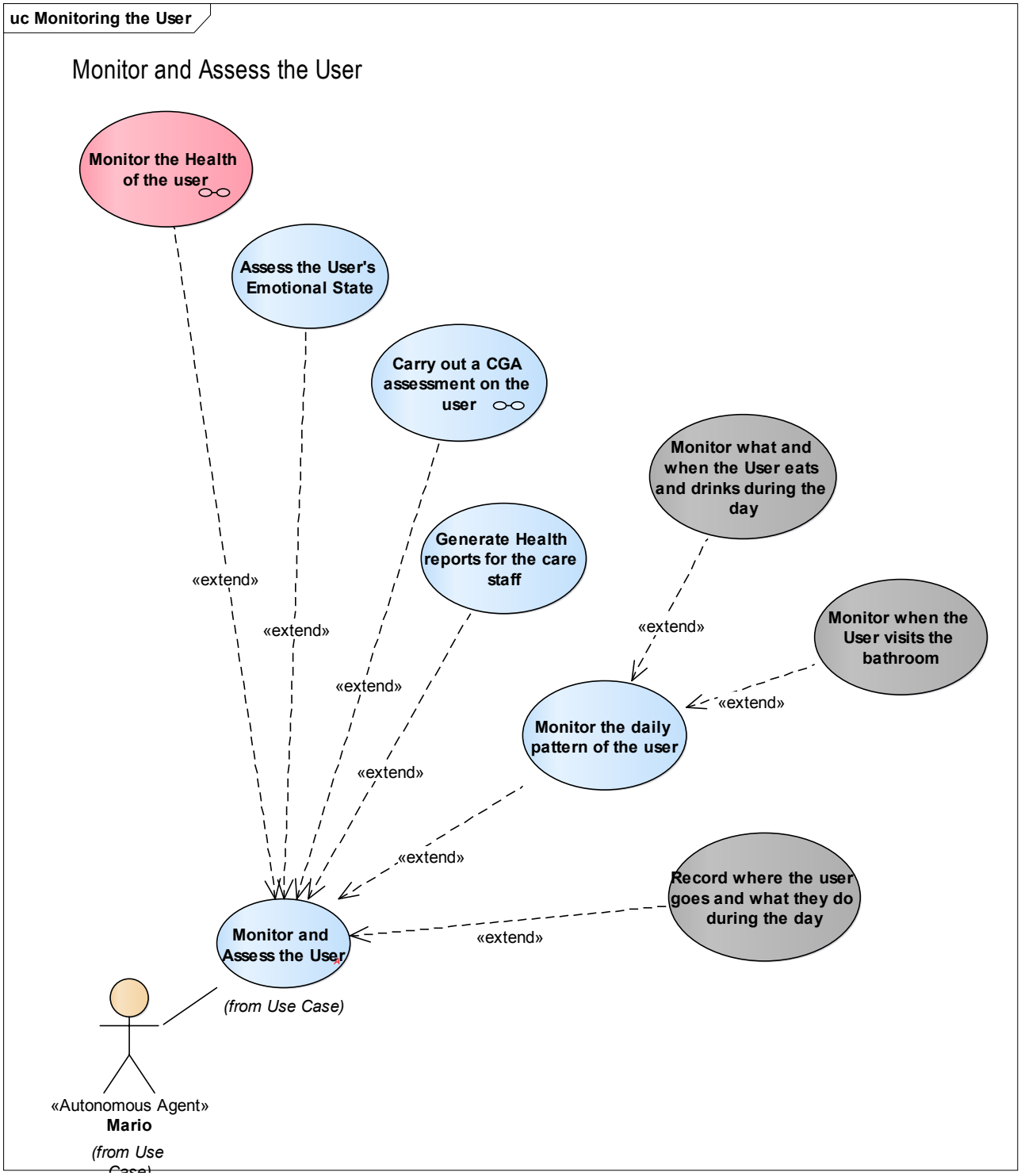

Figure 9: Overview of Monitoring the User Use Cases

The Use Cases for monitoring the user are shown in Figure 8 the Use Cases for carrying out the CGA assessment, which is a key part of the MARIO function is shown separately in Figure 9.

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3.1.6 Use Case: CGA and MPI assessment

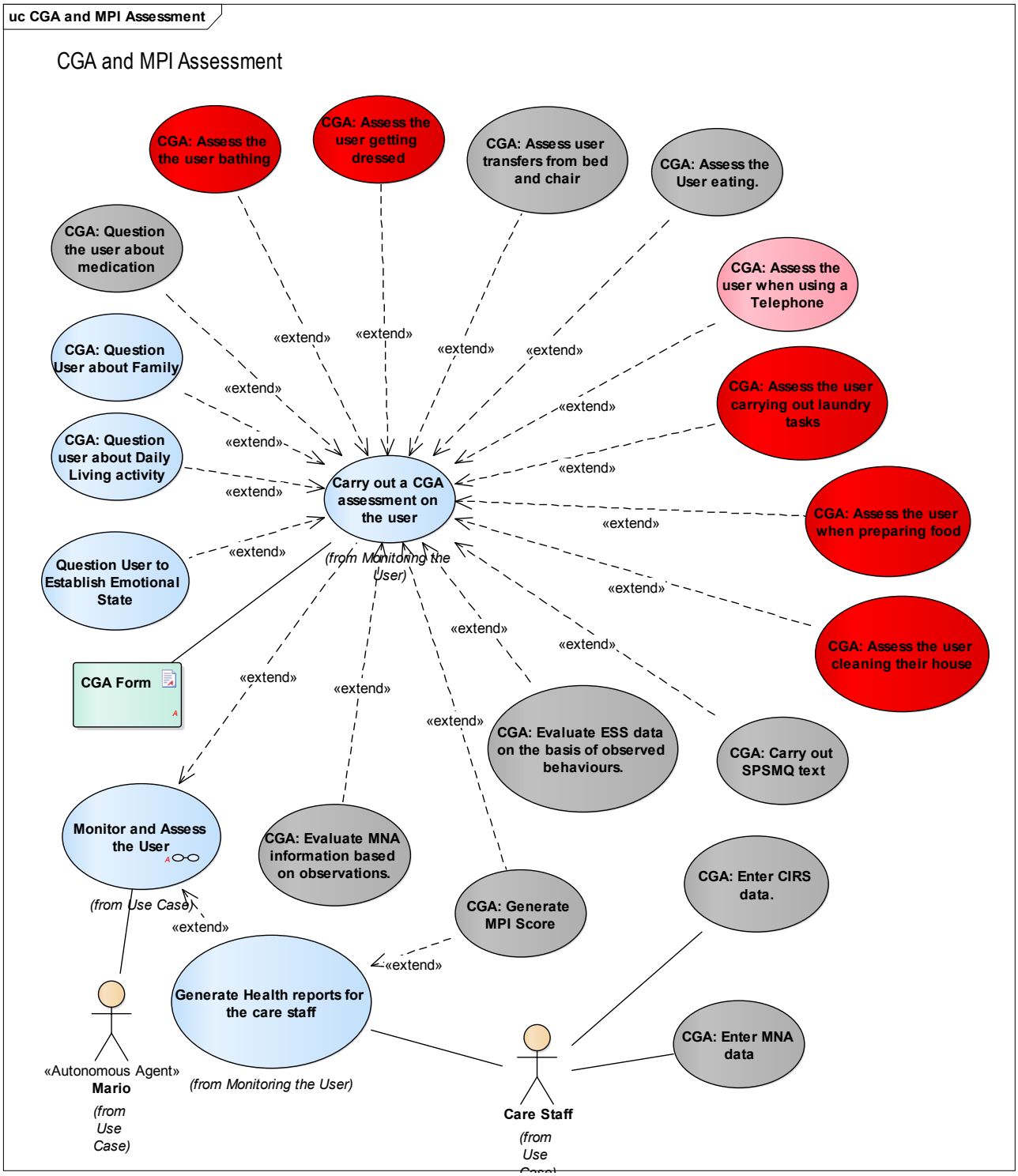

Figure 10: CGA and MPI Assessment Use Cases

3.1.6.1 CGA: Assess the user when using a Telephone

Pilot 1	*Dependency*	*Responsibility*
Limited monitoring based on usage of the Phone App	Usage monitoring in Phone App.	Phone App
Questions asked as part of CGA assessment	Definition of questions	CGA Staff

3.1.6.2 CGA: Question User about Family

Pilot 1	*Dependency*	*Responsibility*
Questions asked as part of CGA assessment	Definition of questions	CGA Staff

3.1.6.3 CGA: Question user about Daily Living activity

Pilot 1	*Dependency*	*Responsibility*
Questions asked as part of CGA assessment	Definition of questions	CGA Staff

3.1.6.4 Question User to Establish Emotional State

Pilot 1	*Dependency*	*Responsibility*
Questions asked as part of CGA assessment	Definition of questions	CGA Staff

3.1.6.5 Carry out a CGA assessment on the user

Pilot 1	*Dependency*	*Responsibility*
Work through the CGA forms with a user after having verified their RFID tag	User is wearing an RFID tag. Need to be sure the user is answering the questions not someone else.	CGA App

CGA assessments will be carried out at times that depend on the trial site.

- At admission and discharge from hospital
- At admission to Care home
- At beginning and end of Pilot 1

However it needs to be clear that the user is attending to the questions and that the user identity is validated. RFID tags will be used to validate the user.

3.1.6.6 Generate Health reports for the care staff

Pilot 1	*Dependency*	*Responsibility*
Identify Care Staff member to give access to Health Report App.	Care Staff registration and access control	Care Manager

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Generate report for user	Mechanism to deliver report	Staff App
Deliver report to Care Staff member.		

Report generated based on non-interpreted data from sensors.

Together with raw responses from CGA assessments where the user identity has been validated. Reports will not attempt to collate or analyse any data.

Reports are generated by request from validated staff.

Requirement

CGA question responses are only valid if the User has an RFID tag that has been detected at the time of questioning.

Issue

There are a number of open questions:

- How are staff validated?
- How are reports communicated?
- How is data on the user kept secure?

3.1.6.7 Monitor the Health of the user

Pilot 1	*Dependency*	*Responsibility*
Data gathered from Web interface of Health Monitor	Connectivity to Web	Monitor the User App
Data included in Health Report	Connectivity to Web	Staff App

The user will need to wear a health monitor. This will sync data every few minutes with the internet via a Bluetooth connection.

3.1.6.8 Monitor the daily pattern of the user

Pilot 1: This will not go beyond the basic recording of known locations of the user through the day.

3.1.6.9 Record where the user goes and what they do during the day

Pilot 1: This will be limited to what can be recorded by MARIO when the user is identified and MARIO can supply a location where the user is. This may simply be the room in which MARIO is rather than an assessment of where the user is. It may be possible to provide posture info in addition to location.

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3.1.7 Use Case: Reminisce with the User

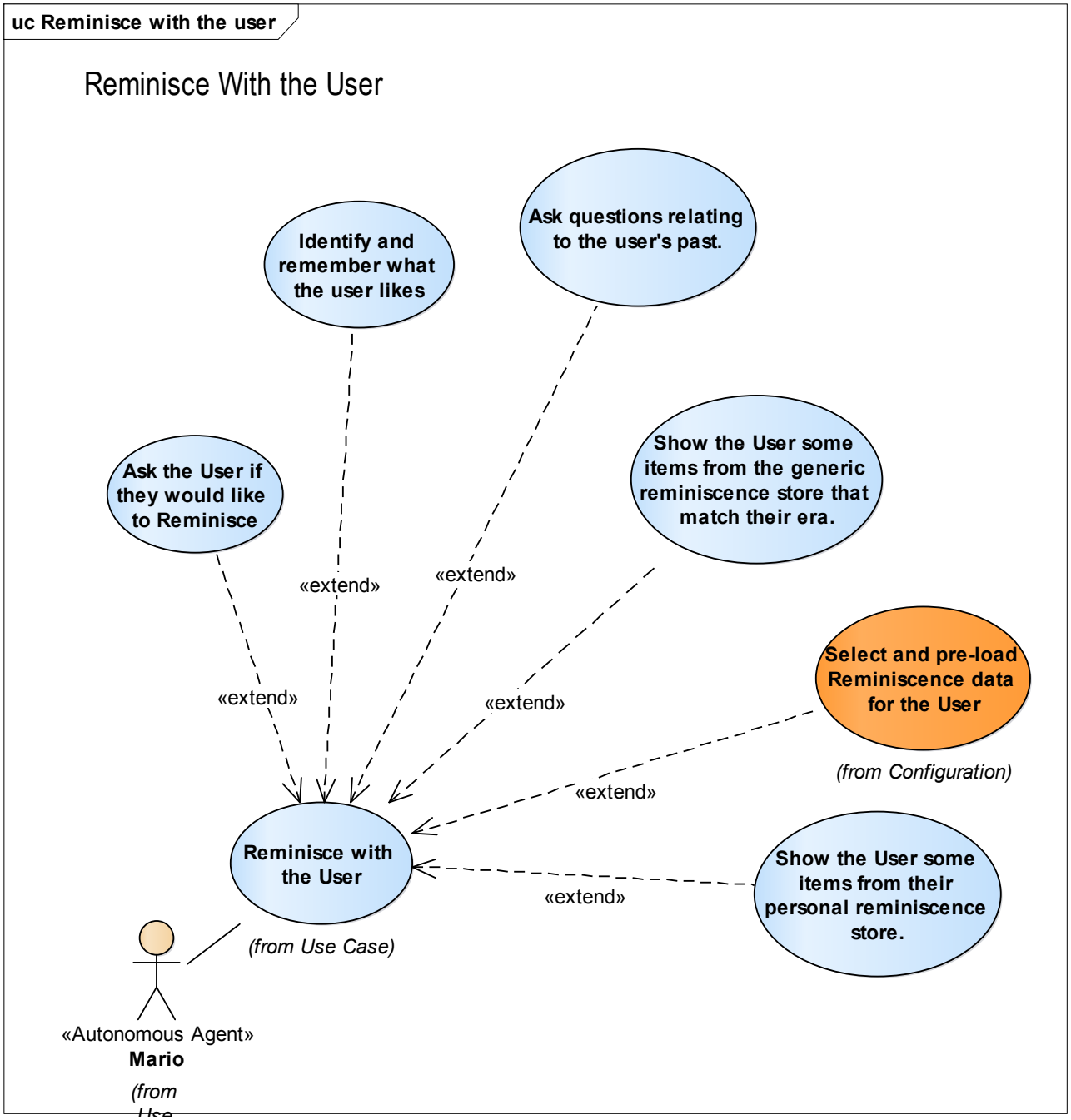

Figure 11: Reminisce with the user Use Cases

3.1.7.1 Ask questions relating to the user's past.

Pilot 1	*Dependency*	*Responsibility*
Establish the range of era's that relate to the User	Pre-loaded generic or personal material	Care Staff

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Script developed for each user		Care Staff
Script loaded into system		Reminiscence App
Offer question in script to user and respond	Ability to determine user response	Reminiscence App

3.1.7.2 Ask the User if they would like to Reminisce

Pilot 1	*Dependency*	*Responsibility*
Identify socially appropriate time and if the User has not interacted but is awake	Correct assessment of social context and user state	Reminiscence App
Trigger request to User		Reminiscence App

3.1.7.3 Identify and remember what the user likes

Pilot 1	*Dependency*	*Responsibility*
Record user preferences during use of reminiscence app.	Material has suitable meta tags	Reminiscence App
Record user preferences for Entertainment	Material has suitable meta tags	Entertainment App

3.1.7.4 Show the User some items from the generic reminiscence store that match their era.

Pilot 1	*Dependency*	*Responsibility*
Preloaded with a sample number of photos of people and events.	Images collected for suitable eras in different categories.	Care Staff/Robosoft
Display photos based on user preference	Images have suitable meta-tags	Reminiscence App

3.1.7.5 Show the User some items from their personal reminiscence store.

Pilot 1	*Dependency*	*Responsibility*
Preloaded with a sample number of photos of people and events.	Images collected from User or Friends and Family	Care Staff
Display photos based on user preference	Images have suitable meta-tags	Reminiscence App

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3.1.8 Use Case: Speak to the User

These Use Cases reflect all the circumstances when MARIO will speak to the user without the user triggering the interaction. This is therefore a sub-set of all possible use cases where MARIO will speak to the user.

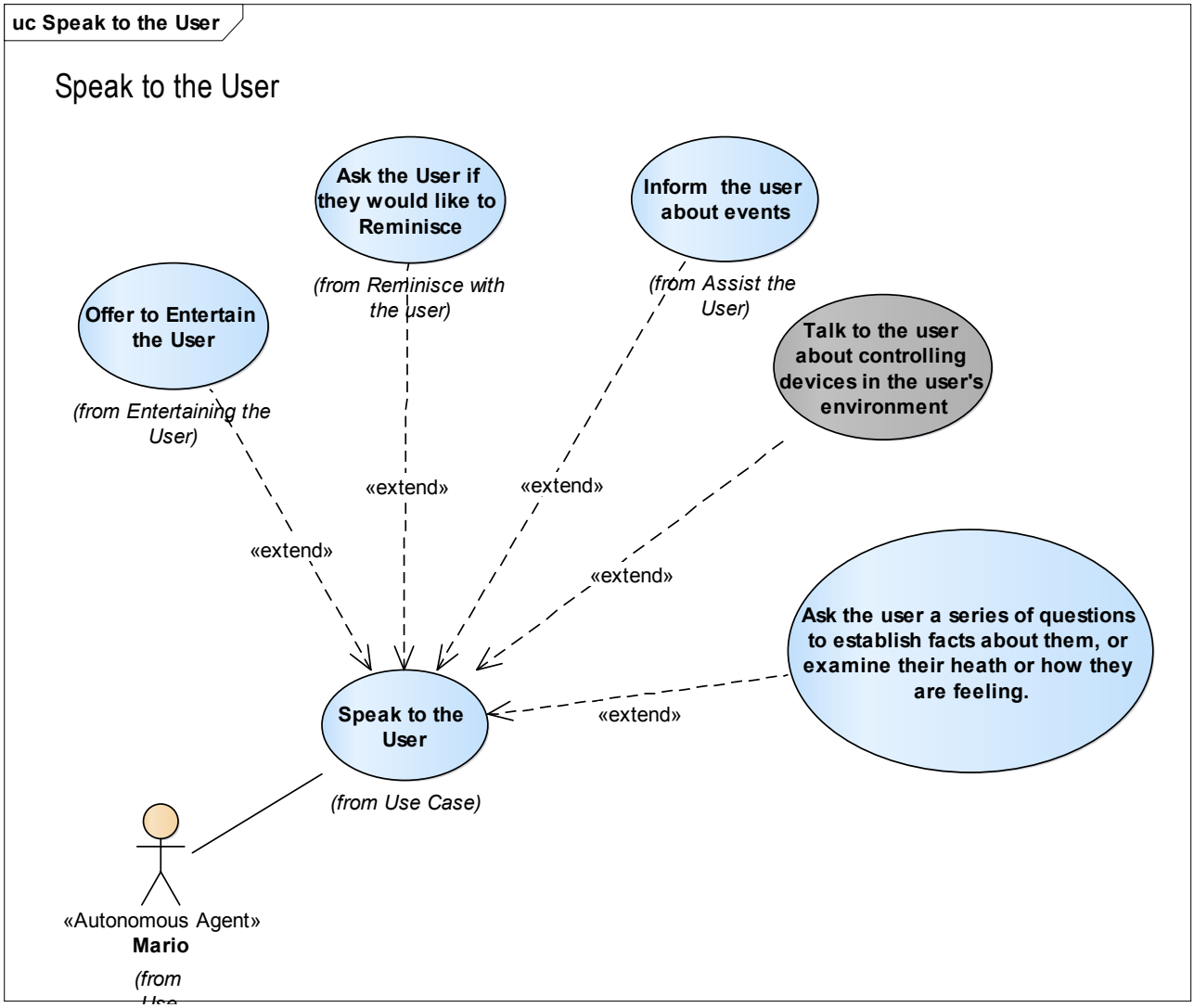

Figure 12: Speak to the User Use Cases

3.1.8.1 Ask the user a series of questions to establish facts about them, or examine their heath or how they are feeling.

Pilot 1	*Dependency*	*Responsibility*
Part of CGA Assessment process.	Questions Defined	CGA preparation
Definition of questions		Care Staff
Capture pre-recorded questions.		Care Staff
Ask user questions and record answers (audio answers as well as UI input)	Defined sets of answers, ability to usefully record user speech.	CGA App

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3.1.9 Use Case: User Communication

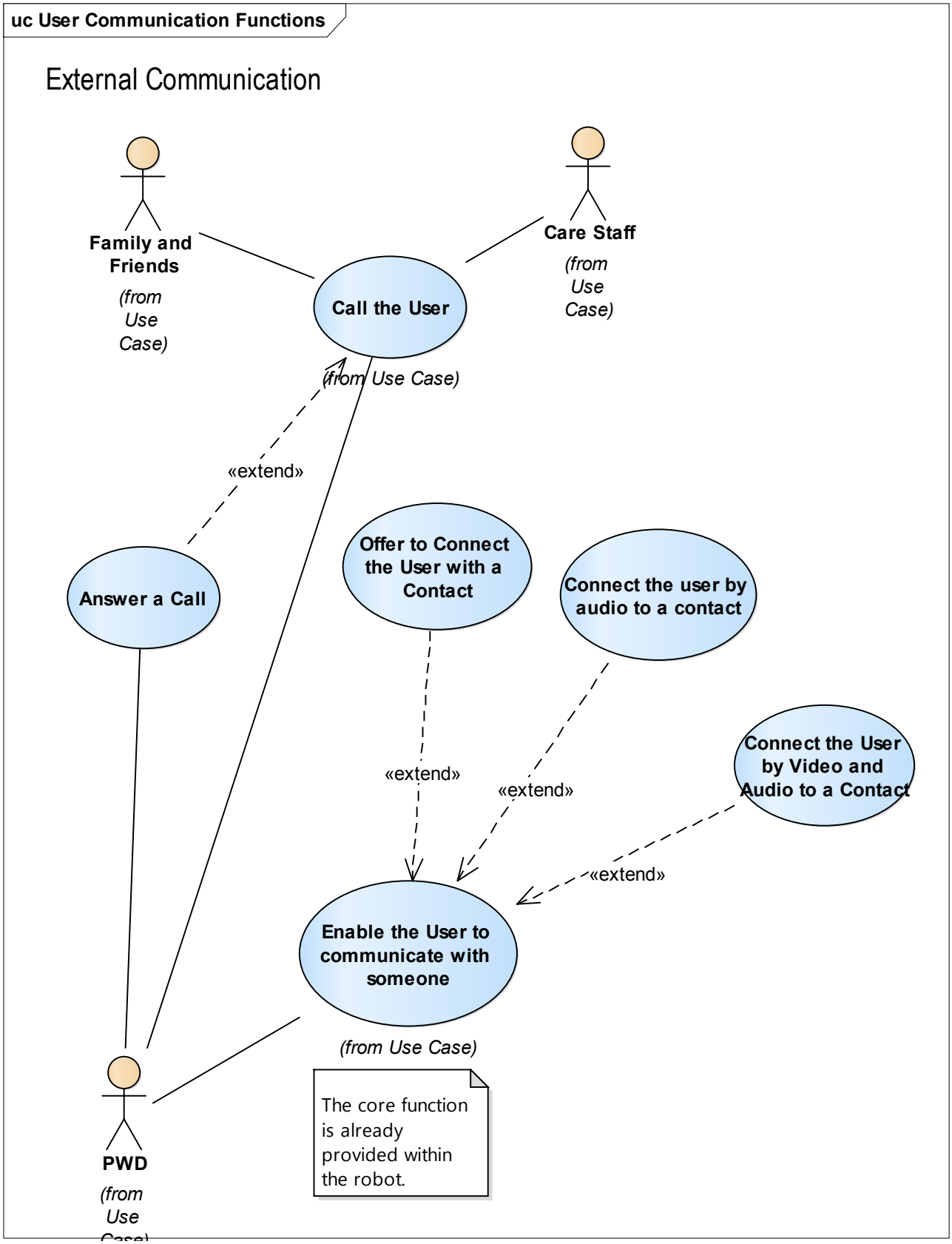

Figure 13: External Communication Use Cases

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3.1.9.1 Answer a Call

Pilot 1	*Dependency*	*Responsibility*
Incoming call presented to User		Phone App

3.1.9.2 Connect the User by Video and Audio to a Contact

Pilot 1	*Dependency*	*Responsibility*
Establish who the User wishes to call.	Contact database of people	Phone App
Set up and manage call.	Availability of connection	Underlying System
Monitor call duration and assess usage.		Phone App

3.1.9.3 Connect the user by audio to a contact

Pilot 1	*Dependency*	*Responsibility*
Establish who the User wishes to call.	Contact database of people	Phone App
Set up and manage call.	Availability of connection	Underlying System
Monitor call duration and assess usage.		Phone App

3.1.9.4 Offer to Connect the User with a Contact

Pilot 1	*Dependency*	*Responsibility*
Identify socially appropriate time and if the User has not interacted but is awake	Correct assessment of social context and user state	Phone App
Set up who can be called by offering to connect		Care Staff
Trigger request to User to see if they would like to call someone.		Phone App

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4 Functional Architecture

Details of functional architecture showing all software packages and their interdependence. Functional descriptions of each package and their dependence on hardware. Package ownership and capability against each implementation phase. Link to requirements.

The following sections detail the functional architecture of the MARIO system. They detail the high level component clusters and the function of each component to be implemented in Pilot 1.

Major interfaces between components are also detailed. Typically these major interfaces are defined where there is either a significant integration effort, or where a “public” interface is defined between different consumers and producers of information. For example, between the support systems and the applications.

The diagrams also show the relationship between the executable packages and the relevant execution environment. However for graphical simplicity only the Windows environment and the Pure execution environments are shown. Any package shown outside of these two execution environments can be assumed to be in the domain of the Linux Application processor.

For completeness these diagrams also show future components illustrated in grey to indicate the expected evolution of the system beyond Pilot 1. However until Pilot 1 integration and trial is complete the exact design and allocation of these components cannot be defined.

The diagrams use a simple colour key to indicate the status of components:

Not implemented in Pilot 1 (Future component

Core component delivered as part of the robot platform

Component to be implemented at Pilot 1

Generic component representing multiple similar components.

The simple dashed arrows used in the component diagrams indicate a dependency between components.

4.1 Package architecture.

Complete set of package diagrams and functional descriptions.

The system components are divided into a number of high level package clusters which define the major functional elements in the system. Each of these is detailed in the following sections. Within each section the key packages that make up the cluster that will be implemented in Pilot 1 are detailed.

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4.1.1 Components: Decision Management

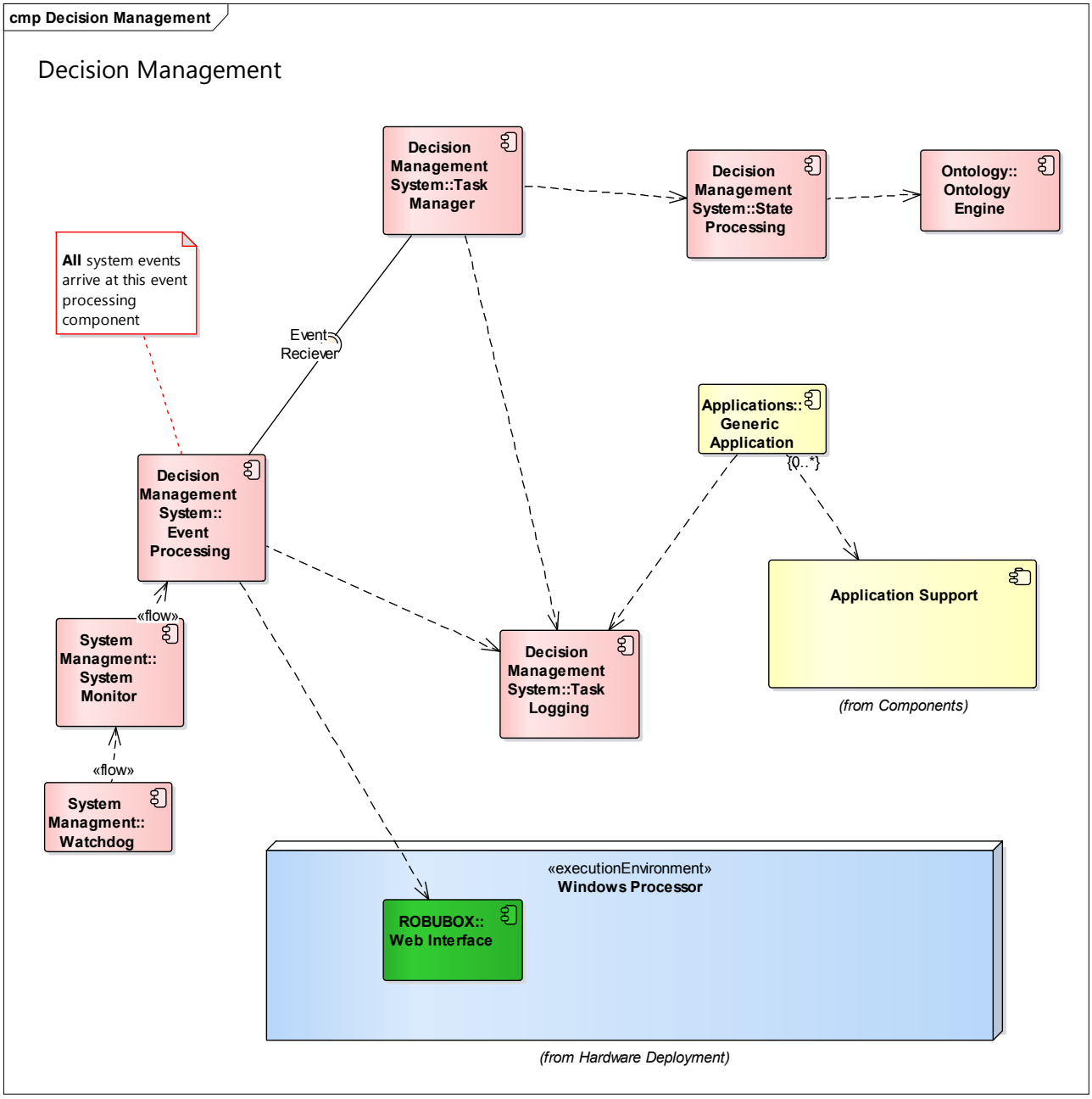

Figure 14: Decision Management Components (Dependencies)

4.1.1.1 Event Processing

The event processor receives all events from within the system. It prioritises them and dispatches them to the task manager for onward transmission to the applications. It does not attempt to interpret the content of any event. It is responsible for queueing events, advancing priority events, removing events that are handled and recording and removing events that are un-handled. The main function of the Event Processor is to isolate the Task Manager from the various and dynamic sources of events within the system.

4.1.1.2 State Processing

The state processor maintains the current state of the system and decides how that state should change depending on events it receives and on other factors such as the social context and the

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actions of the user. It can seek context from the Ontology Engine via a defined interface, and it sends tasking commands to the Task Manager.

4.1.1.3 Task Logging

The task logger takes logging events from any registered element and stores the logging data onto permanent storage. Flushes buffers regularly so that data history is maintained. It also provides an access mechanism to read logs and filter output this can be used to generate a debug tracker output.

4.1.1.4 Task Manager

The Task Manager coordinates the running of the applications and receives events one at a time from the Event Manager. It passes out Events to the Applications and isolates the Event Manager from knowing about the various an dynamic array of applications that are running. It also passes context to the Applications from the Ontology Engine based on requests or triggers from the Ontology Engine.

4.1.1.5 Web Interface

The interface provided to the Task Manager produces events that relate to the ROBUBOX (Detailed below) system that controls the platform motion and sensing systems.

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ROBUBOX

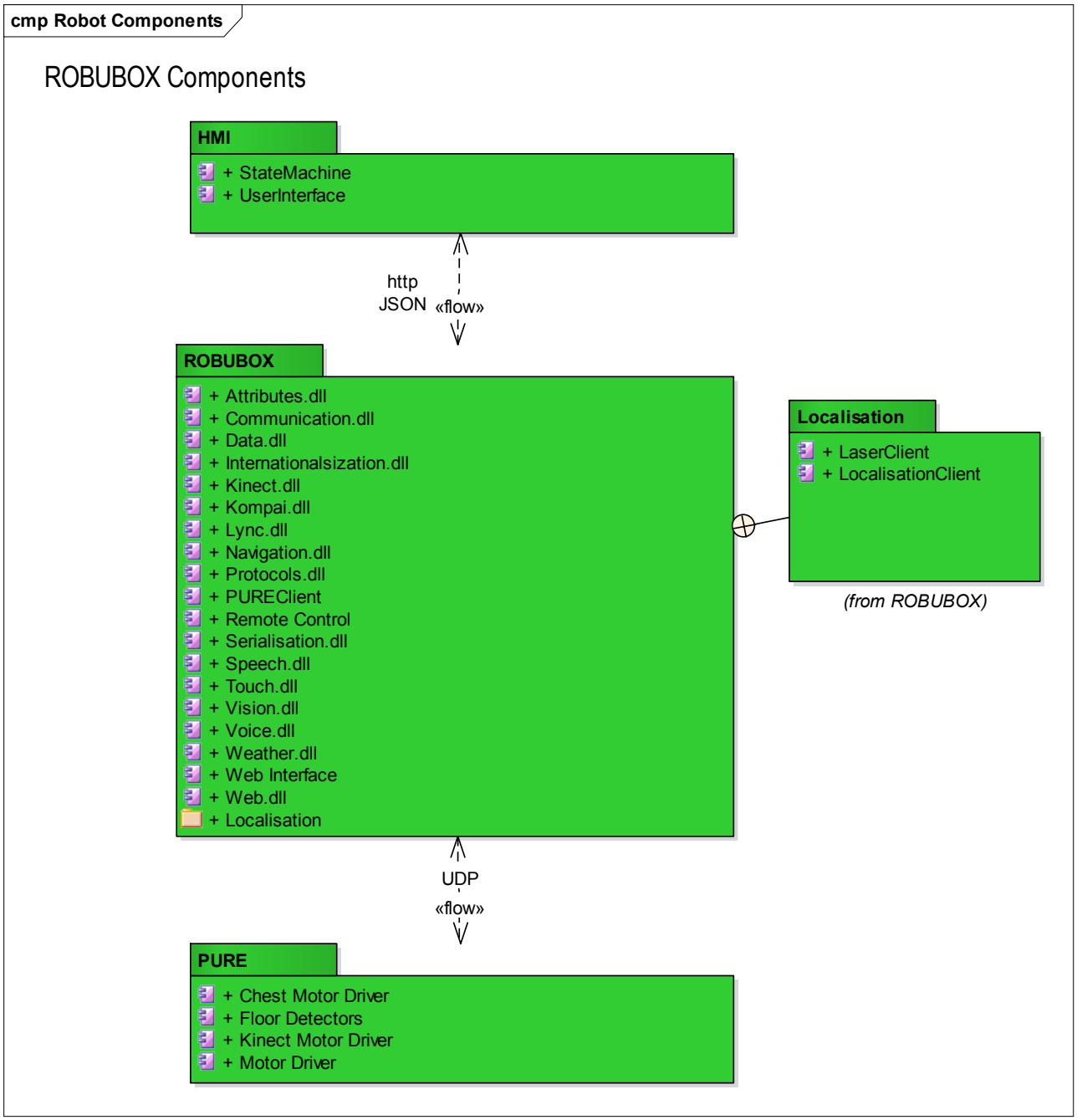

Figure 15: ROBUBOX components

ROBUBOX is the set of standard applications and libraries that ROBOSOFT ships with its products. These are included in the MARIO platform and handle all of the sensing, motion, localisation and navigation functions of the platform. ROBUBOX executes within the Windows execution environment.

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Decision Management Interfaces

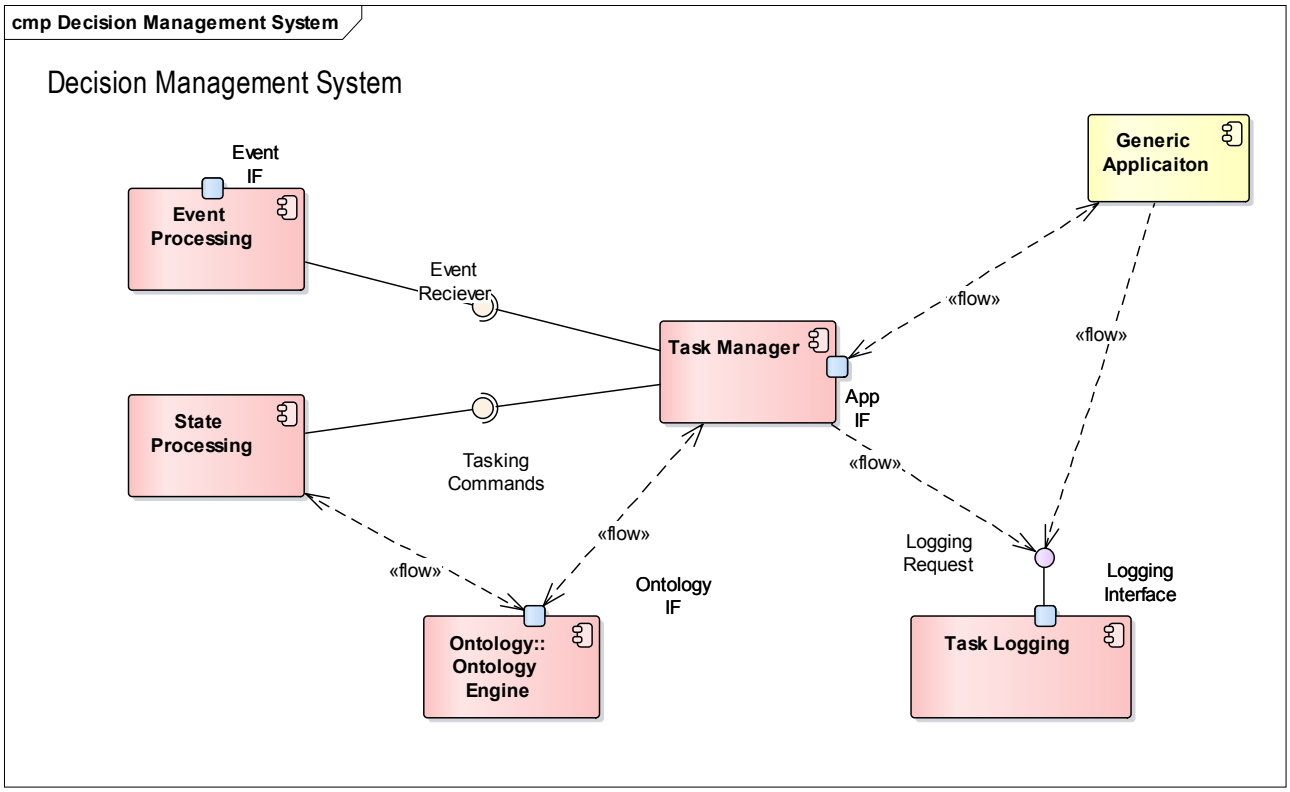

Figure 16: Decision management interfaces

Logging IF	***Parameters***	***Result***
Request connection to Logger.	Source ID and info	Handle, Success/Fail
Log Information	Logging Data	Success/Fail
Query Log	Query Parameters	Result String
Connect to Log Stream	Filter by source and log type	Handle to async stream buffer

Ontology IF	***Parameters***	***Result***
Task Request	Task type	Request Result

The purpose of this Interface to the Ontology Engine is to assess user state and the appropriateness of actions within a social context. Critically the Task Manager has no comprehension of social context or appropriateness. However it can ask questions about specific actions it is being triggered to cause. For example “Is it appropriate to play music?”, “Moving to the lounge”. The Ontology Engine stores the logic and data that can be used to infer the answers to these contextual questions. The Ontology Engine will also store relationships and semantic knowledge of objects and people in the User’s environment as well as capturing User preferences and interpreting requests.

Event IF	***Parameters***	***Result***

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Request notification of events	Event Type	Success/Fail, Handle
Event Notification	Event Type, Data	Success/Fail
Cancel Notification Request	Handle	Success/Fail

4.1.2 Components: Navigation

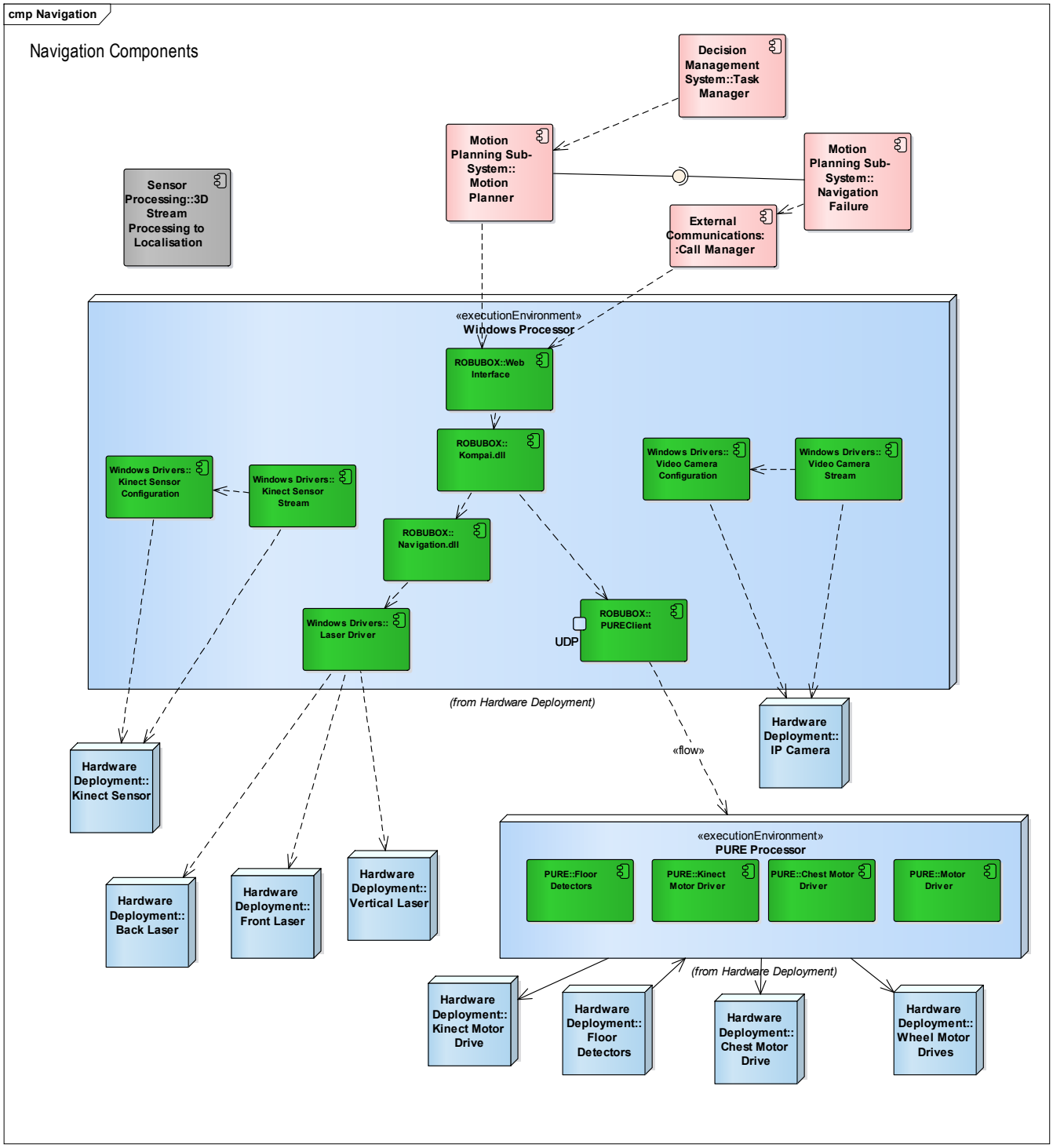

Figure 17: Navigation component dependencies

The standard software systems that are delivered with the robot handle the following functions:

- Motion control of the platform within the environment.
- Control of actuators for moving sensors on the platform.
- Sensor interfaces from navigation sensors.
- 3D sensor interface.
- Localisation and map building.

The platform also includes an application that allows the naming of regions and places on the map generated from scanning the environment.

4.1.2.1 Motion Planner

A motion planner is required to direct the platform within the environment based on the current task being addressed. It sends commands to the platform via the Web Interface and presents application interfaces to the applications that service high level requests. Completion of motion requests are handled by the Event Manager through the Event Interface.

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Motion Planning Interfaces

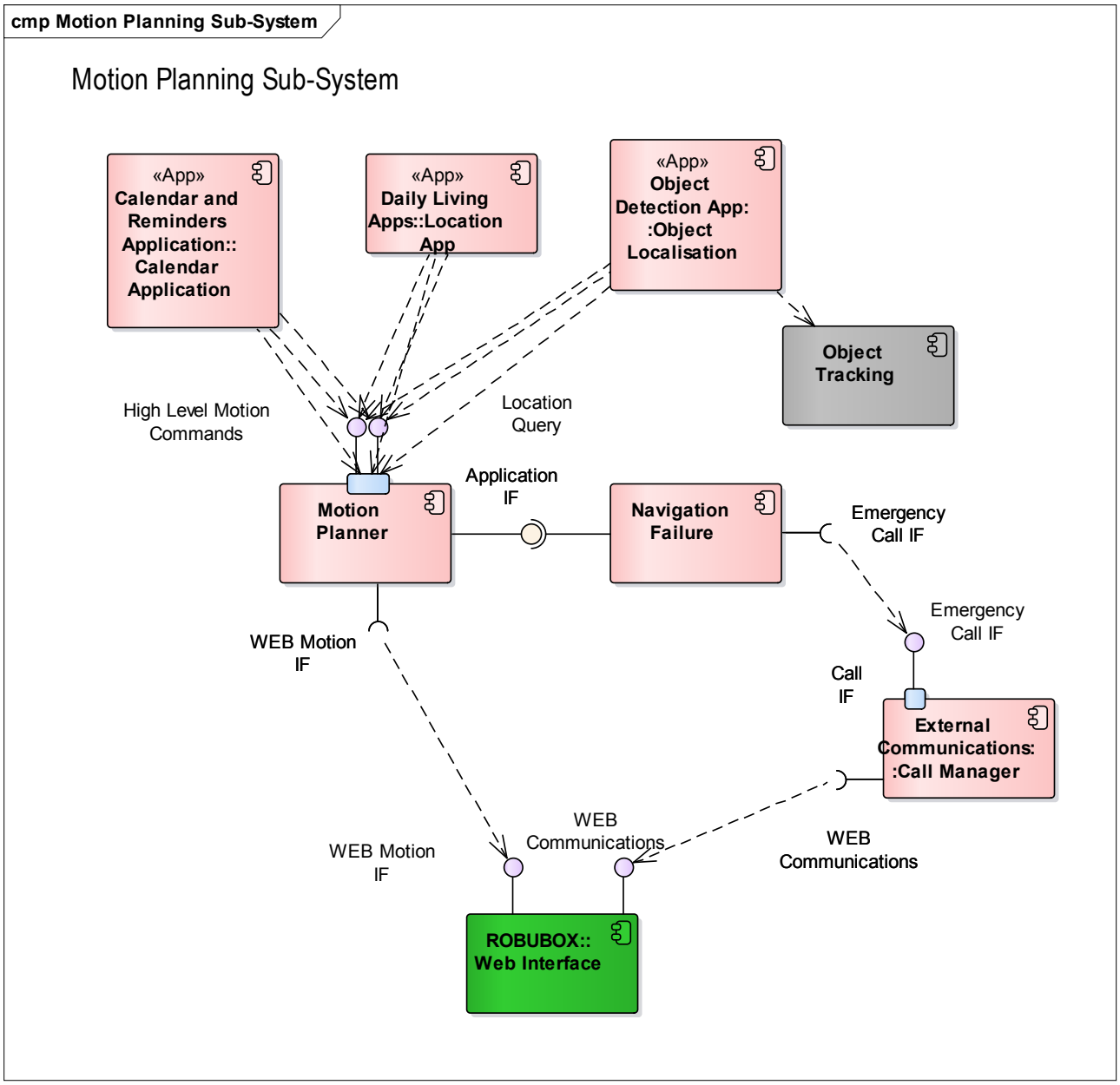

Figure 18: Motion planning interfaces

WEB Motion Interface	***Parameters***	***Result***
Move to Location	Name of location Request ID	Motion Complete Event, (Completion Status)
Move relative	Relative Motion Data Request ID	Motion Complete Event, (Completion Status)
Move Actuator	Name of Actuator, Motion Data Request ID	Motion Complete Event (Completion Status)

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High Level Motion Command IF	***Parameters***	***Result***
Move to Location	Name of location Request ID	Motion Complete Event, (Completion Status)
Move relative to User	Relative Motion Data Request ID	Motion Complete Event, (Completion Status)
Move relative to Location	Name of Location Relative Motion Data Request ID	Motion Complete Event, (Completion Status)

Location IF	***Parameters***	***Result***
Where am I Query	Request ID	Data Response Event Name of Location, room or Coordinates. (Completion Status)
Pose Query	Request ID	Data Response Event Vector of Actuator positions. (Completion Status)

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4.1.3 Components: Speech Recognition

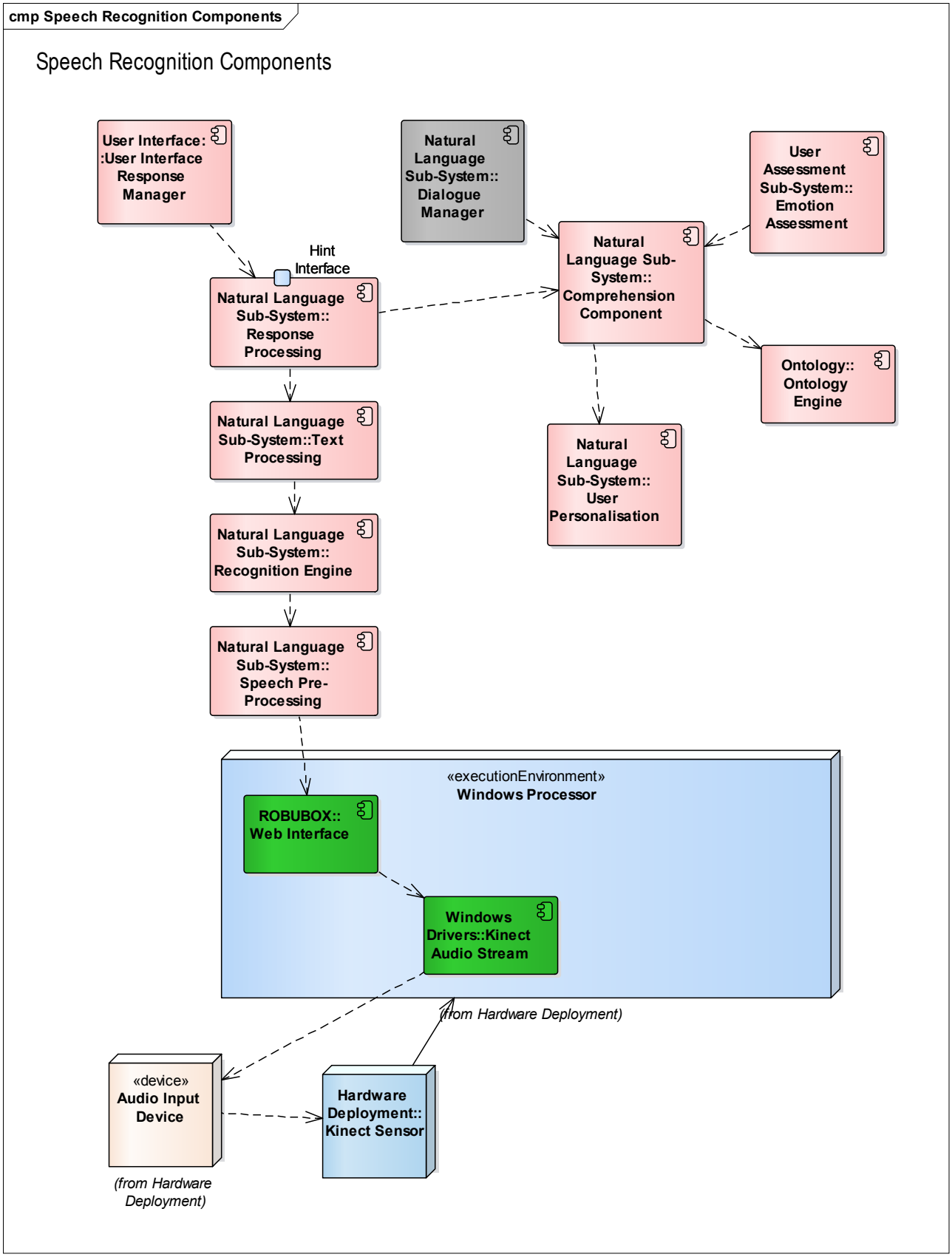

Figure 19: Speech recognition components

4.1.3.1 Speech Pre-Processing

The Speech Pre-Processing component handles the interface to the speech capture mechanisms of the WEB Speech Interface and provides basic noise filtering and segmentation.

4.1.3.2 Recognition Engine

An “off the shelf” speech recognition engine able to take in a sound segment and provide text to speech processing.

4.1.3.3 Text Processing

Text Processing component carries out context based text processing taking the text hints from the Response Processor. It cleans the text string before passing it back to the Response Processor

4.1.3.4 Response Processing

The Response Processor takes expected responses, or sets of expected responses from the Application requesting speech input. It passes the incoming text stream and the expected responses to the Comprehension Component. If there is a match it triggers a User Response Event to the event handler. If there is no match, or there was no expectation of a match because no application is expecting input then the Comprehension Component may signal that this is a free form event that has been recognised. The Response Processor will then send an appropriate event to the Event Handler. In the event that no match occurs then the Response processor has the option to trigger the User Interface to ask the user to repeat their answer or answer a disambiguation question. The interaction between the response processor and the comprehension component will be critical to achieving the cognitive functioning of the system.

4.1.3.5 Comprehension Component

The Comprehension Component takes in clean text strings and possible matching result strings. It uses the resources of the User Ontology and Personalisation Data to interpret the answers given and select a response from those indicated. The Comprehension Component may also be triggered by free form speech in which case it will attempt to interpret the request from the user. It may also request that the user repeat their answer to a specific question in order to disambiguate answers, via repetition or via expressing alternatives.

4.1.3.6 User Personalisation

The User Personalisation component stores known information about the user and can relate this to the expected answers provided by the application. For example it may know the names of family members, or the name of the user so that responses can be interpreted in the context of the user.

4.1.3.7 Emotion Assessment

The Emotion Assessment component watches the text stream from the user speech and monitors words and phrases that may indicate the emotional content on the speech stream. It is able to User Emotion Events to the Event Hander.

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Natural language interfaces

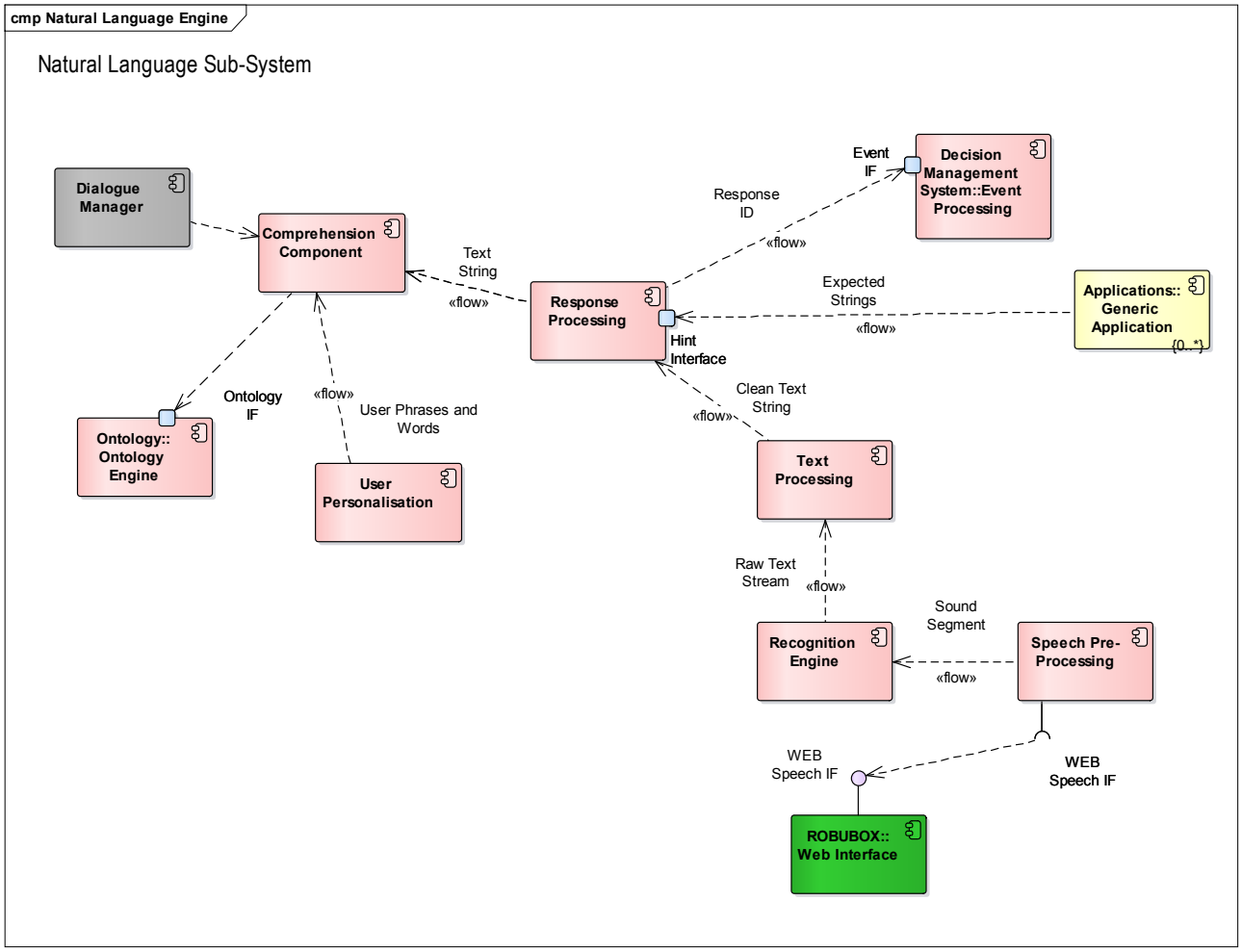

Figure 20: Natural language sub-system interfaces

WEB Speech IF	***Parameters***	***Result***
Capture Speech	Segment Parameters	Audio segment
Capture Status		Status Data

RPC calls result in returned audio segments, multiple segments may be needed to capture an utterance.

Hint IF	***Parameters***	***Result***
Set Options	List of responses	
Clear		

Provides the set of options which are available on the UI based on the state of the currently running Application. These must be cleared once the state changes.

Ontology IF	***Parameters***	***Result***
Get Matching Words	Keyword, Context (e.g.	Alternative Word List

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	location, activity wtc.)	
Word Set	Key Word, Alternative Word, Relationships, Context	
Get Keyword	Word, Context, Relationship	Keyword

Provides an interface to allow the storage and retrieval of words that are equivalent or related to the words in the Hints. Can also be used in reverse to assess matches of spoken words to keywords stored. Filters based on Context and Relationship can be applied to narrow the search

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4.1.4 Components: Audio Output

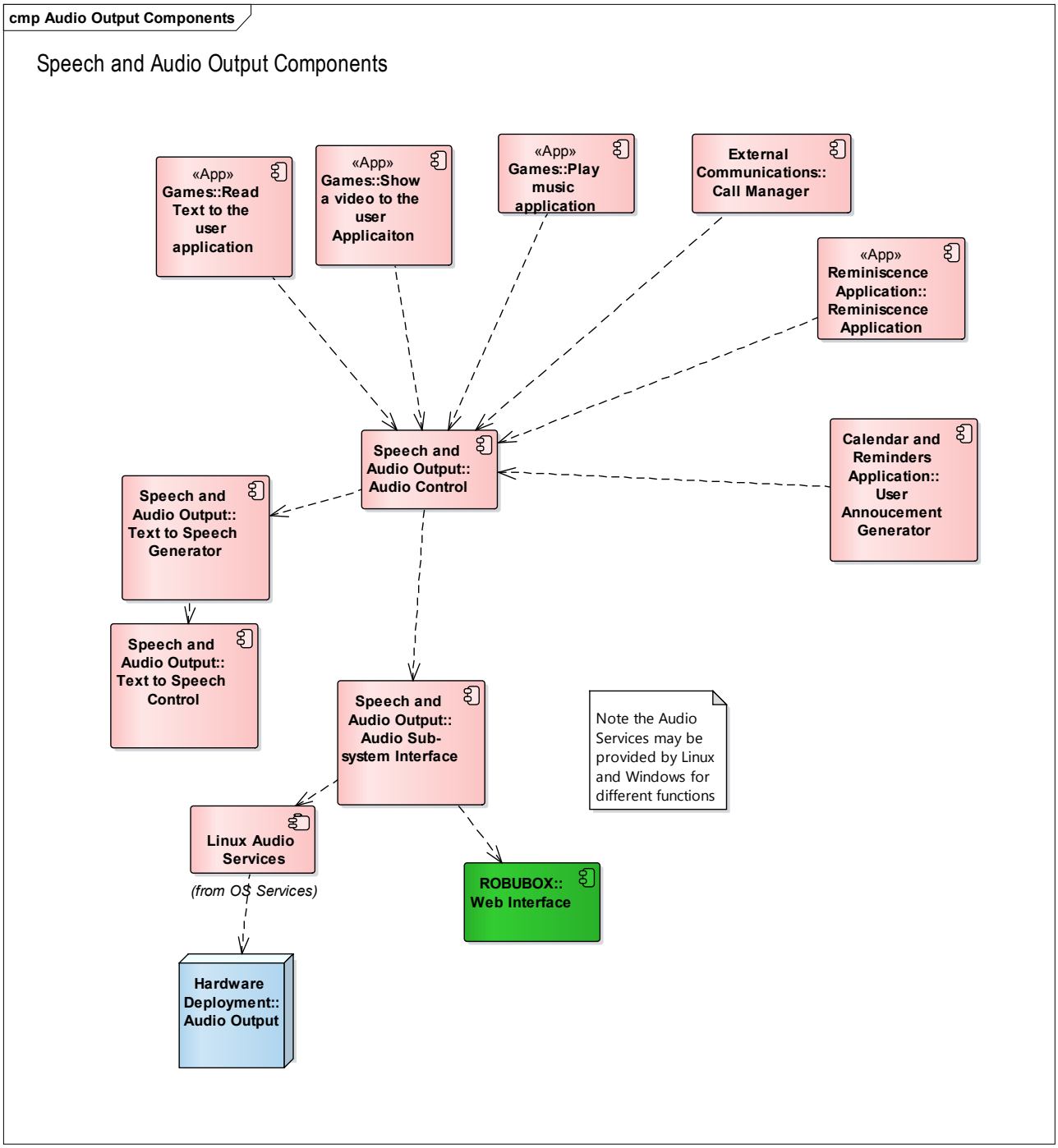

Figure 21: Audio output component dependencies

4.1.4.1 Audio Sub-System Interface

Provides a common interface to the Audio sub-system to control mixer functions, filters and set up audio parameters such as bit rate, segment size etc. Handles Audio Output switching between Windows and Linux based audio output.

4.1.4.2 Audio Control

Handles the delivery and streaming from audio files and the assembly of text to speech segments, integrating recorded fragments as necessary. Accepts instructions over a common interface from

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the Applications. Provides a registration interface for applications to request access to audio functions.

4.1.4.3 Text to Speech Control

Text to speech generators allow tonal, volume and speed adjustments and may require expansion of text strings prior to generation. This component provides these as a service to the Text to Speech Generator. Examples include question phrasing, conversion of numbers and currency symbols etc. While many generators include these functions it is common to find local exceptions and in particular the need to substitute local place name pronunciations to make them intelligible to users.

4.1.4.4 Text to Speech Generator

A wrapper for “off the shelf” text to speech generators. It is important to allow multiple text to speech generators to co-exist as support for multiple languages and in particular all regional accents may not all be available in one package.

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Speech and Audio Output Interfaces

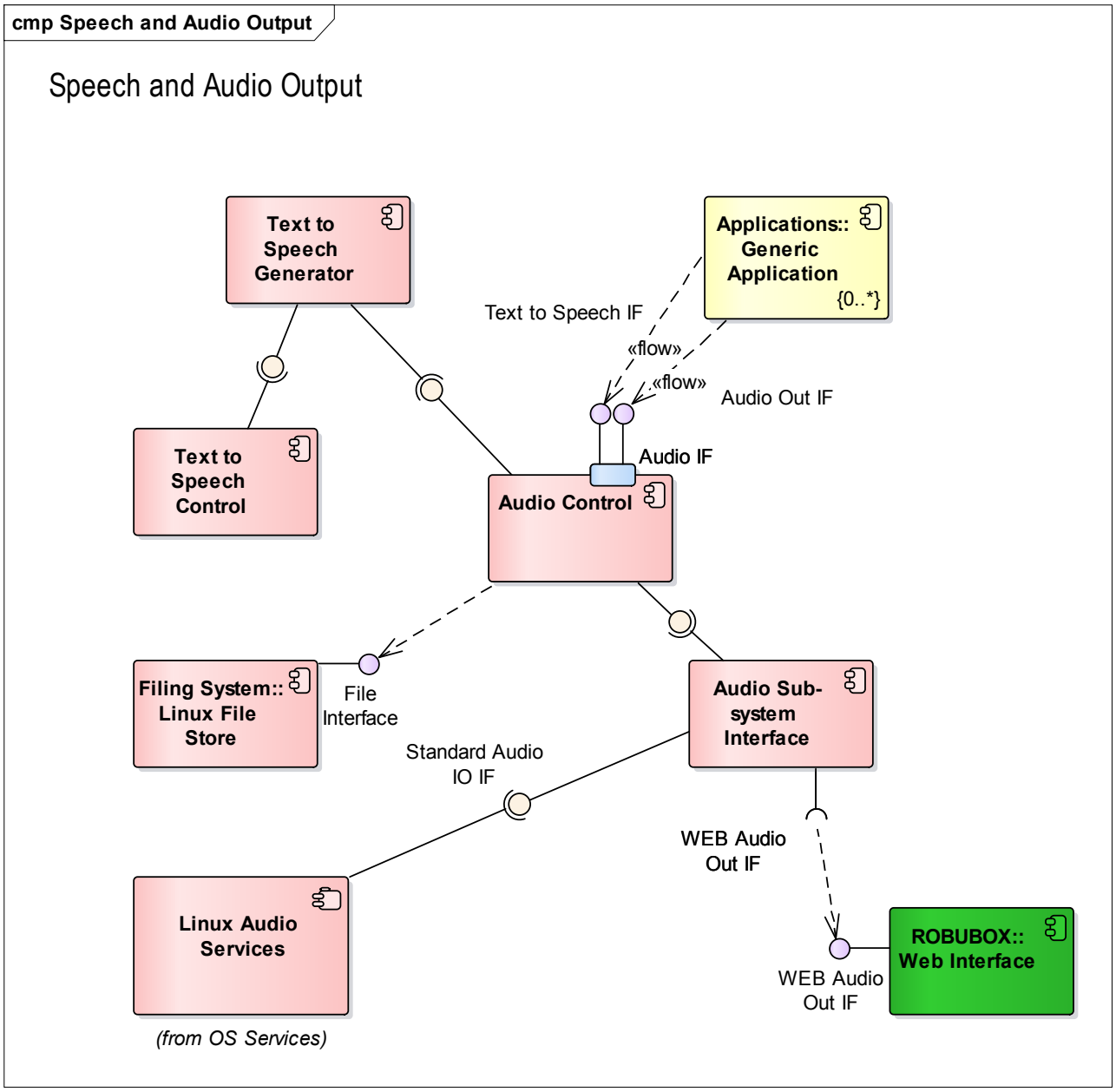

Figure 22: Speech and audio output interfaces

WEB Audio Out IF	***Parameters***	***Result***
Play Audio File	File Name (on windows)	Audio Complete Event
Audio Control	Audio Parameters	Success
Play Audio Segment	Segment Data	Audio Complete Event

The WEB interface is only able to play short audio segments and cannot stream audio. Music and Video must be played from the Windows PC by reference to a file, or by file index.

Text to Speech IF	***Parameters***	***Result***

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Speak Text	Text to be spoken, parameters.	Audio Complete Event
Speak Text and Audio	Text and references to Audio	Audio Complete Event
Set Speech Parameters	Speech Parameters	Success/Fail

Text to speech will need to use the Linux Sound output as streaming of Audio across the WEB interface is not possible.

Audio Out IF	***Parameters***	***Result***
Play Audio File	File Name (on windows)	Audio Complete Event
Audio Control	Audio Parameters	Success

Provides and interface to Applications to play stored audio files.

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4.1.5 Components: Communications

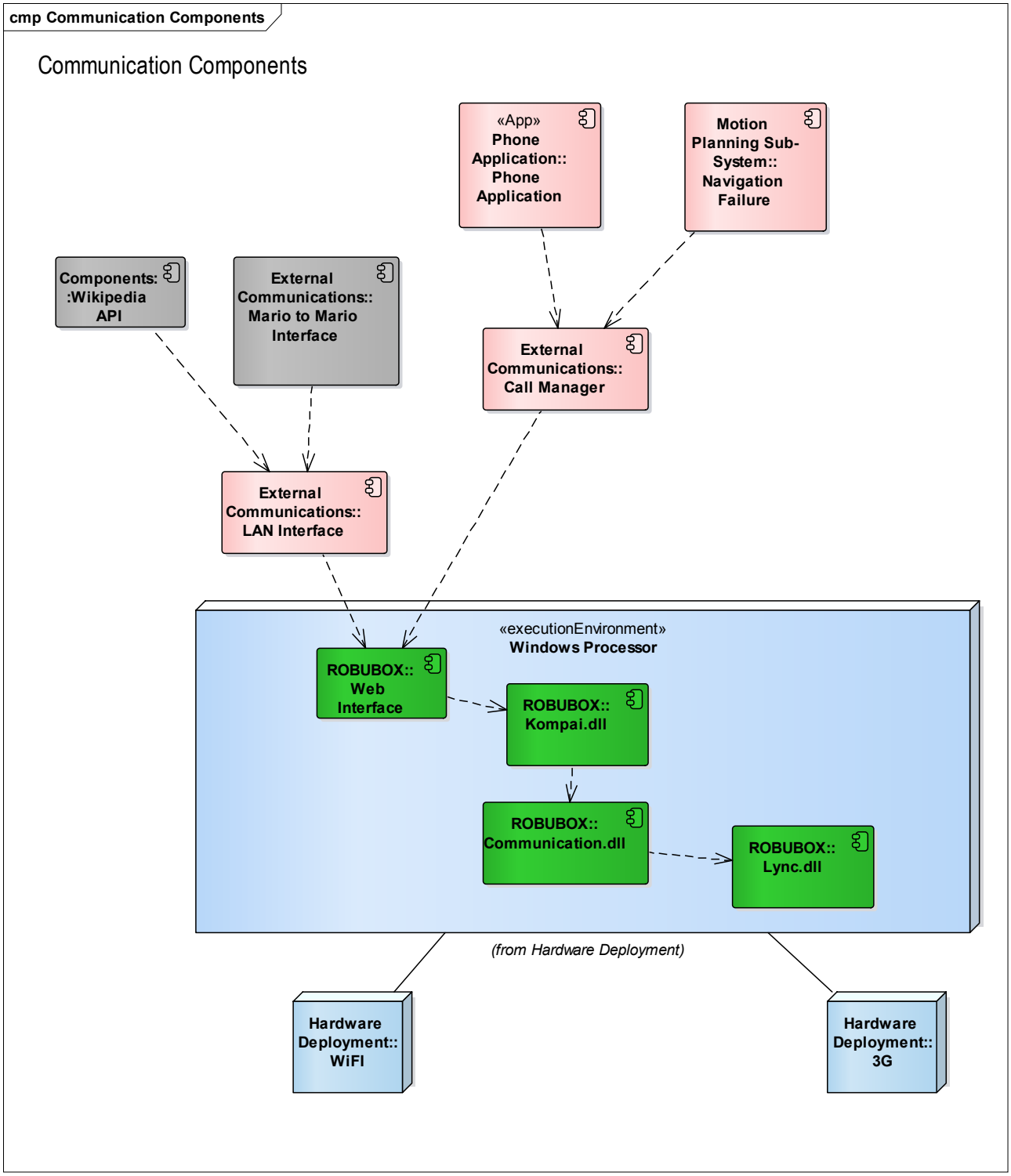

Figure 23: Communication component dependencies

4.1.5.1 Call manager

Phone calls are handled within the ROBOBOX environment by the delivered software and hardware in the robot. The Call Manager provides access to the services offered by the underlying system exposed through the WEB interface.

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4.1.5.2 LAN Interface

Provides the ability to establish and send/receive data from an IP port via the LAN interface hosted by the ROBOBOX system. Provides basic LAN access for processes running in the Linux Execution Environment.

External communications interfaces

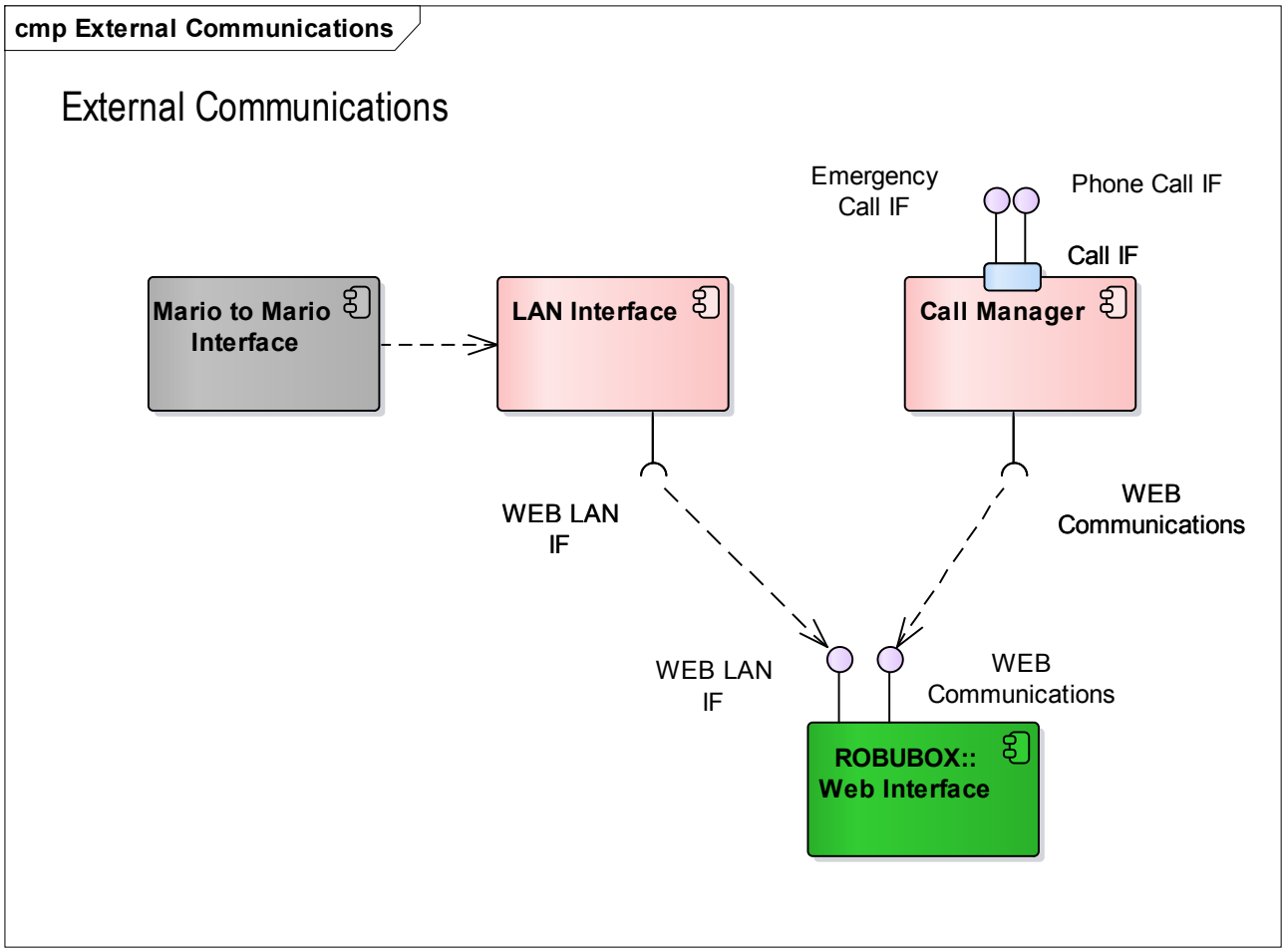

Figure 24: External communications interfaces

Emergency Call IF	*Parameters*	*Result*
Make Call	Current Location Name	Call Success/Fail

Number to call is preloaded at installation along with a voice message as a sound file that can be played over the phone. Current location of robot is added to this via text to speech.

Phone Call IF	*Parameters*	*Result*
Make Call	Person, Number, Call type	Call Success/Fail
Monitor Call Status		Call Status

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WEB LAN IF	***Parameters***	***Result***
Create Connection	IP Address and port	Connection Success/Fail
Packet exchange	Packet of Data	Packet of Data

WEB Communications	***Parameters***	***Result***
Make Call	Phone number, Call type	Call Success/Fail
Monitor Call Status		Call Status

Phone call is fully handled by the ROBOBOX system including all audio and video streaming. This interface provides the ability to periodically check that the call is still in progress.

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4.1.6 Components: Graphical User Interface

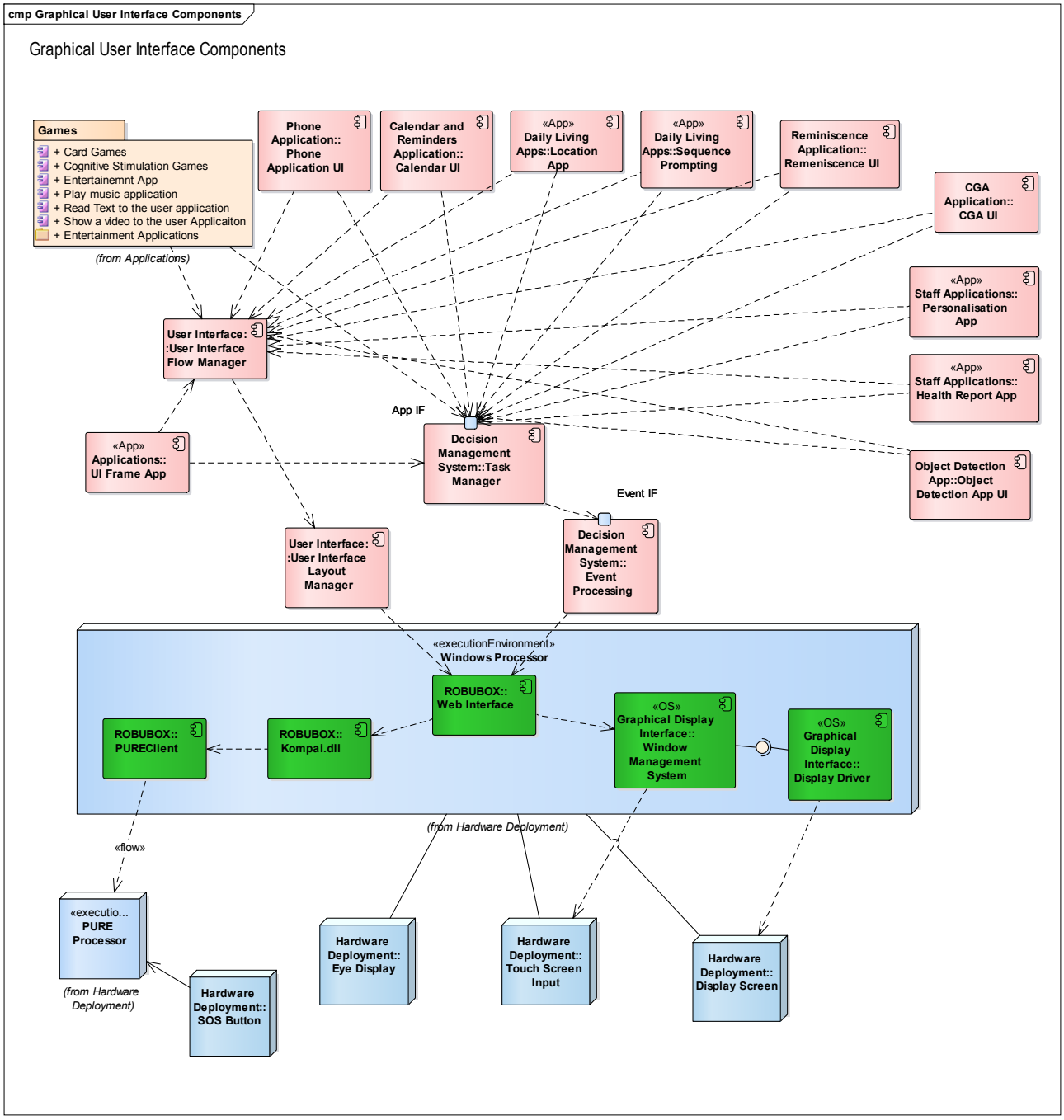

Figure 25: Graphical User Interface component dependencies

4.1.6.1 User Interface Flow Manager

The User Interface Flow Manager provides an interface to Applications that manages the use of UI elements with defined functions and event triggers. These are visually instantiated by the User Interface Layout Manager. Applications send update events to the Flow Manager.

4.1.6.2 User Interface Layout Manager

The User Interface Layout Manager provides the graphical consistency for the individual applications. Applications are written independently of the graphical implementation and layout.

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The User Interface Layout Manager also manages the interaction framework in which the individual applications sit.

4.1.7 Components: Vision

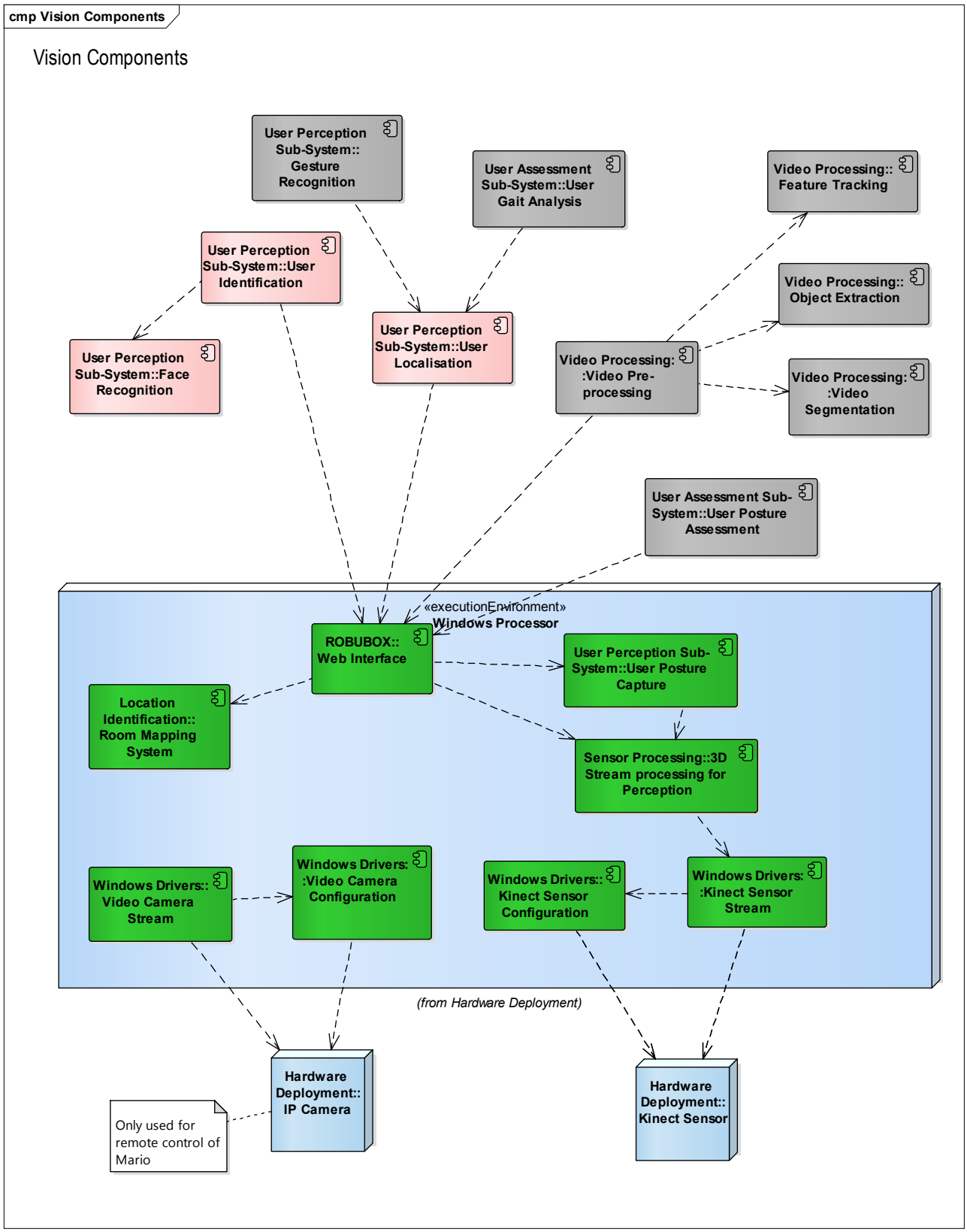

Figure 26: Vision component dependencies

4.1.7.1 User Localisation

The User Localisation component manages the process of locating the user and tracking the location of the user over time. It also obtains pose data from the 3D sensor via the WEB interface.

4.1.7.2 User Identification

The User Identification component uses both image based face recognition to recognise the user as well as short range RFID information. It has the potential to also use voice identification.

4.1.7.3 Face Recognition

The Face Recognition component uses an "off the shelf" face recognition system it provides the ability to recognise the user based on image snapshots from the 3D camera.

User perception sub-system interfaces

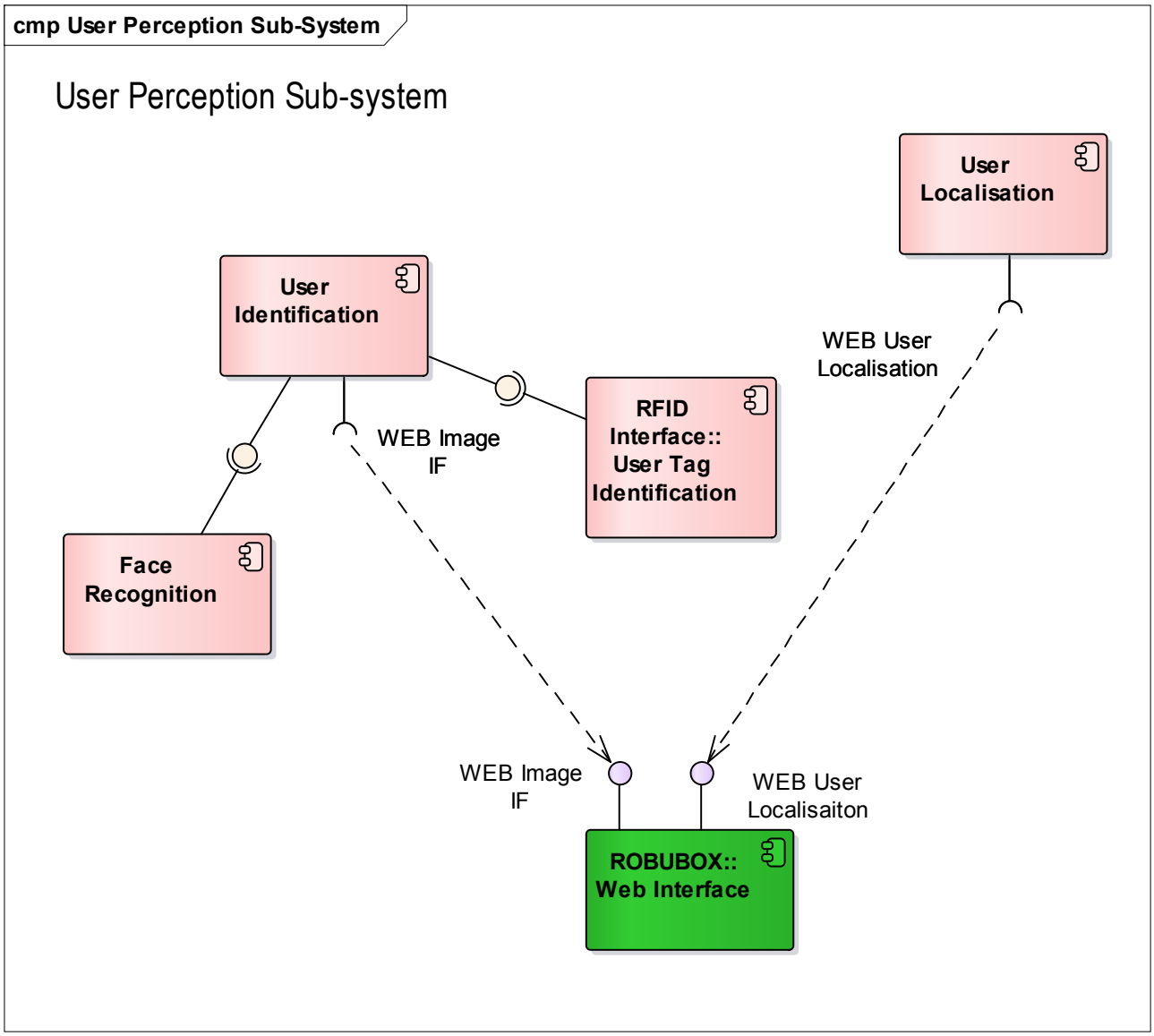

Figure 27: User perception sub-system interfaces

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WEB Image IF	Parameters	Result
Capture Image	Image Data	Image
Move Camera	Motion Data	Motion Complete Event

WEB User Localisation	Parameters	Result
Locate People		People Location Data
Get Person Pose		Person Pose

4.2 Major Interface Clusters

4.2.1 Windows Linux Interface

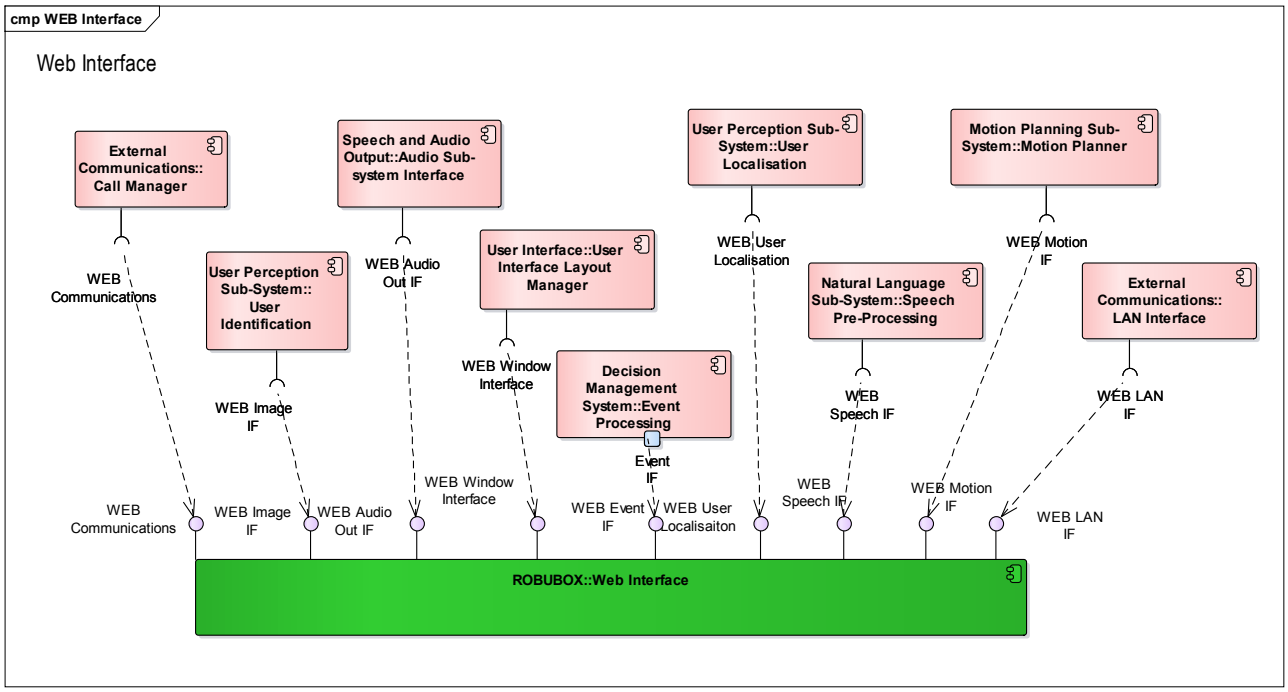

Figure 28: Windows Linux interfaces

The interface between the Windows Execution Environment and the Linux Execution Environment is achieved using a Web based interface based on WAMP. This provides two call mechanisms an RPC and a message registration service. The specification of this interface is divided into a set of individual interfaces supporting particular exchanges of information between the two systems. Each interface may use a mixture of RPC and message registration.

4.2.2 Application Interface

4.2.3

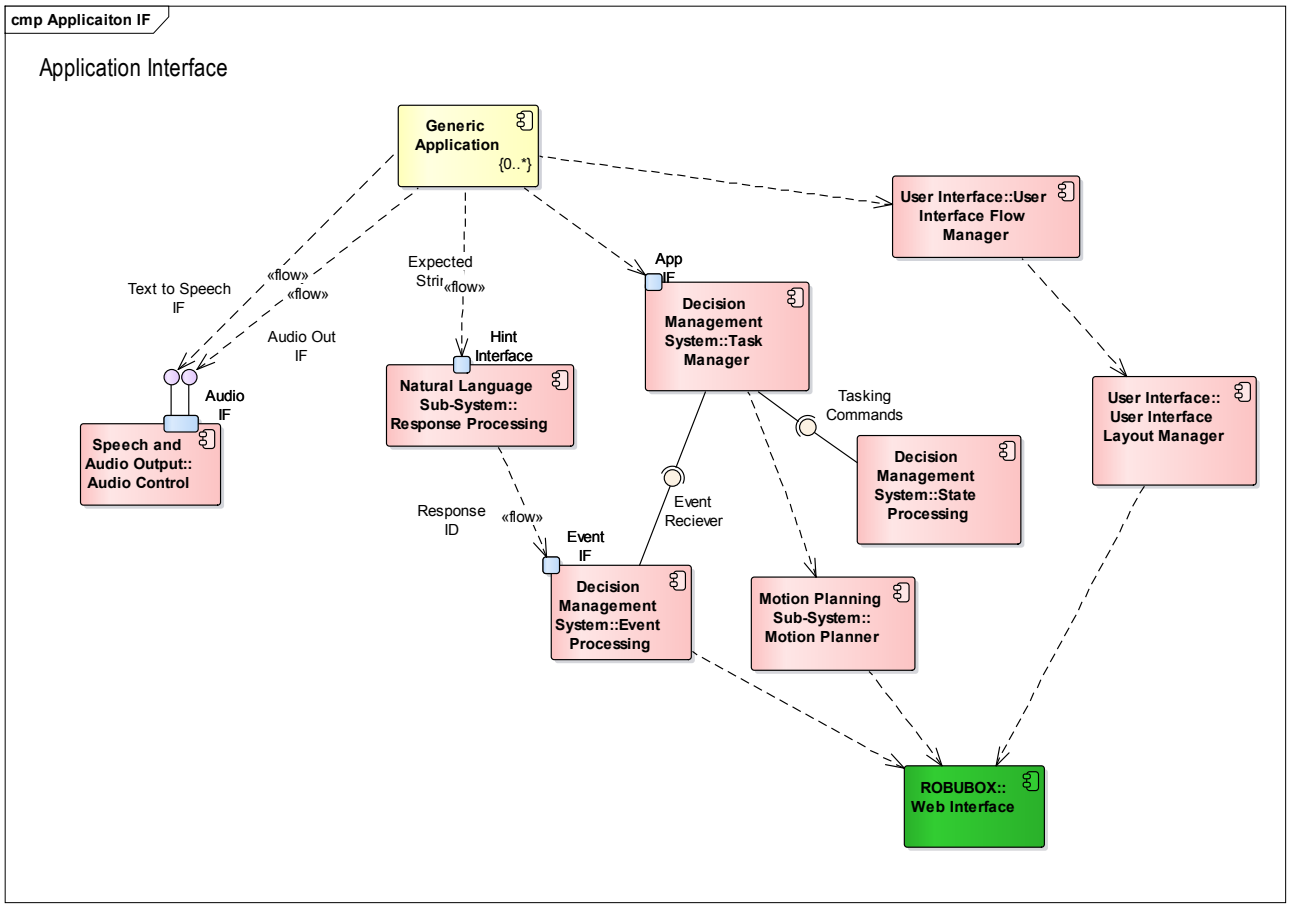

Figure 29: Application interface

Applications are at the core of MARIO and provide the flexibility of delivery and the implementation of the functions that are visible to the user.

Applications have access to a set of public interfaces provided by the underlying system. The goal is to simplify the implementation of applications so that they only contain the necessary logic to execute their function and are not overloaded by details of execution.

Ultimately these applications can be written to be portable between different systems.

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4.3 Databases

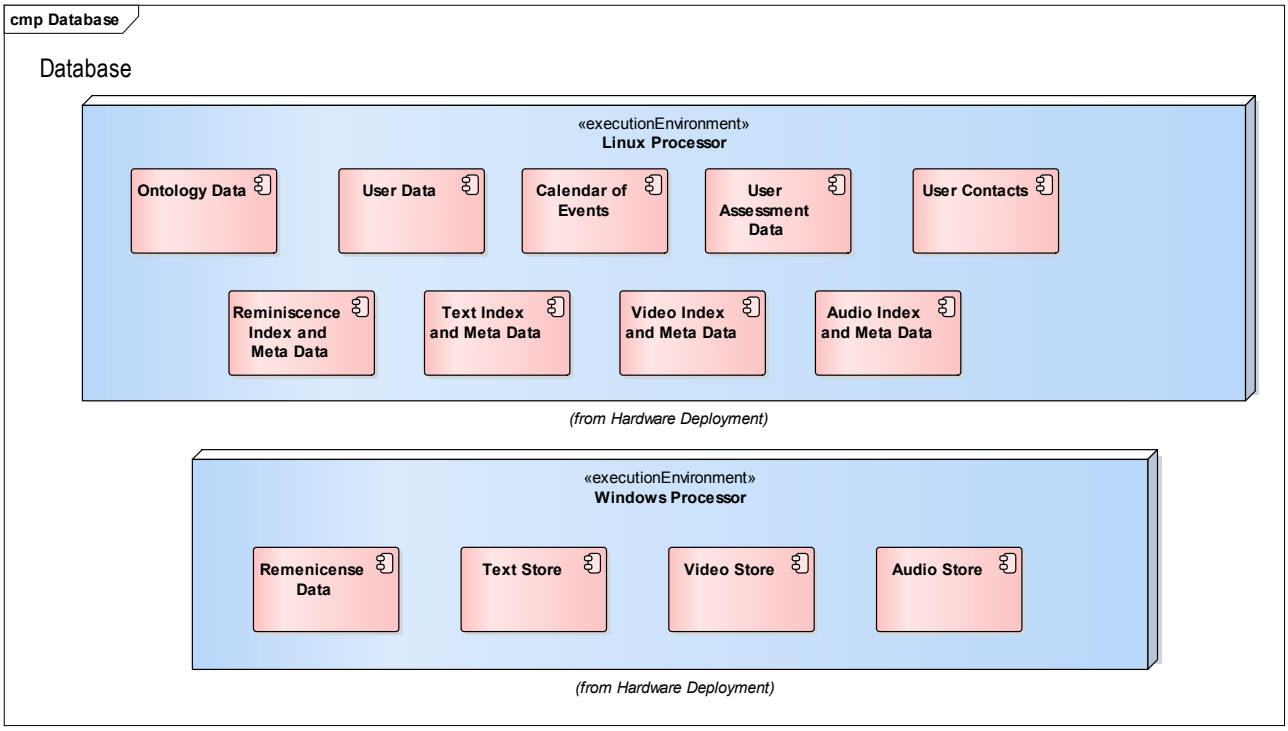

Figure 30: Databases on MARIO

MARIO stores a wide variety of different types of data. This data is divided between the storage mechanisms in each execution environment. In some cases these data stores may be implemented as filing system elements in folders, but in other cases they will need to be searchable databases, for example based on SQL.

For the medical and user data access can only be granted to specific users, either the PWD or more usually specific care staff.

4.3.1 Data Storage

There are two data storage devices in the system, one for each of the main execution environments.

The distribution of data is dependent on the way the data is to be used and displayed. So for example Video Data is stored in the Windows Execution Environment because it must be displayed on the screen attached to that execution environment and streaming will then take place within one environment. However the index to the video store is needed by the Video Entertainment App and so is located in the Linux Execution Environment.

With reference to D10.5 Data Management Plan the databases on MARIO will act as a source of data for Dataset (Robot Interaction) where PWD activity and learned patterns captured within the Ontology Engine (Ontology Data) are a key element in the Dataset, and in Dataset 2 (Health Status) where the CGA assessment data gathered by MARIO is one of the input sources.

In developing the interfaces and structure of these databases care must be taken to adhere to the Ethical Guidelines in MARIO and to the individual national regulations surrounding medical data.

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5 Applications

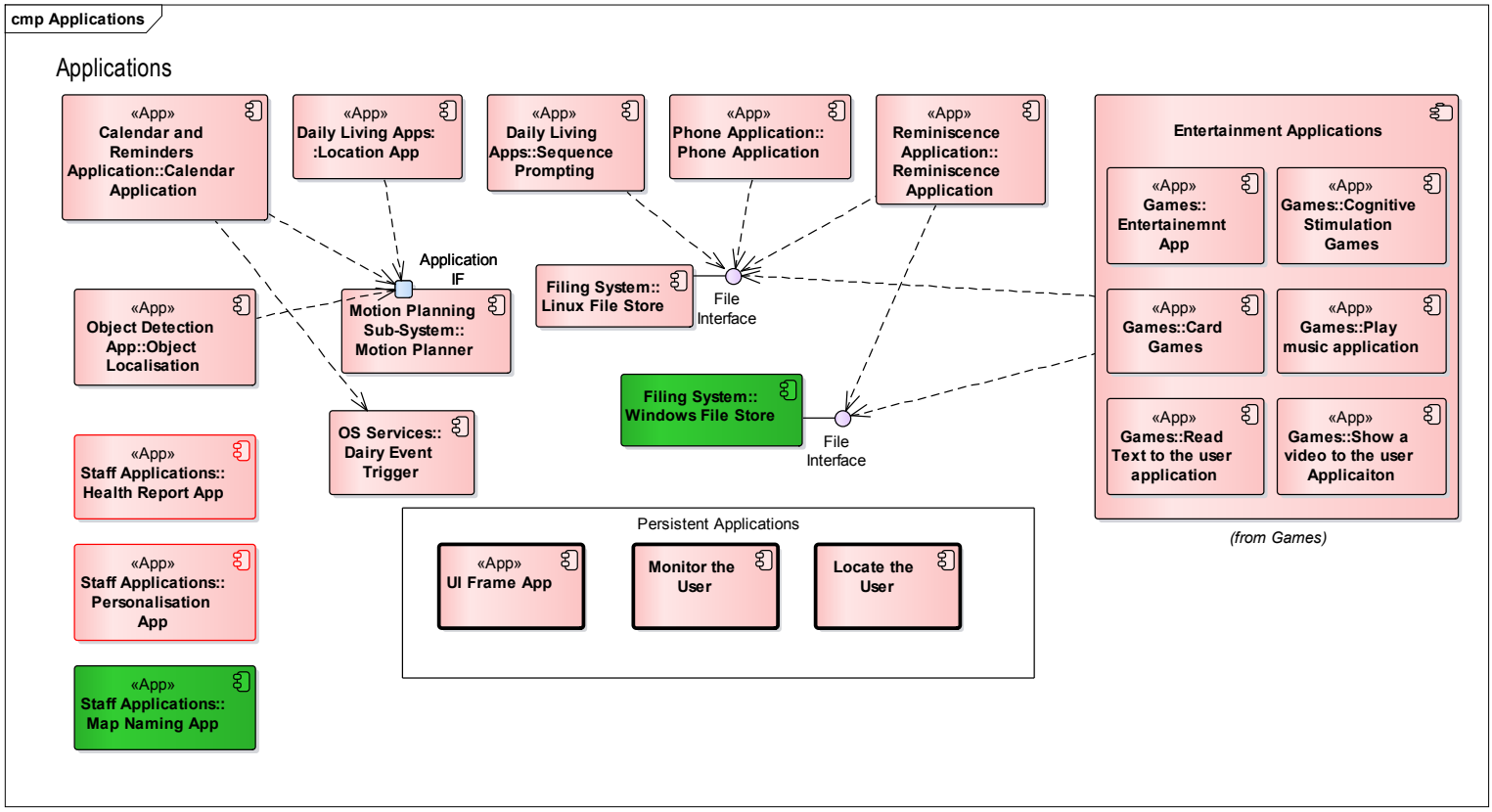

Figure 31: Applications

The functional interface to the user is based on a series of different applications. The system is designed so that multiple applications can be held in the system and can be added to over time.

All applications are event driven and can be given access to the Touch Screen display and the speech recognition interface.

Applications fall into two types:

- Persistent applications.
- Transitionary Applications.

Persistent applications run all, or most, of the time and provide asynchronous events that alter the behaviour of MARIO.

Transitionary Applications are started by a user request, progress by user interaction and are completed either by the user or by MARIO deciding they are no longer being used.

5.1 Persistent Applications

The following are the persistent applications:

- Locate the user
- Monitor the User
- Frame App

Locate the User: MARIO's permanent background task is to locate the user. MARIO does this with some awareness of social context, for example the time of day.

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Monitor the User: MARIO is also listening for spoken words or pre-defined phrases that indicate the User is making a request to MARIO and is also permanently monitoring the user's activity either in terms of location or through the health monitor.

Frame App: This provides control of the frame around the User Interface allowing the display of status information etc.

5.2 Transitionary Applications

All of the remaining applications are triggered by events and closed by the user or by further events.

Most applications are triggered by user selection this can happen in one of three ways:

- The user selects to run an application by interacting with the touch screen thereby selecting from a number of alternative actions.
- The user announces that they would like to use an application
- MARIO offers to start an application for the user and the user accepts.

A small number of applications are started, or can also be started, by external events:

- The Phone application by an incoming call event.
- The Calendar application by a diary event

5.3 User Interface design

The User interface design has been carried out using the following steps:

a) Using the descriptions in D 3.4 the phasing of App delivery has been set for each trial.

b) User interaction proposed for each App has be assessed to ensure the cognitive load is appropriate for PwD.

c) A trial set of screen sequences has been developed for each App and distributed as Web Pages so that an interactive test of the look and feel of the interface can be made by the pilot sites.

d) Assessment of feedback from the pilot has been used to inform design changes.

The first round of App development has concentrated on the delivery of the following Apps:

- Music
- News
- Games

A second round of App development will concentrate on:

- CGA
- Activities

Both rounds of development will deliver Apps for Phase 1 Trial 1.

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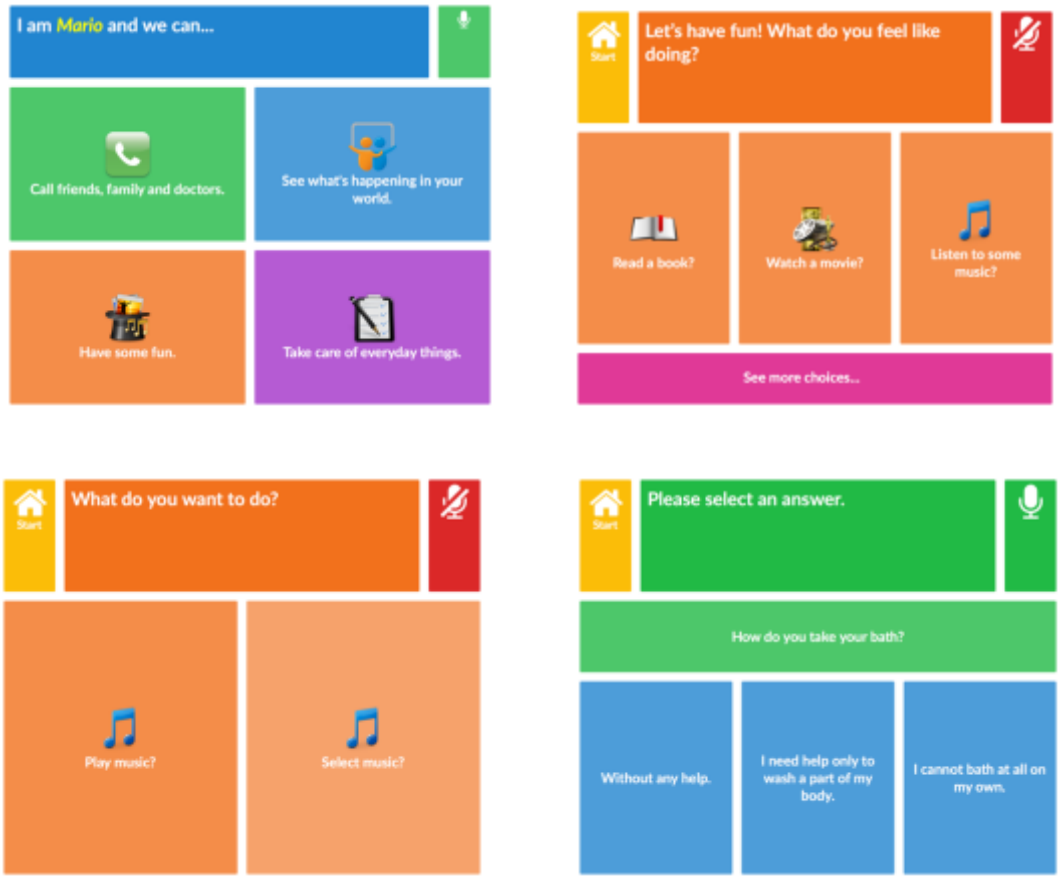

Figure 32: User interface screen examples.

The user interface screen flow can be examined at the following web site:

http://www.mario-project.eu/dev/uidesign/index.html

Figure 32 provides four samples of the graphical layouts of for the User Interface. The bottom right-hand image is one of the CGA questions and is typical of the response screens used on MARIO. There is a degree of customisation that can be carried out with respect to font size and colours. Each screen is accompanied with spoken output.

The UI is based on web pages and a browser is used as the main interface medium. This allows easy simulation of the user interface both over the internet and on a laptop. This has been used to trial the user interface design at the pilot sites and between developers.

Care has been taken to make the cognitive load of each screen and the sequence of screens suitable for a PwD. However careful assessment based on observation of interactions will be used to provide an ongoing assessment of suitability.

5.4 User interface assessment

Each user will have a different experience of using MARIO and in the early stages we expect that this will be an imperfect experience. It is important to capture these early experiences of interaction to allow improvements to be made.

Critical to this will be observations made during the installation and validation phase of the trails at each site particularly observations by clinical and care staff of PwD using MARIO. Deliverable D 8.1 details the pilot protocol that covers this process.

In the early stages of assessing MARIO's user interface there are several risks:

a) The PwD do not interact with MARIO without prompting.

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b) That MARIO is unable to gain the attention of PwD successfully

c) That MARIO fails to understand the spoken input used to select Apps or make selections within Apps.

d) That the Apps MARIO offers are not suited to the particular PwD and the pilot site.

Potential mitigations for these risks are as follows:

a) Improved personalisation (for the individual PwD) of prompted interactions.

b) The development of a more clearly defined "personality" for MARIO that promotes greater engagement.

c) The use of physical gestures, facial expressions, vocalisations or graphical displays designed to attract the user. (For example whistling a tune, or making jokes, or displaying an animation on the screen).

d) Changing the flow and capability of Apps to suit different PwD abilities. For example removing choice screens when selecting music such that MARIO just plays the user's favourite songs, or adding layers of selection to allow the user more choice.

e) Improving the dialogue structure, vocabulary and ontology to better understand the responses from the user, thus providing greater user interaction.

f) Altering the interaction to provide variation in approach to ensure greater social acceptance. For example varying the games or news feeds provided by MARIO.

Assessment of both the circumstances of success and the profile of PwD who successfully interact will help to determine which of these enhancements may be beneficial.

Reviews at the end of each of the key delivery milestones will collate and analyse the results of both specific tests and trials.

5.5 Trial assessment

The trial protocol (D8.1) and the trial metrics set out how trials will be conducted and assessed. Such assessment will cover low level functional assessments such as the ergonomics of MARIO and accessibility issues for PwD and issues related to interaction and intelligibility assessment.

Feeding back assessment from trials is an important part of closing the development loop. In the early stages of product assessment on site well considered evaluation of outcomes and issues coupled to a process of assessment and modification are critical to the successful deployment of MARIO in the full trials.

There are a number of factors that modulate the process of adapting MARIO to the feedback received from trials:

a) The pilot sites are remote from the developers and it will be difficult for developers to gain direct experience of users.

b) The technical expertise at the pilot sites will not have a detailed understanding of how the robot operates such that they can precisely contextualise issues with the design of the system.

c) The users, both PwD and clinical staff are non-technical and have little experience of robotics.

d) It may be difficult to generalise interaction failures based on the experiences of individual PwD partly because each is an individual and partly because it will be difficult to collate common experiences when reported differently.

e) It may be difficult to generalise issues across the three pilots, with the possibility that opposite conclusions may be drawn on the direction of design enhancement.

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f) Regional and language differences between the pilots may create additional issues that need to be addressed.

g) The long term impact of MARIO may be very difficult to assess from early trial data and as a consequence design modification may need to contain an element of experimentation.

In order to mitigate these risks to assessment it is important to have a well defined process for the capture and assessment of trial data and a process to manage the development of modifications and their approval.

A common reporting template will be agreed with the pilots as a part of the Pilot Protocol and the outcomes of trials will be reviewed at each concluding milestone by the technical team. Where permission can be obtained it will be valuable to collect video recordings of interactions. The combined evidence from the trials will be used to identify key changes to the system. These will be prioritised and planned into the development activity to M24.

5.6 Software Update

Design update will take place up to M24. However there are defined points in the project where updates can be delivered to add functions to the robot. Notably these are just prior to each phase of the trials and can be identified as follows:

Milestone	Month (End)	Update
At delivery to Pilot sites	M19	Upgrade of Apps and Motor Behaviours
Prior to Phase 1 Trial 1.	M21	Upgrade of all software, addition of new Apps
Prior to Phase 1 Trial 2	M23	Addition of new Apps and upgraded speech recognition
Configuration for Phase 2.	M24	Addition of new Apps and motion behaviour upgrade.

Table 5: Software update milestones

The Pilot Protocol (D 8.1) will be updated to detail the roll out of Apps and features in the system at each trial.

Beyond M24 only a limited capability exists within the project to update the system. The expectation must be that at M24 a complete system is functional and can be used for extended testing. Only limited fixing of bugs and routine maintenance can be carried out after this time.

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6 Data Management

6.1 Description

This section provides an overview of the data management policy for the data and knowledge resources present at Pilot 1, including all data[3] that will be collected, shared, processed or generated. More specifically, this section will describe information about the data (ontologies, schemas, datasets, etc.) used within MARIO and the management of this data (what type of data, how the data will be collected, shared, handled, preserved, any used standard) within the scope of pilot 1. For a full picture of the project data management processes and policies, please refer to the MARIO Data Management Plan (DMP).

MARIO's DMP is a hybrid of the template provided by the European Commission[4] and the checklist provided by the Digital Curation Centre (DCC)[5] as suggested by the University of Sheffield[6]. The current DMP version reflects the latest status of the datasets descriptions, standards, data sharing and archiving guidelines. It builds upon the first plan that NUIG created for the grant agreement process, which was further extended according to the MARIO indicators (adapted to the EIP AHA indicators).

In the following sections we list the set of data management artefacts, processes and policies which will be the target of the deployment of MARIO at Pilot 1. These elements are summarized in Figure 33

[3] The MARIO project consortium has not committed to participate in the Pilot on Open Research Data in Horizon 2020. Nevertheless, the project partners will still aim to provide open access to certain research data as discussed in more detail in Section 2 of this deliverable.

[4] http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf - Annex 1

[5] http://www.dcc.ac.uk/sites/default/files/documents/resource/DMP_Checklist_2013.pdf

[6] https://www.sheffield.ac.uk/library/rdm/dmp

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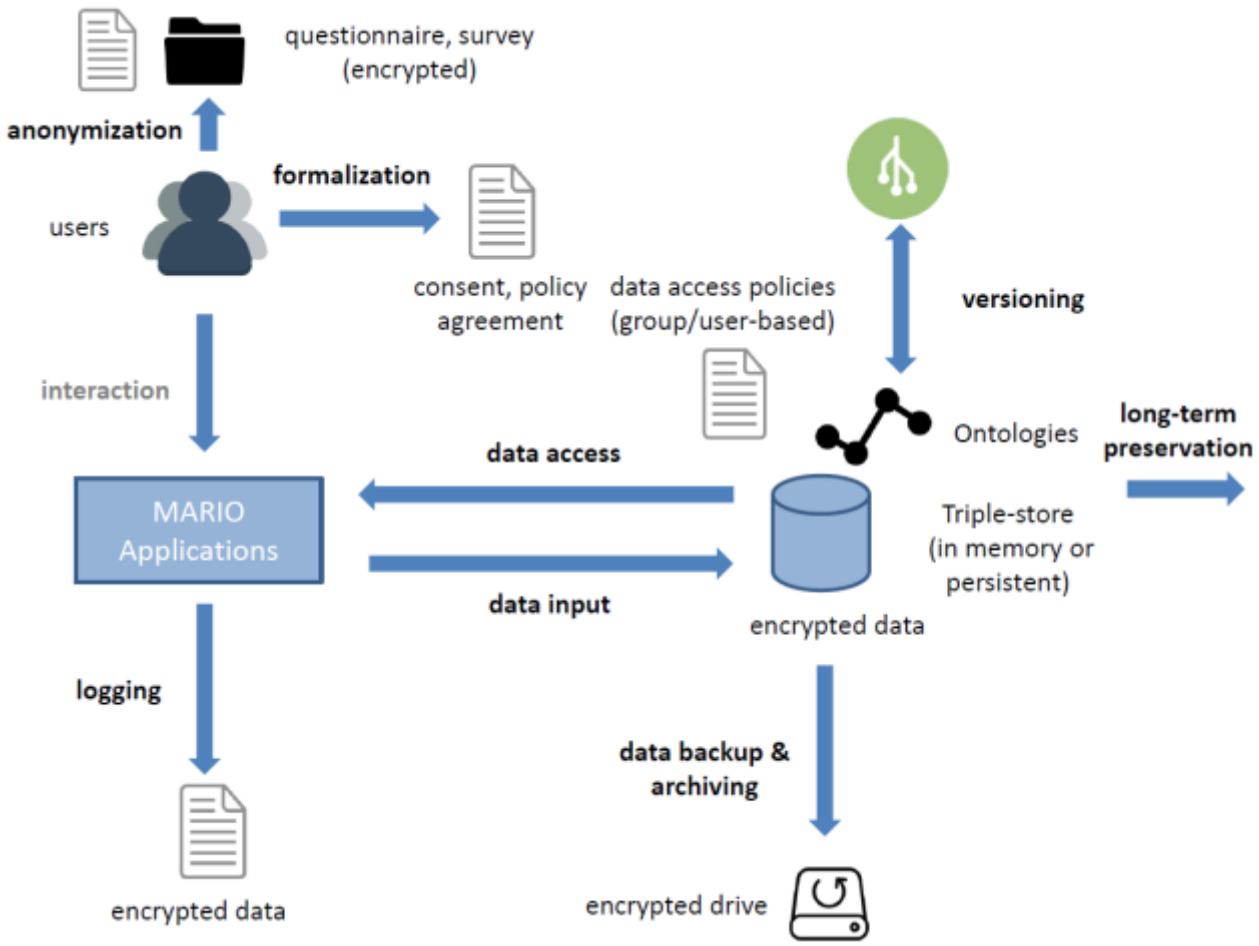

Figure 33: High-level artefacts and processes behind MARIO's data management.

6.2 Data Management Artefacts

6.2.1 Data Model, Standards and Metadata

The MARIO project uses the Resource Description Framework (RDF)[7], which is a standard of World Wide Web Consortium (W3C)[8] specifications as a metadata data model. In particular, most of the system's data will be managed by the RDF/OWL framework and will be accessible through a SPARQL endpoint and a dedicated API. RDF 1.1[9] and OWL 2[10] will be used, where the best practices, ontology design patterns and W3C guidelines will be followed and applied. Existing ontologies will be reused for representing data. As per the data protection policy proposed by the European Commission in January 2012, any data sets held on laptops will be PC password protected and encrypted as per University policy (QA409 2014).

[7] https://www.w3.org/RDF/
[8] http://www.w3.org/
[9] http://www.w3.org/TR/rdf-schema/
[10] http://www.w3.org/TR/owl-guide/

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6.2.2 Ontologies

MARIO will be supported by a set of ontologies developed within the following macro-areas: personal sphere, life events and patterns, social and multimedia content, environment, health sphere, emotional sphere, open knowledge, regulatory sphere, robot proprioception. MARIO ontologies will be represented using the OWL standard. The first version of the ontologies (MARIO Ontology Network) target the sub-areas of the project which are the priority scenarios for Pilot 1. Further information can be found at the supporting document of the MARIO Ontology Network.

6.2.3 Sensor Data

Sensor data streams will be received directly by the middleware of MARIO. Most of these data streams will be used to activate events on the components and applications coupled to MARIO's middleware and will not have long-term persistence.

6.2.4 Supporting Database Management Systems

The supporting long-term Database Management System (DBMS) (triple-store) behind the platform will be initially based on Apache Jena (prototyping version) and further on Openlink Virtuoso. The long-term DBMS should support efficient reads, updates, creates and deletes. Additionally it should support a fine-grained specification of users and data access policies, i.e. which type of operations and user applications have access to each subgraph (knowledge base).

6.2.5 Files and folders

Each pilot site will have a pilot folder. The overall site folder will hold technical data and contextual data about the site. Each participant in that site will be allocated a code within the anonymization process and data will be held for that participant in that file, only the code will appear on the file. The file consist of sub folders related to physiological data, interview data, questionnaire data, life history data, social care plan, medical data.

6.2.6 Long-term Scientific data repository/archive

MARIO open data will be archived into a public repository. Zenodo will allow long-term preservation of datasets beyond the project lifetime. It is an open dependable home for the long-tail of science, enabling researchers to share and preserve any research outputs in any size, any format and from any science. Zenodo is open and free of charge.

6.3 Data Management Processes

6.3.1 Versioning

Versioning will be handled by numbers and by date. They will be added as metadata of the reference RDF datasets (datasets with background data for MARIO) and OWL files. The version number is composed by a sequence of three numbers separated by dots e.g. 1.0.2, where the first number indicates major revisions, the second one indicates minor revisions that are deployed, and the third number indicates internal revisions. The date is specified in the format yyyymmdd (e.g. 20150830).

6.3.2 Data Reuse & Opening

By definition Open Data "can be freely used, modified, and shared by anyone for any purpose". In the context of MARIO, the robots should be able to make use of relevant open data sources for proper actions.

MARIO reuses and extends existing ontologies and data sources within the project for the construction of its knowledge base. MARIO also aims at contributing back to the community

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making some of its general-purpose data available as open data for system construction and scientific analysis.

Data related to Pilot 1 which is subject to consideration for release as open data are concentrated within the following categories:

- Ontology, terminology/schema-level data.
- Any general-purpose data which is not patient-specific, including but not limited to, symptoms, questionnaires, interaction protocols and navigation.
- Data which emerge from the interaction between MARIO and its environment, including the interaction with patients and professionals, in which the identity of the human agent can be fully anonymized.
- Aggregate data which does not affect the identification of professionals or patients.

6.3.3 Archiving and Preservation

The data collected throughout the project lifetime will be selected and preserved according to the project scientific demands and compliance to European and local laws and best-practices.

Each partner is responsible for the curation of data that is gathered in the scope of their application and scientific focus. Preservation will be taken care of through the project's web site and long-term archiving solutions. The research data from Pilot 1 will be deposited within a common repository (if no privacy restrictions apply, such as interview data which is confidential and thus can be shared only in synthesis versions.

6.3.4 Storage and backup

Different kinds of data will be collected during the project lifetime, namely i) patient data, ii) general data and iii) robot data. Patient data needs to be secured with regard to its storage and transmission/transportation, whereas security for the general data is not mandatory.

All forms of data (patient, general and robot) will be backed up within a central repository data locally to a separate hard disk on a weekly basis in an encrypted form.

6.4 Data Security Policies

6.4.1 Access

In order to keep the data secure, access will be controlled by passwords for each data repository managed by the DBMS. Collaborators (physicians) can access the data securely by providing Web access to them via password control.

Additionally, each user group profile (patients, nurses, doctors) will have access profiles to different attributes within the MARIO database. The individual user profile will have access to the data for the associated patients which are under their care. The policy will be specified at Pilot 1 by a manual setup of these access restrictions, while in the future this functionality will be extended to a data access administration interface.

In the context of the Pilot 1, all data access will be constrained to the local environment of the MARIO data computer.

6.4.2 Encryption

These are the recommendations regarding to the user and application data at rest following ENISA (The European Union Agency for Network and Information Security). All data stored should use Authenticated Encryption (AE) to provide confidentiality, integrity, and authenticity assurances on the data, all at once. Decryption is combined in a single step with integrity verification.

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At this point only software solutions for disk encryption are under consideration. Two potential compliant encryption solutions are CCM (Counter with CBC-MAC) and GCM (Galois/Counter Mode). As a supporting system, *dm-crypt* provides a transparent disk encryption subsystem in Linux kernel versions 2.6 and later. Note that it's not mandatory to encrypt the whole disk but only the critical partitions where the user and application data are stored.

Opting for a storage encryption raises several questions to be addressed by the data management process, including:

- Encryption key recovery policy
- The Key(s) Lifecycle (generation, exchange, storage and replacement);
- Multiple Keys for different purposes (user data, application data);
- Performance considerations when accessing the data;
- Store unencrypted keys away from the encrypted data, prefer a Key Vault;
- Limit amount of data encrypted with one Key;
- Use a cryptographic hardware;
- Software breaches and regular updates.

The points are further discussed in the Data Management Plan.

6.5 Ethics and Legal Compliance

6.5.1 Consent for data preservation and sharing protocol

To accomplish its functions, the MARIO robot need various types of sensitive and personal data. Some of them are patient's data, but much of the reminiscence-related material is about family members, friends and other people. To collect and process these data, an informed consent form will be provided from participants and other related people before participating in the studies.

6.5.2 Storage & Backup Policies

6.5.2.1 Patient data

For Pilot 1 patient data will be protected using a three-layered security scheme: database password, the specification of strict user/group database policies and the encryption of data at the hard disk level.

However, the consortium is seeking a long-term solution with higher compliance levels.

With regard to patient data, storage and backup policies depend on the country rules for the respective pilot sites (i.e. Italy, United Kingdom and Ireland). For example, France is one of the rare countries outside of the United States to create a special legal status for entities that process and store patient health data. A law in 2002 created this status, which was put into effect in 2009. In essence, entities that are not licensed health care establishments must obtain an authorisation from the French Ministry of Health in order to lawfully store patient health data originating from such establishments. The authorisation requires implementation of rigorous measures to ensure security and confidentiality of patient health data at all phases of the data lifecycle; these requirements are generally seen as the most robust in all of Europe and indeed throughout most the world. A bill that is currently pending in the French Parliament would simplify the requirements to obtain authorisation and notably align the security requirements with globally-recognised standards.

The complexity intrinsic to the regulatory environment behind patient data points in the direction of a long-term solution for MARIO which can better support its scalability as a commercial product. The creation of partnerships with companies that have the necessary authorisation to lawfully store

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and manage patient health data, such as Domicalis[11], is one possible way to better support future deployments of the platform.

6.5.2.2 Robot data

The robot data consists on the collection of the data logs from the motion sensors (encoders, lasers), the status of the actuators and the high-level actions performed by the robot (its action workflow). This data does not require long term preservation, except during the assessment of the robot behaviour, typically in the pilot scenarios. The robot data can consist of logs with different levels of details: action log and full debug log.

The action log allows the monitoring of the sequence of high level actions performed by the robot, including the set of invoked applications. The debug log enriches the set of actions with the fine-grained sensor data and the set of parameters received as an input and returned as an output to the robot associated functions.

While the action log does not contain explicit user data (while the debug information can), its contextual information can be used to infer some attributes about the user. For this reason both types of logs will be stored with the same security restrictions of the patient data.

6.5.3 Handling of sensitive data

For Pilot 1, to ensure that data is stored and transferred securely:

- It will not be possible to access sensitive and personal data from outside the MARIO robot itself,
- Only identified caregivers or close family will be authorised by the robot to access such information in joint interactions with the person with dementia,
- Stored data will be specifically protected and never shared with third parties except data which cannot be linked to the individual,
- An encrypted password system will be used and assigned new passwords will be defined and changed based on the security policy,
- Sharing with other systems will be possible only over a secure network,
- Shared and/or transferred data will be protected under the same conditions in the corresponding systems.

6.6 Data Confidentiality

Within one year after the conclusion of the pilot trials, a summary of the results should be made publicly available. This summary should include information on the primary outcome, of any secondary outcome and statistical analyses. All data should be recorded according to standards procedures.

MARIO users participate voluntarily in pilot activities with the assurance of help to improve scientific knowledge about their disease and related therapeutic innovations. Therefore, with the publication of the results the researchers meet the ethical obligation to users enrolled, as defined by the Declaration of Helsinki (more information in Section 6.6.1). The publication of all results from the pilot activities and reduction in reporting bias will help produce more reliable systematic reviews on the efficacy and safety of health interventions.

The summary of the results of a pilot activity should contain at least the items provided by the results page clinicaltrials.gov: summaries of the participants, the original protocol, and any corrections, summary of the results for the primary endpoint and secondary default, details of any adverse events and statistical analysis.

[11] http://domicalis.com/

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As already mentioned, data will be stored in triple stores and certain datasets will be made publicly available. However, personal data will be kept anonymous using the necessary encryption methods. To do that, named entities (such as proper nouns or organisations) will be detected and encrypted. Access to personal data will be allowed only to members of the consortium and according to the existing Consortium agreement. More information is provided in the sub-sections below.

6.6.1 Confidentiality Laws

MARIO partners should act in accordance to the following documents for data confidentiality:

- International regulations, such as the Nuremberg Code of 1949, the Declaration of Helsinki, 1980 OECD Recommendations of the Council Concerning guidelines Governing the Protection of Privacy and Trans-Border Flows of Personal Data etc.
- The legal documents by the European Union such as the Directive 95/46/EC of the European Parliament and of the Council (1995), Directive 2002/58/EC on Privacy and Electronic Communications (ePrivacy Directive), Directive 2006/24/EC on Data Retention (Data Retention Directive) the Handbook on European Data Protection Law (2013) etc. and,
- The relevant regulations and guidelines of all participating countries (e.g. Data Protection Guidelines on research in the Health Sector of Data Protection Commissioner of Ireland).

Moreover, each stakeholder involved in Pilot 1 should comply to the described confidentiality rules within the scope of the Data Management Plan.

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7 Conclusions and Summary

Since this document is concerned with the design of MARIO and in particular the hardware and software design of the robot system deployed within the MAARIO project to the pilot sites it is premature to provide a conclusion in advance of the design being used within the intended operating environment.

There is no doubt that designing systems for PwD is challenging both with respect to the interaction design and the physical design. The fact that MARIO must operate in unstructured everyday environments provides a significant navigation challenge that will require the best possible 3D mapping and localisation capability.

The design specified in this document is only concerned with the system interface level. Each partner in the project is tasked with providing sufficient and operational software and hardware to meet the challenges of the interaction and environment based on their existing platforms and experience.

The main added value in this document is the use of a user led design process with PwD. This is perhaps novel and only possible because of the clinical expertise within the consortium. The capture of desired system features provides some insight into the needs of PwD and their own perception of how technology can help in everyday tasks and the activities of daily living.

This document sets out the initial features and architecture for MARIO. Feedback from the trails and from further experimental interactions will shape the direction of development that precedes the second and third trails.

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8 Appendix A

8.1 Table Headings

8.1.1 Requirement's Source

Each requirement is marked with a symbol to indicate where the requirement is derived from:

O: Means the requirement came from User Interviews.

◆: Means the requirement came from the project proposal.

■: Means the requirement was derived from other requirements or from a distillation of several lesser requirements.

: Means the requirement has been added during the review phase.

8.1.2 Primary Technology

Notes the primary technology, or technologies that will implement the requirement. These should be high level statements rather than the details of a particular technology method. For example:

> "2.2.3 It must be possible to personalise the system for a specific user."
>
> *Primary Technology*: Database, Touch Screen UI.

All requirements will require some technology to implement them. However this column should **only** be used where there is a strong relationship between a technology and the requirement.

8.1.3 Technical Status

The following technical status indicators show the basic technical status of each requirement.

The notes column can be used to provide more detail if this is necessary.

NP	It is believed that achieving the requirement as stated is not possible with technology available within the Mario project nor is it possible to perform the research needed to make it possible.
RES	The requirement contains a significant element of research that must be carried out within the project to achieve the requirement.
INT	The requirement can be met through the integration of existing technology available to the project.
OTS	The requirement can be met using "Off The Shelf" components or system modules.
NK	The technical status of the requirement cannot be stated without investigation.

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8.2 Key Requirement Summary

1.1 The system must improve outcomes for the user. 92
1.2 The system must work within the team of care givers and staff 93
1.3 The system must carry out monitoring and assessment of the user 93
1.4 The system should operate using the best ethical principles that are applicable to the application. 94
1.5 The system must execute a range of different applications 96
1.6 The system must have the ability to be configured. 97
1.7 The System must operate with a high level of dependability. 97
1.8 The system must be able to move within the operating environment. 99
1.9 The system must be able to perceive its operating environment. 101
1.10 The system must be able to perceive and assess the user. 102
1.11 The system must show cognitive ability in its operation. 106
1.12 The system must be able to adapt over time to the operating environment. . 108
1.13 The system must be able to adapt over time to the user. 109
1.14 The system must provide connectivity internally and externally from the operating environment. 110
1.15 The system must be able to interact with the user. 111
1.16 The system will be able to make autonomous decisions. 113
1.17 The system must show social ability in its operation 115
1.18 The system should provide a detachable device to communicate with the user. (See 5.10 for physical requirements) 116
1.19 The system should be able to detect specific objects within its operating environment. 117
1.20 The system should be sensitive to ethical concerns in its storage and use of data (See 1.4). 117
1.21 The system must be able to perform time and calendar based functions 119
1.22 The system must be able to perform functions based on location. 121
1.23 The system must be able to perform functions relating to people. 122
1.24 The system must be able to carry out environmental control functions. 123
1.25 The system must be able to carry out medical assessment. 124
1.26 The system must be able to carry out communication based functions. 125
1.27 The system must be able to entertain the user. 126
1.28 The system must be able to provide reminiscence stimulation to the user. .. 128
1.29 The system must be able to prompt the user to undertake life pattern actions. 129
1.30 The system must be able to monitor life patterns (see 2.6.3.4) 129
1.31 The system must be able to guide the user through a sequence of actions step by step. 129
1.32 The system must be able to log usage. 130
1.33 The system must have an understanding of spoken language. 130
1.34 The system must recognise when the user is attending to the system. 131
1.35 The system must be able to recognise the user 132

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1.36 The system must provide flexibility in the flow of user interactions. 133
1.37 The system should be able to engage with people other than the user in the operating environment. 133
1.38 The system must be composed of mechanical components appropriate to the application. 134
1.39 The system must be able to present information to the user. 134
1.40 The system must be able to accept input from the user. 135
1.41 The system must be able to communicate with devices in the environment. 135
1.42 The system must be able to sense the environment. 135
1.43 The system must be able to sense the user. 136
1.44 The system must be able to communicate within the operating environment. 137
1.45 The system must be able to communicate externally to the operating environment. 137
1.46 The system must be able to execute applications. 137
1.47 The system must provide a detachable device the user can use when away from the platform (See 2.13 for system requirement) 138
1.48 The system should be able to operate while charging. 138
1.49 The system touch screen must be adjustable. 139
1.50 The system must provide a high level of operational availability. 139
1.51 The System must comply with regulations necessary for the legal operation. 139
1.52 The system should comply with prevailing standards relevant to its operation. 140
1.53 The system must keep a log of failures. ■ 140
1.54 The system must fail safe. ◆ 140
1.55 The system must be capable of operating for up to 2 weeks without service 141
1.56 The system must have a remote control capability so that it can be controlled moved remotely. 141
1.57 The system must be able to accept push updates. 141

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System Functional Goals

Words or phrases in italics refer to terms defined in the Glossary.

1.1 The system must improve outcomes for the user.

Requirements	*Status*	*Notes*	*Prime.Tech.*	*Tech. Status*
1.1.1 The system must mitigate the effects and severity of dementia.	◆			
1.1.2 The system should improve retention of the user's cognitive capacity.	◆			
1.1.3 The system should reduce social exclusion.	◆			
1.1.4 The system should be designed to combat or alter the perception of loneliness for the user.	◆	*The system must enable the connection to others through its social media platforms. The system also has to be able to engage with the persons interests, for example play music that they like, read a book.*		
1.1.5 The system should be designed to increase the resilience of the user	○◆■	*The system builds internal resilience by helping maintain cognitive capacity. External assets are part of resilience and are part of connecting to others.*		
1.1.6 The system must strengthen personal attributes.	○◆■			
1.1.7 The system must act as a companion using a user centred "Mutual Care" approach.	◆			
1.1.8 System should promote acceptance of	◆			

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the "changing self".				
1.1.9 The system must enhance the user's connectedness.	◆			
1.1.10 The system should act as a companion to the user.	◆			
1.1.11 The system must integrate behavioural, social and cognitive skills.	○◆■			

1.2 The system must work within the team of care givers and staff

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.2.1 The system must help care givers and staff in their tasks.	◆			
1.2.2 The system must help to improve care team communication.	◆			
1.2.3 The system must aid in the checking of rehabilitation plans.	◆			
1.2.4 The system must operate in coordination between the user, care providers and the community	◆			

1.3 The system must carry out monitoring and assessment of the user

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.3.1 The system must monitor the user's daily living patterns and	◆			

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habits.				
1.3.2 The system must be able to detect changes in the user's daily living patterns and habits.	◆			
1.3.3 The system must contribute to the evaluation of behavioural change in the user.	◆			
1.3.4 The system must be able to contribute to the Comprehensive Geriatric Assessment (CGA) of users.	○◆			
1.3.5 The system must contribute useful data to the construction of a Multi-Dimensional Prognosis Index (MPI) for the user.	◆			
1.3.6 The system must contribute to the evaluation of an MPI for the user.	◆			
1.3.7 The system must provide a more precise characterisation of the user.	○◆■			

1.4 The system should operate using the best ethical principles that are applicable to the application.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.4.1 The system must interact with the user in a way that is compatible with the ethical treatment of people				

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with dementia.				
1.4.1.1 The system must avoid interactions that objectify the user.				
1.4.1.2 The system must avoid interactions that infantilise the user.				
1.4.1.3 The system must avoid actions that increase the frailty of the user.				
1.4.1.4 The system must avoid interactions with the user that create an unethical bond.				
1.4.2 The appearance of the system must not unnecessarily increase anthropomorphic attachment.				
1.4.3 The functioning of the system must be designed to respect the privacy of the user.				
1.4.3.1 The system must not invade the user's privacy.				
1.4.3.2 The system must conform to ethical guidelines when using vision sensors.				
1.4.3.3 The system must protect the privacy of personal data held within the system.				
1.4.4 The system must protect the user data stored in the system in an ethical way.				
1.4.5 The system must allow access to the user data stored in the system in an				

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ethical way.				
1.4.6 The system must adhere to any applicable ethical codes of practice when used in a clinical setting.				

System Operational Requirements

1.5 The system must execute a range of different applications

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.5.1 The system must decide which application to run.	○◆			
1.5.1.1 The system must run applications appropriate to the user.	■			
1.5.1.2 The system must run applications at an appropriate time.	■			
1.5.2 The system must be able to allow the user to choose which application to run.	■			
1.5.3 The system must allow the user to choose when applications run.	■			
1.5.3.1 The user must be able to start and stop the system from operating.	■			
1.5.4 The system must be able to execute additional applications.	◆			
1.5.4.1 The system must be able to download additional applications.	◆			
1.5.4.2 The system must support the development of new applications.	◆			
1.5.4.3 The system must be able to support 3rd party applications.	◆			

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1.6 The system must have the ability to be configured.

Requirements	Status	Notes	Prim. Tech.	Tech. Status
1.6.1 The system should be composed of configurable modules.	○◆			
1.6.2 The system must be able to configure applications.	■			
1.6.2.1 It must be possible to select which applications run for each user.	■			
1.6.2.2 It must be possible to vary the configuration of each application per user.	■			
1.6.2.3 The system must allow the configuration of any additional applications.	■			
1.6.3 It must be possible to personalise the system for a specific user.	○◆			
1.6.3.1 It must be possible to configure a set of life data for a user.	○			
1.6.3.2 It must be possible to configure the spoken voice used by the system for the user.	○			
1.6.3.3 It must be possible to configure a set of personal preferences for the user.	○◆			
1.6.4 It should be possible to personalise the system for multiple specific users.	○◆			

1.7 The System must operate with a high level of dependability.

Requirements	Status	Notes	Prim. Tech.	Tech. Status
1.7.1 The system must operate safely within its	○◆			

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operating environment.				
1.7.2 The system must be robust within its *operating environment.*	◆			
1.7.3 The system must be reliable within its *operating environment.*	◆			
1.7.4 Moved to 2.15				
1.7.5 Moved to 2.15				
1.7.6 Moved to 2.15				
1.7.7 The system must be capable of operating 24/7. *This requires quantification: Day and Night operation must also allow for recharging time*	◆	*Important as people with dementia may wander at night, needs to recharge quickly*		
1.7.8 The system development must employ an ethical approach. *This will require an ethics based assessment of operation and design*	◆			
1.7.8.1 There must be an ethical approach to the design of data structures.	■			
1.7.8.2 There must be an ethical approach to data storage.	■			
1.7.8.3 There must be an ethical approach to data access.	■			
1.7.8.4 There must be an ethical approach to the design of the user interaction.	■			
1.7.8.5 There must be an ethical approach to the design of behaviours.	■			
1.7.9 The system must be able to withstand				

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environmental hazards				
1.7.9.1 The system must be able to withstand getting wet. *Needs careful definition of withstand and "getting wet".*				
1.7.9.2 The system must withstand being bumped. *Needs careful definition of withstand and "being bumped"*				
1.7.9.3 The system must withstand being pushed. *Needs careful definition of withstand and "being pushed"*				

1.8 The system must be able to move within the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.8.1 The system must be able to move within in an everyday dynamic *operating environment*.	○ ◆	*May be uneven surfaces, doors to get through*		
1.8.2 The system must operate in both care and home environments.	○ ◆			
1.8.3 The system must work appropriately within the context of an assisted living environment.	◆			
1.8.3.1 The system must be able to operate in an environment with visually impaired users.	■			
1.8.3.2 The system must be able to operate in an environment with physically impaired users.	■			
1.8.3.3 The system must be able to operate in an environment with hearing impaired users.	○			

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1.8.4 The system must be able to follow the user.	○◆			
1.8.4.1 The system must be able to follow the user in a way that is compatible with social context.	■			
1.8.4.2 The system must follow the user so that it does not impede their movement.	■			
1.8.5 The system must be able to explore its *operating environment*.	○◆			
1.8.5.1 The system must know where it is in the *operating environment*.	○◆			
1.8.5.2 The system must know where the boundaries of the *operating environment* are.	■			
1.8.5.3 The system must remain within the operating environment.	■			
1.8.6 The system must be able to navigate around the *operating environment*.	○◆			
1.8.6.1 The system must be able to navigate to specific locations.	○◆			
1.8.6.2 The system must be able to recognise that it cannot reach a specific location without assistance.	○◆			
1.8.7 The system must be able move in the *operating environment* without causing damage.	○◆			
1.8.8 The system must be able to move so that it is oriented to the user.	■			
1.8.8.1 The system must be able to move so that	■			

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it faces a seated user.				
1.8.8.2 The system must be able to move so that it faces and orients to a standing user.	■			

1.9 The system must be able to perceive its operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.9.1 The system must be able to perceive structural features in its operating environment.	■			
1.9.1.1 The system must be able to recognise openings which are traversable.	■			
1.9.1.2 The system must be able to perceive features of the operating environment with persistence over time.	■			
1.9.1.3 The system must be able to update its perception of the environment in a timely manner.	■			
1.9.1.4 The system must be able to distinguish the user, as an entity, from the operating environment.	■			
1.9.1.5 The system must be able to perceive its location in the operating environment.	○◆			
1.9.1.6 The system must be able to perceive points of contact with the operating environment.	○◆			
1.9.1.7 The system must be able to perceive points of contact with the user.	○◆			
1.9.1.8 The system must be able to predict points of contact in the operating environment.	■			
1.9.1.9 The system must be able to predict points	■			

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of contact with the user.				
1.9.2 The system must be able to gather data from ambient sensors in the environment.	◆			
1.9.2.1 The system must be able to identify ambient sensors in the operating environment.	■			
1.9.2.2 The system must be able to interpret the data from ambient sensors in the operating environment within the current operating context.	■			
1.9.2.3 The system should be able to make use of immediate data from ambient sensors in the environment.	■			
1.9.2.4 The system may be able to make use of historic data from ambient sensors in the environment.	■			
1.9.2.5 The system should make use of ambient sensors to help monitor the user.	◆			
1.9.2.6 The system should be able to use ambient sensors to help monitor specific objects in the environment.		*See also 2.15*		

1.10 The system must be able to perceive and assess the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.10.1 The system must be able to recognise an individual user within the operating environment.	○◆			
1.10.2 The system must be able to locate an individual user within the operating environment.	○◆			

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1.10.3 The system must be able to monitor and assess the daily living processes of the user.	◆			
1.10.3.1 The system must be able to track the user in the operating environment.	■			
1.10.3.2 The system must keep a record of the user's significant movements in the operating environment.	■			
1.10.3.3 The system must keep a record of *significant events* that occur.	■			
1.10.3.4 The system must keep a record of the user's *living pattern*.	◆	*The system needs to know that the user is receiving care or attending to personal hygiene or talking to someone else*		
1.10.3.5 The system must be able to provide a summarised report on the user's *living pattern* to the care staff.	◆			
1.10.4 The system must be able to monitor and assess the health of the user.	○◆			
1.10.4.1 The system should be able to capture *vital signs* measurements from the user.	○◆			
1.10.4.2 The system should be able to make assessments of the *health state* of the user based on *vital signs* measurements.	■			
1.10.4.3 The system should be able to recognise *health patterns* within the user's health	■			

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data.				
1.10.4.4 The system must be able to build up a health profile of the user based on the assessment of *vital signs* and *health patterns*.	■	*including cognitive decline*		
1.10.4.5 The system must be able to carry out health monitoring over long periods of time.	◆			
1.10.5 The system must be able to contribute to the integration of assessment data leading to an assessment of health.	◆			
1.10.5.1 The system must be able to communicate health profiles to the care staff.	○◆			
1.10.5.2 The system must be designed to produce reliable health monitoring data.	■			
1.10.6 The system should be able to detect the *emotional state* of the user within defined contexts.	○◆			
1.10.7 The system should be able to interpret the *emotional state* of the user in defined contexts.	○◆			
1.10.8 The system must be able to monitor and assess the food intake of the user.	◆			
1.10.8.1 The system should be able to detect that the user has had a meal.	■			
1.10.8.2 The system should be able monitor the fluid intake of the user.	◆			
1.10.8.3 The system should be able to assess the	■			

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regularity of meal taking.				
1.10.8.4 The system should be able to assess the regularity of fluid intake.	■	*should be able to prompt user if they have not eaten in a specified period of time {see proposed 3.9}*		
1.10.9 The system must be able to recognise a set of defined *critical events.*	■			
1.10.10 The system must be able to recognise what is within the *user's environment.*	■			
1.10.11 The system should be able to assess the user's state of consciousness.	■			
1.10.12 The system must to be able to perceive the physical state of people in the operating environment.	○			
1.10.12.1 The system must be able to perceive that a person is sitting down.	■			
1.10.12.2 The system must be able to perceive that a person is standing.	■			
1.10.12.3 The system must be able to perceive that a person is lying down.	■	*The system should be able to monitor movement over time and encourage person to exercise {See proposed 3.9}*		
1.10.13 The system needs to be able to recognize abnormal physical states of users.	■			

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1.10.13.1 The system should be able to detect that the user has fallen over.	○			
1.10.13.2 The system should be able to detect that the user has remained motionless for a period of time.	■			
1.10.13.3 The system should be able to detect that the use has an abnormal posture either while sitting or standing.	○			

1.11 The system must show cognitive ability in its operation.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.11.1 The system must show cognitive ability in its user interaction.	◆			
1.11.2 The system must show cognitive ability in its behaviours.	◆			
1.11.3 The system must use *cognitive ability* to enhance its interaction with the operating environment.	◆			
1.11.4 The system must use semantic knowledge to enhance its operation.	◆			
1.11.4.1The system must be able to use semantic knowledge to improve user interaction.	◆			
1.11.4.2The system must be able to use semantic knowledge when interpreting the operating environment.	◆			
1.11.4.3The system should be able to use semantic knowledge to interpret text in the context of the operating environment.	◆			
1.11.5 The system should use stored knowledge to	◆			

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enhance its operation.				
1.11.5.1 The system must use stored knowledge to enhance its behaviours.	◆			
1.11.5.2 The system should use stored knowledge to interpret the operating environment.	◆			
1.11.5.3 The system should use stored knowledge to enhance user interaction.	◆			
1.11.6 The system must be able to utilise cognitive knowledge to enhance its operation.	◆			
1.11.6.1 The system must be able to utilise cognitive knowledge of relevant objects in the operating environment.	■			
1.11.6.2 The system should be able to utilise cognitive knowledge when interpreting data gained from ambient sensors.	■			
1.11.6.3 The system should be able to utilise cognitive knowledge related to periodic events.	■			
1.11.6.4 The system should be able to utilise cognitive knowledge of user needs.	■			
1.11.6.5 The system should be able to utilise cognitive knowledge of life events.	■			
1.11.7 The system should be able to add to its knowledge by integrating new information.	○◆			
1.11.7.1 The system should be able to add to its knowledge by integrating information gained through interaction with the user.	○◆			
1.11.7.2 The system should be able to add to its knowledge by integrating new information gained through interaction with the environment.	○◆			

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1.11.7.3 The system should be able to add to its knowledge by integrating new information gained through interaction with other systems.	◆			
1.11.8 The system must be able to utilise the outcome of interaction with the *operating environment* to improve future interactions.	○◆■			
1.11.9 The system must be able to utilise the outcome of interaction with the user to improve future interactions.	◆			
1.11.10 The system must be able to utilise *shared knowledge* when communicating with other systems.	◆			
1.11.10.1 The system should be able to access a repository of shared *cognitive knowledge*.	◆			
1.11.10.2 The system should be able to share its internal knowledge with other systems.	◆			
1.11.11 The system must integrate multiple sources of data and multiple methods of data integration to acquire knowledge.	◆			
1.11.12 Multiple instances of the system must be able to share learned knowledge.	◆			

1.12 The system must be able to adapt over time to the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.12.1 The system should be able to recognise and discover interaction and behavioural patterns within its interaction with the operating environment and use these to	○◆			

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enhance its interaction.				
1.12.2 The system should be able to recognise and discover interaction and behavioural patterns within its interaction with the user and use these to enhance its interaction.	◆			

1.13 The system must be able to adapt over time to the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.13.1 The system should be able to adapt to user preferences over time.	○◆			
1.13.2 The system should increase the level of personalisation to the user over time.	◆			
1.13.3 The system should increase the level of personalisation to care staff over time.	■			
1.13.4 The system must be able to adapt its behaviours to the user over time.	◆			
1.13.5 The system should utilise learning to improve its performance.	◆			
1.13.5.1 The system should learn through interaction with the user.	◆			
1.13.5.2 The system should use learning to modify its behaviours.	◆			
1.13.5.3 The system should use learning to increase its knowledge of the user.	◆			
1.13.5.4 The system should use learning to become more personable over time.	◆			
1.13.5.5 The system should use learning to	◆			

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become more acceptable over time.				
1.13.6 The system should be able to learn over long periods of time.	■			
1.13.7 The system must be able to alter its behaviour and interaction in response to the user's emotional state.	◆			
1.13.8 The system should be able to modify its social skills through interaction with the user. *System modifies its social skills by interacting with the user for example learning during a conversation.*	◆	*how it interacts;*		

1.14 The system must provide connectivity internally and externally from the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.14.1 The system must provide connectivity between the user and the care team.	◆			
1.14.2 The system must provide connectivity between the user and their friends and family.	○◆			
1.14.3 The system must provide connectivity to the user's social network.	○◆			
1.14.4 The system must be able to connect the user to their medical provider.	◆			
1.14.5 The system must be able to connect the user to their local community.	○◆			
1.14.6 The system must provide connectivity to the community social services.	◆			

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1.14.7 The system must be able to connect a user to services related to their personal interests.	○ ◆			
1.14.8 It should be possible to configure personal preferences.				
1.14.8.1 It may be possible to extract preferences from social media accounts.				
1.14.8.2 The system should provide a way for user preferences to be entered by friends and family.				
1.14.8.3 The system should provide a means for the user to enter their personal preferences				
1.14.8.4 It should be possible to pre-configure personal preferences *In a hospital setting where there is minimal opportunity to configure the robot it may be possible to pre-configure based on gender and age.*				
1.14.9 The system must be able to connect to a local network to gain access to local resources and assets.	■			
1.14.10 The system must be able to connect to the internet.	■			
1.14.11 The system must provide information about the user to the medical community.	◆			

1.15 The system must be able to interact with the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*

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1.15.1 The system must be able to establish a personalised interaction with each individual user.	○◆	*The system needs to know that the user is receiving care or attending to personal hygiene or talking to someone else*		
1.15.2 The user interaction must be at a level appropriate for each user.	■			
1.15.3 The system must be able to start an interaction with the user.	○◆			
1.15.4 The system must be able to interact with users using natural language.	○◆			
1.15.5 The system must interact in ways that are appropriate to the users' cognitive condition.	■			
1.15.6 The system must be able to interact with users using speech.	○◆			
1.15.7 The system must be able to interact with users non-verbally.	○◆			
1.15.8 The system must be able to attract the attention of the user.	■			
1.15.9 The system must be able to make emotional expressions.	○◆			
1.15.10 The system must be able to interact in response to the user's emotional state.	○◆			

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1.15.11 The system must allow users to access and manage the information repositories within the system.	◆			
1.15.12 The system must have a core repository for user interactions.	■			
1.15.13 The system must be friendly when interacting with users.	○◆			
1.15.14 The system must interact with users in a way that is acceptable to the user.	○◆			
1.15.15 The system must have the ability to engage in a “mutual care” interaction with the user.	◆			
1.15.16 The system must be able to utilise multi-modal interactions with the user.	○◆			
1.15.17 The system will have a wide range of different and appropriate interactions with the user.	◆			
1.15.18 The system must be able to exhibit a range of different interaction behaviours.	◆			

1.16 The system will be able to make autonomous decisions.

Requirements	*Status*	*Notes*	*Prim.Tech.*	*Tech. Status*
1.16.1 The system must be able to alter its behaviours based on its specific location.	◆			
1.16.2 The system must be able to alter its	○◆			

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behaviours based on the identity of the user it is interacting with.				
1.16.3 The system must be able to alter its behaviours based on responses from the user it is interacting with.	○ ◆			
1.16.4 The system must be able to utilise knowledge of its environment in making decisions.	○ ◆			
1.16.5 The system must be able to make decisions about the health of the user it is interacting with.	○ ◆			
1.16.6 The system must be able to make decisions based on the emotional state of the user it is interacting with.	○ ◆			
1.16.7 The system must make decisions to alter its behaviour that are beneficial to the user.	○ ◆			
1.16.8 The decisions that the system makes must be made within an ethical framework for interaction.	○ ◆			
1.16.9 With respect to its decision making the system must embody the concept of "dynamic informed consent". *"Dynamic informed consent", refers to the ability of the system to be configured by the user such that it conforms to their consented preferences. This impacts on aspects of operation from data access to which functions are performed and how the system interacts.*	◆			

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1.16.9.1 The system needs to provide a means to allow the user's preferences to be enacted within the system.				
1.16.9.2 It must be possible to select the functions carried out by the system on a per user basis. *It is likely that an assessment process will be needed to select the most relevant functions for a particular user and to then periodically review the selection.*				
1.16.9.3 It must be possible for users to decline access to their personal data. *Even though they may have consented to its use by the system.*				
1.16.10 The system must perform socially and physically appropriate behaviours that are helpful to the user.	◆			

1.17 The system must show social ability in its operation

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.17.1 The system must show social ability when interacting with the user				
1.17.2 The system must show social ability in its behaviours				
1.17.3 The system must use social knowledge in its decision making				
1.17.4 The system must show social ability when interacting with the operating environment.				

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1.18 The system should provide a detachable device to communicate with the user. (See 5.10 for physical requirements)

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.18.1 The detachable device must provide the user				
1.18.2 The detachable device must provide the user with appropriate “remote applications” when separated from Mario.				
1.18.3 The usage mode of the “remote applications” must have usefully similar interactions to the equivalent applications on Mario.				
1.18.4 The detachable device must be able to synchronise data relevant to the remote applications from Mario.				
1.18.5 The detachable device must be able to synchronise relevant data back to Mario.				
1.18.6 The detachable device must have a visual interface that is sufficiently similar to the display on Mario.				
1.18.7 The detachable device should provide auditory feedback to the user.				
1.18.8 The detachable device may provide audio input.				
1.18.9 The detachable device should provide a communication capability.				

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1.19 The system should be able to detect specific objects within its operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.19.1 The system must be able to identify objects specific to the user.				
1.19.1.1 The system must be able to register a number of specific objects as belonging to the user.				
1.19.1.2 The system must be able to identify objects that belong to the user.				
1.19.2 The system must have the ability to search for a specific object in the operating environment.				
1.19.3 The system must be able to indicate to the user where the object is in the operating environment.				
1.19.4 The system must be able to respond to defined “place” questions about a user’s specific objects.				

1.20 The system should be sensitive to ethical concerns in its storage and use of data (See 1.4).

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.20.1 The system must protect private data.				
1.20.2 The system may be able to detect				

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circumstances when ethical concerns exist in the operating environment.				
1.20.3 The system must provide appropriate data privacy measures for user data stored within it.	○ ◆			
1.20.3.1 The system must restrict access to user data to *authorised people*.	■			
1.20.3.2 The system must isolate data for each user.	○ ◆			
1.20.4 The system must maintain user privacy with respect to data captured by the system.	◆			
1.20.4.1 The system must not permanently store video.	■			
1.20.4.2 The system must restrict access to information about each user that is gathered during operation.	■			
1.20.4.3 Access to system video sources must be not be possible by external access.				
1.20.5 The system must address all appropriate data safety issues *These will need to be identified and catalogued.*	◆	*A major issue for people*		
1.20.6 The system must ensure that aggregating data from multiple sources does not create a breach of consent.				
1.20.7 The system must ensure that access to private data is logged				
1.20.8 The system must ensure that access to				

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private data is only given to authorised users				
1.20.9 The system must clearly indicate to a user when they are accessing private user data.				

Function Requirements

1.21 The system must be able to perform time and calendar based functions

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.21.1 The system must be able to answer questions about the time and day.	O ◆			
1.21.1.1 The system must be able to respond to the user with the time of day.	O			
1.21.1.2 The system must be able to respond to the user with the day of the week.	O			
1.21.1.3 The system should be able to respond to the user with relative time information.	O			
1.21.2 The system is able to tell the user what is happening today.	O ◆			
1.21.2.1 The system is able to announce to the user events stored in an internal diary.	O			
1.21.2.2 The system is able to announce to the user daily events.	O			
1.21.2.3 The system is able to announce to the user that an event is about to happen.	O			
1.21.2.4 The system is able to announce to the user information about external events	O			

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of interest to the user.				
1.21.2.5 The system must be able to announce events that relate to the user's family.	○			
1.21.2.6 The system must be able to announce events that relate to the user's interests.	○			
1.21.3 The system is able to prompt the user about regular daily events.	○◆			
1.21.3.1 The system is able to remind the user to take a drink at appropriate times during the day.	○◆			
1.21.3.2 The system should remind the user to eat at the appropriate time.	○◆			
1.21.3.3 The system should remind the user to sleep at the appropriate time.	○◆			
1.21.3.4 The system should remind the user when to take medication		Rejected, will invoke medical device status		
1.21.3.5 The system is able to remind the user at appropriate times about specific events or activities taking place during the day.	○◆			
1.21.3.6 The system must be able to remind the user that an important event is going to happen.	○◆			
1.21.3.7 The system must be able to remind the user that an activity needs to take place.	◆			
1.21.3.8 The system should be able to respond to questions about what will happen	○			

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during the day.				
1.21.4 The system should be able to record the events of each day based on what has happened.	○			
1.21.4.1 The system should be able to respond to questions about the events that have happened during the day.	○			
1.21.4.2 The system should be able to respond to questions about people the user has encountered during the day.	○			
1.21.4.3 The system should be able to construct a simple story about what happened during the day based on where the user was, what events took place and who they encountered.	○			
1.21.5 The system should allow authorised users to make changes to the event diary.	■			
1.21.6 The system must act appropriately depending on the time of day.	○◆			

1.22 The system must be able to perform functions based on location.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.22.1 The system must be able to use user centric naming of location and place.	○			
1.22.1.1 The system must be able to name the room it is in.	○			
1.22.1.2 The system must know the names of other rooms in the operating environment.	○			
1.22.1.3 The system must know the spatial	○			

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relationship between rooms in the operating environment.				
1.22.2 The system must know the semantic properties of the operating environment.	○			
1.22.2.1 The system must know the properties of the doors in the environment.	○			
1.22.2.2 The system must know the semantic properties of the rooms connected to the current room.	○			
1.22.3 The system must be able to answer user questions about location.	○			
1.22.3.1 The system must be able to announce which room it is in.	○			
1.22.3.2 The system must be able to answer defined questions about a door specified by the user.	○			
1.22.3.3 The system must be able to answer defined questions about a room specified by the user.	○			

1.23 The system must be able to perform functions relating to people.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.23.1 The system must be able to identify a specific user in the *operating environment*.	○◆			
1.23.2 The system must be able to identify the known people in the *user's immediate environment*.	○◆			

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1.23.2.1 The system must be able to respond to questions about the people in the users' immediate environment.	○			
1.23.2.2 The system must be able to respond to questions that relate people to locations.	○			
1.23.3 The system must be able to respond to the emotional state of the user.	○◆	Note linkage to 1.1.4		
1.23.3.1 The system should be able to respond to the user being lonely.				
1.23.4 The system should be able to prompt the user during a verbal exchange.	○			
1.23.4.1 The system should be able to show the face and name of people in the user's environment.	○			
1.23.4.2 The system should be able to display images of objects mentioned by the user during a conversation.	○			

1.24 The system must be able to carry out environmental control functions.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.24.1 The system must be able to control devices within the *user's environment.*	○◆			
1.24.1.1 The system must know the devices that can be controlled in the *user's environment*.	■			
1.24.1.2 The system should be able to discover the devices that can be controlled in the *user's environment*.	■			
1.24.1.3 The user must be able to request that a	○			

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device be turned on or off.				
1.24.1.4 The user must be able to request that the device changes its operating mode.	○			
1.24.1.5 The user must be able to request that the device changes its settings.	○			
1.24.1.6 The system must be able to control a variety of devices with different types of control interfaces.	■			

1.25 The system must be able to carry out medical assessment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.25.1 The system must be able to assess the health of the user.	◆			
1.25.2 The system must assist caregivers and staff in carrying out CGA.	○◆			
1.25.2.1 The system must be able to detect changes in health based on the methods within the CGA approach.	◆			
1.25.2.2 The system should be able to autonomously perform parts of the CGA assessment.	◆			
1.25.3 The system must be a tool for enabling the evaluation of users using MPI.	◆			
1.25.3.1 The system may be able to carry out MPI.	◆			
1.25.3.2 The system should facilitate the evaluation of MPI.	◆			
1.25.3.3 The system should be able to use speech metrics to assess the “sentiment” of the user.				

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1.26 The system must be able to carry out communication based functions.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.26.1 The system must be able to establish a connection to a person whose details are kept in a contact database.	○ ◆			
1.26.1.1 The system must only connect to a person that is associated with the current user.	■			
1.26.1.2 The system must be able to contact a specific person when a *critical event* occurs.	○ ◆			
1.26.2 The system must be able to provide audio communication with people outside of the operating environment.	○	*Use of skype and social media*		
1.26.2.1 The system must be able to provide audio communication between the user and a person associated with the current user.	○			
1.26.3 The system must be able to provide visual communication with people outside of the operating environment.	○			
1.26.3.1 The system should be able to provide visual communication between the user and a person associated with the current user.	○			
1.26.4 The system must be able to communicate with care staff.	○ ◆			
1.26.4.1 The system must be able to communicate its location to care staff.	○ ◆			

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1.26.4.2 The system must be able to communicate the state of the user to care staff.	○ ◆			
1.26.4.3 The system must be able to communicate health monitoring data to care staff.	■			

1.27 The system must be able to entertain the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.27.1 The system must be able to provide audio entertainment to the user.	○			
1.27.1.1 The system must be able to play audio for the user.	○			
1.27.1.2 The system must learn what type of audio entertainment the user likes.	○			
1.27.1.3 The system must be able to play audio entertainment appropriate to the time of day.	■			
1.27.1.4 The system must let the user select the audio entertainment to be played.	■			
1.27.1.5 The system must be able to respond to requests to control the playing of audio entertainment.	■			
1.27.2 The system must be able to provide visual entertainment to the user.	○			
1.27.2.1 The system must be able to show a video to the user.	○			
1.27.2.2 The system must learn what types of video entertainment the user likes.	○			

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1.27.2.3 The system must let the user select a video to be shown.	■			
1.27.2.4 The system must be able to respond to requests to control the playing of the video.	■			
1.27.3 The system must be able to play a game with the user.	○			
1.27.3.1 The user must be able to select a game to be played.	○			
1.27.3.2 The game must be played at a level appropriate to the user's cognitive ability.	○			
1.27.3.3 The system should be able to play multi-player games.	○			
1.27.3.4 The system must be able to play games that are designed to stimulate cognition.				
1.27.4 The system must be able to read text to the user.	○	*This includes reading an audio book*		
1.27.4.1 The system must be able to read from text stored in the system.	○			
1.27.4.2 The system should be able to read text from sources external to the system.	○			
1.27.4.3 The system must be able to learn the favourite texts for a user.	○			
1.27.5 The system must be able to identify occasions where offering to entertain the user is socially appropriate.	■			

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1.28 The system must be able to provide reminiscence stimulation to the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.28.1 The system must be able to select *reminiscence material* appropriate to the user.	○			
1.28.1.1 The system must be able to select reminiscence material from an internal store of generic material.	○			
1.28.1.2 The system must be able to select reminiscence material from an internal store of material specific to the user.	○			
1.28.2 The system must be able to offer to show reminiscence material to the user.	○			
1.28.2.1 The system must offer to show reminiscence material in an appropriate context.	■			
1.28.2.2 The system must allow the user to select reminiscence material to be shown.	■			
1.28.3 The system must be able to interpret commands from the user to sequence the reminiscence material.	■			
1.28.4 The system must let the user choose specific reminiscence material.	○			
1.28.5 The system should keep a record each time it plays reminiscence material for the user.	■			

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1.29 The system must be able to prompt the user to undertake life pattern actions.

Requirements	Status	Notes	Prim. Tech.	Tech. Status
1.29.1 The system must be able to prompt the user to eat if they have not done so within a specified time period.				
1.29.2 The system must be able to prompt the user to drink if they have not done so within a specified time period.				

1.30 The system must be able to monitor life patterns (see 2.6.3.4)

Requirements	Status	Notes	Prim. Tech.	Tech. Status
1.30.1 The system should analyse the user's life pattern in order to decide when to recharge.				
1.30.2 The system may decide to recharge when the user is asleep				

1.31 The system must be able to guide the user through a sequence of actions step by step.

Requirements	Status	Notes	Prim. Tech.	Tech. Status
1.31.1 The system should be able to recognise which step the user is at in the sequence.				
1.31.2 The system should be able to recognise that the user has skipped a step.				
1.31.3 It should be possible to upload new sequences.				
1.31.4 It should be possible to personalise the sequencies				

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1.32 The system must be able to log usage.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.32.1 The system must be able to log the usage of each major application.				
1.32.2 The system must be able to log the words used by the user during interaction				
1.32.2.1 The system may be able to detect key words that indicate the emotional state of the user.				
1.32.2.2 The system should be able to count key words against a pre-loaded vocabulary.				
1.32.3 The system needs to monitor the usage of paths through the user interface.				

User Interaction Requirements

1.33 The system must have an understanding of spoken language.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.33.1 The system must use spoken language as the main form of interaction with the user.	○ ◆	*Must be clear and simple*		
1.33.2 The system must be able to understand the language patterns of people with various levels of cognitive impairment.	■			
1.33.3 The system must be able to understand speech patterns that contain regional accents.	○			
1.33.4 The system must be able to understand language patterns that contain regional characteristics.	○			

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1.33.5 The system needs to understand language relating to the following:				
1.33.5.1Time, events and the calendar.	○			
1.33.5.2Daily routine.	○			
1.33.5.3People, relatives, friends, family, carers, and visitors.	○			
1.33.5.4Pictures, images, photos.	○			
1.33.5.5Places within the working environment.	○			
1.33.5.6Basic personal medical descriptions.	○			
1.33.5.7User state including emotions.	■			
1.33.5.8Environmental control and device control.	■			
1.33.5.9Activities, reading, playing a game.	○			
1.33.5.10 Television and radio control.	○			
1.33.5.11 Reminiscence and historical events.	○			
1.33.5.12 Life events, birth, marriage, work.	○			

1.34 The system must recognise when the user is attending to the system.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.34.1 The system must be able to recognise when the user is speaking to it.	■			
1.34.2 The system must be able to recognise when the user is speaking to another person in the user's environment.	■			
1.34.3 The system must be able to recognise when other people are speaking.	■			

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1.34.4 The system must recognise when the user is not attending to the system.	■			

1.35 The system must be able to recognise the user

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.35.1 The system must be able to recognise the user.	○◆			
1.35.1.1 The system must be able to recognise the user's voice.	○◆			
1.35.1.2 The system must be able to recognise the user's face.	○◆			
1.35.2 The system must be able to recognise the user amongst other people.	○◆	*To differentiate user from others in a room*		
1.35.3 The system must be able to take part in interactions within the operating environment.	○◆			
1.35.3.1 The system must be able to take turns during communication.	■			
1.35.3.2 The system must be able to alter its responses based on location.	■			
1.35.3.3 The system must be able to alter its responses based on *social context.*	■			
1.35.3.4 The system must be able to personalise the interaction based on the identity of the user.	■			
1.35.4 The system must be able to recognize gestures made by the user in defined contexts.	○◆			

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1.35.4.1 The system must be able to use gesture recognition in conjunction with user speech to provide interpretation context.	■			
1.35.4.2 The system should be able to extract directional information from the user's gestures.	■			
1.35.4.3 The system should be able to extract positional information from the user's gestures.	■			

1.36 The system must provide flexibility in the flow of user interactions.

Requirements	*Status*	*Notes*	*Prim. Tech*	*Tech. Status*
1.36.1 The system must provide the ability to alter the phrases and messages communicated to the user during interactions.				
1.36.2 The system must provide flexibility in the interface flows to allow alternative paths to be taken by the user.				
1.36.3 The system must avoid extensive repetition in the user interface flow.				

1.37 The system should be able to engage with people other than the user in the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.37.1 The system should be able to engage in games which involve the user and others in the environment				
1.37.2 The system should be able to convers with non-users				
1.37.3 The system must be able to distinguish				

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between users and non-users in an interaction.				

Physical Requirements

1.38 The system must be composed of mechanical components appropriate to the application.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.38.1 The robotic part of the system will be integrated onto a single platform.	◆			
1.38.2 The system will require a charging mechanism.	O			
1.38.2.1 The system should recharge in 4 hours.		*needs to recharge quickly*		
1.38.3 The system display must be movable to match user preferences.	O	*See 5.12*		
1.38.4 There may be a detachable device the user can interact with when away from the platform.		*See 5.10*		

1.39 The system must be able to present information to the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.39.1 The system must have at least one user display.	O◆			
1.39.1.1 The system must have a user display capable of displaying videos.	O			
1.39.1.2 The system display must provide information related to the current application.	O			

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1.39.2 The system must have an audio output facility.	○◆			
1.39.3 The system must be able to display the system state.	■			
1.39.3.1 The system must be able to display the charge status of the battery.	■			
1.39.3.2 The system must clearly indicate if it is operational.	■			
1.39.4 The system must have a communications interface.	■			

1.40 The system must be able to accept input from the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.40.1 The system must have a user display that includes a touch panel.	◆			
1.40.2 The system must have an audio input.	◆			

1.41 The system must be able to communicate with devices in the environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.41.1 The system must be able to gather data from ambient sensors.	◆			
1.41.2 The system must be able to control devices in the environment.	○			

1.42 The system must be able to sense the environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.42.1 The system must be able to detect the	○			

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ambient temperature in the operating environment.				
1.42.2 The system should be able to detect an abnormally high temperature that might cause injury to the user in the operating environment.	○			
1.42.3 The system should be able to detect smoke.	○			
1.42.4 The system should be able to detect water in the environment.	○			
1.42.5 The system should be able to operate at in the dark.				

1.43 The system must be able to sense the user.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.43.1 The system should be able to measure the user's heart rate.	○			
1.43.2 The system should be able to measure the user's body temperature.	○			
1.43.3 The system must have a visual sensor that can observe the user.	○◆			
1.43.4 The system must have an audio sensor that can capture the user's vocalisations.	○◆			
1.43.5 The system must have a sensing system that can detect objects in its immediate environment.	○◆			
1.43.6 The system must have a sensing system	■			

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that can provide sufficient information to localise the robot within the operating environment.				
1.43.7 The system must be able to distinguish between day and night.	■			

1.44 The system must be able to communicate within the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.44.1 The system must be able to communicate with other instances of the system in the operating environment.	◆			
1.44.2 The system must be able to communicate with ambient sensors in the operating environment.	◆			
1.44.3 The system must be able to communicate to the care staff.	○◆			

1.45 The system must be able to communicate externally to the operating environment.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.45.1 The system must have access to the internet.	○◆			
1.45.2 The system must be able to establish audio communications with third parties.	○			
1.45.3 The system should be able to establish video communications with third parties.	○			

1.46 The system must be able to execute applications.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*

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1.46.1 The system must have a data and information processing system.	■			
1.46.2 The system should have access to a remote processing system.	■			

1.47 The system must provide a detachable device the user can use when away from the platform (See 2.13 for system requirement)

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.47.1 The detachable device must be able to charge from the platform when it is attached.				
1.47.2 The detachable device must be ergonomically compatible with the user				
1.47.3 The detachable device must have a data connection to the platform when it is attached				
1.47.4 It must be possible to update the systems on the detachable device from the platform when it is attached.				
1.47.5 The detachable device may also be the main display for the platform.				
Can we have a mobile device that person connects to Mario but can be used outside, has GPS but would have the shopping information				

1.48 The system should be able to operate while charging.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.48.1 The system should be able to carry out interaction with the user while charging.				

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1.48.2 The system should be able to observe the user while charging.				

1.49 The system touch screen must be adjustable.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.49.1 The system must have a touch screen that is adjustable in height as well as being able to extend outward toward the person rather than have the PWD having to lean in.				

1.50 The system must provide a high level of operational availability.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.50.1 The system should be capable of 24/7 operation.				
1.50.2 The system should manage when and where it recharges its batteries.				
1.50.3 The system must ensure that its battery does not run flat.				

Conformance with Regulations.

1.51 The System must comply with regulations necessary for the legal operation.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.51.1 The system must comply with CE marking standards.	■			
1.51.2 The system should comply with data protection	■			

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legislation				

1.52 The system should comply with prevailing standards relevant to its operation.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.52.1 The system should comply with the safety standards laid out in ISO 13482.	■			
1.52.2 The system will align to emerging ontology standards for robotics.	◆			
1.52.3 The system should conform with ethical guidelines.		(defined by who / separate for each country?)		

Service and Maintenance Requirements

1.53 The system must keep a log of failures. ■

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.53.1 The log of system failures must be available via a remote communication link.				

1.54 The system must fail safe. ◆

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.54.1 It should be possible to move the system by pushing it in the event of a system failure.				
1.54.2 It should be possible for the system to restart itself in the event of a				

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system failure.				
1.54.3 The system may be able to move itself to a safe location in the event of a system failure.				
1.54.4 The system must indicate to users that it has failed.				

1.55 The system must be capable of operating for up to 2 weeks without service

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.55.1 The system should be able to operate without physical servicing for more than 2 weeks.				
1.55.1.1The system may require remote servicing at intervals of 2 weeks.				
1.55.2 The system should keep a log of all service activity.				

1.56 The system must have a remote control capability so that it can be controlled moved remotely.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.56.1 It should be possible to move the system using a remote control function in the event of a system failure.				
1.56.2 The remote control function may operate over the internet				

1.57 The system must be able to accept push updates.

Requirements	*Status*	*Notes*	*Prim. Tech.*	*Tech. Status*
1.57.1 The system should decide when to accept push updates				
1.57.1.1The system may only accept push updates when it is charging.				
1.57.1.2The system may only accept push updates when the user is asleep.				
1.57.2 The system should be able to connect to the internet to check for				

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updates.				

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9 Appendix B

The following diagrams show the intermediate working of the requirements based on the extracted data from the DoW and the interviews carried out at each pilot site.

{*Appended as PDFs*}

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MARIO Analysis Ireland

Apperance
- He looks rather frightening, not sure they would like him as he now is, in terms of appearance to be around the nursing home.
- MARIO to speak as a human and not sound as it does now like a robot; maybe have the voice of someone they know but for others they thought that a familiar voice would be confusing
- The voice needs to be clear, he needs to speak slowly and a bit loudly so we can hear
- To have more softer or warm features- 'he is like a fridge'
- Could he have some hair? Can we put a shirt of some clothes on him to make him a bit more friendly looking?
- Needs to speak like a human not a computer or a sat nav
- The colour green is very cold on MARIO, could we have a different colour, maybe a brighter warmer colour eg pale blue
- He needs to appreciate humour and 'have a laugh' with us.
- Concerned that at the moment MARIO is unfriendly in appearance and would frighten residents and looks very mechanical; needs to look more friendly and warm
- Maybe give him a wig and put a shirt on him
- Could he smile, express some emotion, appear to make eye contact ? Needs to be able to communicate empathy to the residents.

Time & Calendar
- MARIO at the start of the day to automatically tell you date and time and year and a list of the day's activities and events planned for that day.
- MARIO in their own home to be able to remind them when the shopping needs to be done and bills need to be paid; able to regulate the heating in the house and lock all the doors at night time or at least remind them to lock all the doors; able to select the TV channels that they like via voice commands; alert them when someone is going to visit them eg 'your best friend Tom is coming to see you today"
- Able to call out your personal diary to MARIO and he would record it for you.
- In the nursing home could he remind you that you had visitors earlier in the day and who they were as sometimes we forget and think no one has visited?
- Reminders for social events- BINGO, Dementia advocacy group meeting, other social events
- Reminders to eat and to drink; have photos beside different foodstuffs and drinks so it prompts them what they are

Technical Features
- Detachable mobile piece on MARIO that could be taken in their pocket or handbag which would have GPS, face recognition, voice recognition, reminders and prompts calendar; able to call out directions to you as you go to the shop or are in the car in a human sounding voice.
- Can we control MARIO? Would there be a remote control that we could use to control him and summons him when we need him? Can we switch him off when we don't want to b annoyed by him? Can we switch him off at night? Who controls him us or the nurses?
- That MARIo could show a video back to the relatives of themselves in the nursing home and what they are doing,
- Able to Skype family and friends through Mario, they call out the number and MARIO rings the person. That family could send videos to MARIO over the wifi and it would then play back the video to the person eg if they were missing a wedding or a family event in Australia that they couldn't attend, getting a life feed to the event would be great.
- MARIO needs to be robust, we are afraid he will fall over, what if we accidently knock into him or maybe we could even fall over him?
- Store phone numbers and photos of the person attached to the phone number so they are prompted as to who is making the phone call
- How will he alert the nurse that something is wrong with a resident if he is away down the ward and the nurse is a distance away? How will he communicate? Could the nurse have a remote in her pocket that bleeps or alerts her when something is wrong with the residents that MARIo is with?
- MARIO to have an adjustable height, at the moment concern that he is too small and people with dementia will try and use him as an assistance to get up out of a chair and will knock him over; needs to be robust as they could hit him with their stick on the head or the body.
- What happens if something happens to MARIO, he falls over or crashes into another piece of equipment like the floor polishing device or a commode?
- Can MARIO identify someone in distress in terms of their emotional wellbeing but not just by pressing the ipad but some type of sensor and then alert the staff?
- MARIo needs to have a falls detection; motion sensors on the person? Sensors to pick up the residents physiological status; sensors to detect if the blood sugar is low orhigh? That they are moving around in the room or wandering? Smoke detector in MARIO
- Restrict the choice on the IPAD icons as too many options will be confusing for people with dementia, it looks like there are 4 options at the moment consider reducing that down to just two; Personalise the icons on the MARIO IPAD.
- MARIo must be able to distinguish between day and night.
- Who will be responsible for MARIO when he is in the home, what if his system crashes while he is here, how does he reboot?
- Can MARIO have 360 degrees or all around auditory ability to pick up sounds?
- Voice activation and face recognition key items and the Ability to skype ; could MARIo take photos of the resident to share with family members? Have a writing pad on the IPAD where visitors can record their names and details when they visit?
- The space in each room is small, MARIO could clutter up the place and residents might fall over him? Need to consider how he can move around the nursing home on his wheels!
- Is it possible for MARIO to show a 3D image/hologram to the person of their relative when they are talking to them via skype or the phone?
- Can the IPAD be adjustable as at the moment it seems the person has to lean into the screen, could the screen move out more towards them and then back again when they are finished?
- MARIO to read out local parish newsletters, show local football games on his TV screen; the horse racing.
- Remote control to summons him not just voice activated? Who controls him the nurse or the resident? Can there be a sleep mode for MARI at night? When will he recharge his batteries and how long will that take?

Physical Tasks
- Would like if MARio could walk outside in the garden with me or along the path of the nursing home
- Marion needs to be able to move around in small spaces as bedrooms are small in the nursing homes. In the proposed pilot sites residents are on average 4 per room and these rooms are small.
- That MARIo would be able to motivate them and deliver words of encouragement eg 'lets do it" "Don't give up" " come on have a go" .
- Could he play a game of bowling with you? Could It help me to do my paintings?
- Subtopic

Cognitive Tasks
- Be able to read a book to them as many have failing sight and concentration is poor
- MARIo to play soothing music to you at night and to gently wake you in the morning
- Remind them where their keys and their purse are.
- That MARIO could detect when they are feeling depressed or lonely and would cheer them up or send out a signal to someone to come and visit them.
- MARIO to remind you what clothes to put on when you get muddled eg put your underwear on first Mary, ...now put on your dress, that red one over there looks nice...how about those red shoes...they would match your dress"
- MARIo has face recognition so knows who people are and can prompt you so your not embarrassed when you cant remember
- Have games on it like Golf; be able to play their favourite music; ability to do karaoke in the nursing home for those who want to have a singalong; want MARIo to be able to entertain them as a group in the nursing home; play games with you maybe do quizzes and crosswords with you but not having to use the pad at the front to do that all the time, could he be activated by voice alone?
- That MARIO becomes their memory bank and stores their memories for them and then prompts them eg tell me again how you met your wife? That was a great holiday in France when your children were young, tell me about visiting Disneyland"
- MARIO has to be able to have in putted the life history/life story of the person, must really know the person; must have their interests and hobbies
- Religion is important for residents, can MARIO say the rosary with them?
- MARIO mush have the lifestory for the person and be individualised to each person.
- Ability to orientate residents to time place and date

Healthcare Tasks
- Able to record, vital signs, person's height, weight, monitor their food and drink intake
- Sometimes I forget that the nurse has given me my medicine, could he remind me that I have taken them rather than I bothering the nurse?
- If you're a diabetic would he be able to sense when my blood sugar levels are dropping too low and tell me or the nurse
- In Emergencies that MARIO knows if someone is not responding, say they have fallen and are unconscious and will automatically send for help
- Like the idea of having MARIo undertake the Comprehensive geriatric assessment,
- MARIO would send information on vital signs to the nurse who would then make the decision on care outcomes not send information direct to the doctor.
- If a client has a tendency to fall can MARIO check the client's physiological data overtime and then generate a graph where the nurses can see what the reason might be that lead to these falls?

Ethics
- Will our secretes be safe with MARIO?
- Who will have access to the information that we give to MARIo and he has in his memory?
- Will he share private conversations that I have with one family member with another family member? Will he tell my business to someone's?
- Will he start the conversation or will I have to start it ?
- Where will he hold all his information, on chip in his head?? Who can access my information that he has?
- Will each resident have a personal log in number for MARiO so that he keeps their data safe and distinct from other residents?
- How will MARIO work with more than one resident?
- Can the information collected by MARIO generate a CARE plan for the resident without the nurses input? How safe is this information in terms of storage and security. Who will have access to this information?
- Privacy and confidentiality of the information stored in MARIO. Who owns that information? How will it be stored safely so that others cannot acces it? Will the information in MARio be backed up somewhere, and will it be safe?
- Could MARIO have two memories for a resident, in one memory private information is stored and in another memory the social material is stored?
- Concern that MARIO might be used to replace nurses in the future .

Rollout
- Important to involved the family members in the launch of MARIO and in advance of his arrival to the nursing home
- Most staff welcomed the idea of MARIO and keen to see him in person!
- Probably best to introduce MARIO to the residents with very mild dementia for the pilots

Floating Topic

Site B 270415
- Needs to use recorded family voices that the user may react to.
- Need to understand and produce regional accents
- Need to detect fires etc
- Needs to adapt over time to the changing person
- Needs to learn or be told what interaction is possible with an individual,
- May need a set of interaction levels that can be progressed thorugh
- Needs to recognise that he action requested of the user is unrespoinded to.
- Can it measure a persons motion
- Capture personal knowledge about the user music likes, sport likes, reminiscence photos
- Read story books
- Do bingo
- Reassurance behaviours
- Need to know who it being addressed, if amir dedicated to one person mario needs to know who that is even in a communal area
- Prompting behaviours, toilet, bed time, recognising social context and personal context
- Dinner menu
- event prompting
- Need to be abel tot tell Mario to shut up
- Make it softer and more appealing
- Brighter colours
- Differnet promptin patterns at night,
- Can it control the lights
- Night time monitoring
- Needs to be compatible with the technology in the environment like IR alarms
- Connect to a persons original region and home, give local news etc, sports resist May be family can email mario with updates, photos etc.
- CGA assessment did the user understand the question can Mario tell?
- Mario takes pictures of events to remind the user
- Dinner questions
- Face prompting
- MARIO needs to have a name that is local
- MARIO needs to learn speech from the user.

Subtopic
- Conversations around life story
- intepretation if life story
- Use personal knowledge to make appropriate interactions
- Individual profiles
- Eye level contact when sitting
- Must avoid being too close to user, out side of feet range
- Detailed daily diary hour by hour events
- Behaviour related to medical condition, a diabetic eating too much gets noticed.
- Control of home environment, TV etc
- Control central heating
- Knowing the name of people in the room
- Local accent, recognising people
- Personal event reminder like birthdays
- Must know names of rooms and doors — Hipocampus relacemtne
- maybe mix gestures and answers.
- Contextual prompting, shows ice-cream when ice cream is said
- Motivation talk
- Subtopic

MARIO Analysis Italy

Time & Calendar

- remember appointments and things to do during the day, acting as a calendar

Apperance

- The robot could have a more noticeable and light colour like orange
- The robot could wear a hat and have a smiling face so that the patient feels comfortable when it arrives

Cognitive

- Usually patients stay seated on their sofa doing nothing for a long time. When this state is detected by the robot, it could propose engaging tasks to keep him/her active
- Unfortunately, drugs alone don't resolve the course of the illness. It is necessary to perform runs of cognitive stimulation to empower the residual abilities and to slow down the cognitive decay. The robot could perform daily exercises for cognitive stimulation
- The robot could recite the rosary
- The robot could announce news headlines
- The robot could play cards
- The robot could show pictures of the patient and ask him/her if he/she remembers when and where one particular shot has been taken, and who are the people with him in the pictures
- The robot could retrieve events from the life history of the user (e.g. "Dear Tom, do you remember when you were in France…"), elaborate them and interact with the user encouraging him/her to talk about this events proposing also to analyse some pictures (see following point)
- The robot could propose the listening of musical tracks, previously chosen according to the specific individual tastes, to relax the patient
- act as a companion proposing stimulating tasks such as reading news, calling a friend
- video-call friends

Healthcare

- The inversion of the circadian rhythm (sleep-wake cycle) is the more frequent psycho-behavioural symptom in people with MCI, and it represents a serious burden for the caregiver. The robot could record the patient during the sleep and wake him up at the correct time. Proposing activities it could also help not to fall asleep in a period of the day when this could alter the sleep-wake cycle
- video-call the medical center or and his/her relatives in case of emergencies
- check posture to detect possible falls
- detect the emotional status
- check if he/she eats

Rollout

- it doesn't transmit emotions and it is important to underline that it has not to replace a real person, but it can be considered just as a valuable tool to reduce the burden of the caregivers
- it is difficult that the patient accepts the robot in his/her daily living environment without proper information and instructions
- it is difficult for a patient to accept a robot that follows the patient outside his/her home. Patients are not happy to be seen with a robot.

Proposal Text

- **Motivation {M}**
  - To combat loneliness and the effects suffered by PWD, effective techniques include those that target change of a person's perception of loneliness and those that increase a person's resilience. Resilience is an adaptive capacity that refers to one's ability to "bounce back" and cope in the face of adversity. Interventions focusing on strengthening the personal attributes and external assets (i.e. resilience) of PWD show much promise as they may help retain cognitive capacity and reduce social exclusion.ICT solutions can be used to increase psychological skills like resilience8. There is also important new research in the use of robots to deliver ICT solutions and to act as companions (combatting perception of loneliness) via a novel user-centred concept called "Mutual Care" which provides the possibility for the human to "take care" of the robot like a partner9. In this way, real feelings and affections are created making it easier to accept assistance from a robot when - in certain situations - in return the human can also support the machine.
    - Functional Goals
      - {M} Alter the user's perception of loneliness
        - Using robot as a companion using user centred "Mutual Care"
      - {M} Increase the user's resilience
        - Strengthen personal attributes
        - Strengthen external assets
      - {M} Improve retention of user's cognitive capacity
      - {M} Reduce social exclusion
  - Moreover, ICT solutions are increasingly pervasive in a holistic and comprehensive approach that benefits not only patients/end users but caregivers and medical staff. One such approach targeted in MARIO is the Comprehensive Geriatric Assessment (CGA) which targets the evaluation of the patients, the improvement of the communication inside the team who is in charge of the care, and to manage and check rehabilitation plans.
    - Functional Goals
      - {M} System to help care givers and staff as well as user.
      - {M} Carry out Comprehensive Geriatric Assessment (CGA) to evaluate user.
      - {M} Improve care team communication
      - {M} Allow checking of rehabilitation plans
  - With respect to the evaluation of patients within a CGA approach, IRCCS is leading research on the use of direct (measurements) and indirect (have behaviours changed?) information for the construct and evaluation of a Multidimensional Prognosis Index (MPI). Such an index provides information to caregivers that can only be attained by spending large periods of time with the patient. In MARIO, the service robot will provide information to MPI survey and evaluation process based on its observation of the instrumental activities of daily living and detection of changes regarding them.
    - Functional Goals
      - {M} Directly carry out user evaluation
      - {M} Indirectly carry out evaluation of behavioural change in the user.
      - {M} Contribute to the construction of a Multi-Dimensional Prognosis Index (MPI)
      - {M} Contribute to the evaluation of an MPI
      - {M} Monitor user's daily living patterns and habits
      - {M} Detect changes to the user's daily living patterns and habits

- **R&D Challenges {RDC}**
  - How can service robots be most effectively used to combat the perception of loneliness, increase resilience, and mitigate the effects and or severity of dementia?
    - Functional Goal
      - {RDC} Seek ways to combat the perception of loneliness
      - {RDC} Seek ways to Increase resiliance
      - {RDC} Mitigate the effects and severity of dementia
  - What attributes and functionalities should such robots have? Technically, how do we achieve, assess and deploy them?
    - Functional Goal
      - {RDC} How can robots be designed to combat the perception of Loneliness, increase resilience and mitigate the effects and severity of dementia.
  - How can robots be used within the context of Comprehensive Geriatric Assessment and to conduct Multidimensional Prognosis of end users through explicit and implicit data and observations?
    - Functional Goal
      - {RDC} How can robots be used to assist with CGA and the generation of MPI through data gathering and observation
  - How can service robots best connect and create positive actions between older persons, their communities and caregivers?
    - Functional Goal
      - {RDC} How can robots be used to create interaction between users and their communities and care givers.

- **Objectives**
  - **Macro Level Objectives {MLO}**
    The macro level objectives capture the aim and ambition of the project. They are assessed and will be communicated by the projects expected and final impact. They are:
    - To address and make progress on the challenging problems of loneliness, isolation and dementia in older persons through multi-faceted interventions delivered by service robots
      - Requirement
        - {MLO} System must use multi-faceted interventions
        - {MLO} System must deliver progress via a service robot
    - To conduct near project length interaction with end users and assisted living environments to enable iterative development and preparation for post project uptake
      - Requirement
        - {MLO} System must work within assisted living environment
        - {MLO} System must be capable of long term interaction with user
    - To assist caregivers and physicians in the comprehensive geriatric assessment (CGA) of subjects at risk to loneliness, isolation or dementia through the use of service robots.
      - Requirement
        - {MLO} System must assist caregivers and staff in carrying out CGA using service robot.
    - The use of near state of the art robotic platforms that are flexible, modular friendly, low cost and close to market ready in order to realize field contributions in the immediate future
      - Requirement
        - {MLO} Service robot must be flexible
        - {MLO} Service robot must be modular
        - {MLO} Service robot must be friendly
        - {MLO} Service robot must be low cost
        - {MLO} Service robot must be near market ready.
    - To make Mario capable to support and receive "robot applications" similar to the developer and app community for smartphones. This will empower development and creativity, enable the robot to perform new functionalities over time, and support discovery and improve usefulness for end users while lowering costs.
      - Requirement
        - {MLO} System must be able to support 3rd party application development
        - {MLO} System must be able to support the download of 3rd party applications.
    - Through novel advances in machine learning techniques and semantic analysis methods to make Mario more personable, useful, and accepted by end users (e.g. gain perception of non-loneliness).
      - Requirement
        - {MLO} The system must use machine learning techniques to be more personable, useful and acceptable to users
        - {MLO} They system must use semantic analysis methods to be more personable, useful and acceptable to users
    - To bring MARIO service robot concepts out of the lab and into industry by addressing licensing aspects via Apache, the integration of telecommunication aspects and application hosting environment.
      - Requirement
        - {MLO} Apache requirement unclear: The System must run Apache?
        - {MLO} The system must have telecommunication capability
        - {MLO} The system must be able to host alternative applications.
  - Level 1. Building Resilience for Loneliness and Dementia. {OL1}
    - New research in the development of advanced ICT solutions to build resilience, enhance and maintain social connectedness and change self-perceptions of loneliness.More specifically, in MARIO we explore the use of service robots in order to:
      build resilience as a "behavioural process" by strengthening personal attributes and external assets and by means of using robot companions such as the Kompai R&D platform as a method of enhancing connectedness and social interactions and as a catalyst for building dementia research capacity and maximize effectiveness in highly personalized and patient-centric care for people with dementia (PWD) across Europe
      - Requirement
        - {OL1} System must build resilience in the user as a result of behavioural processes.
        - {OL1} The system must enhance the user's connectedness
        - {OL1} The system must enhance social interaction
        - {OL1} The system must catalyse demential research capacity
        - {OL1} {Unclear is the system required to maximise or is it the application of the system that maximises} The system must maximise effectiveness in highly personalized patient centric care
        - {OL1} The system must work across Europe
    - focus on strengthening PWD's resources for coping with challenges and difficulties and provide a base for developing interventions and empowering PWD, their families, carers and the community
      - Requirement
        - {OL1} System must strengthen PWD's resources for coping with challenges.
        - {OL1} System must act as a base for developing interventions.
        - {OL1} System must empower the user
        - {OL1} System must empower the user's carers
        - {OL1} System must empower the community the user is in
    - identify assets, resources and protective factors internal and external to the individual PWD ,including a positive self-concept and attitude, acceptance of changing self, affirming person centered environments, social support networks and community supports.
      - Requirement
        - {OL1} System should enhance a positive self-concept and attitude
        - {OL1} System should promote acceptance of "changing self"
        - {OL1} System should affirm the concept of a person centred environment.
        - {OL1} System should enhance social support networks and community support.
    - As part of the above, in MARIO we will develop a novel approach to employing robot companions, build a unique evidence-based "toolkit" of resilience strategies that foster social inclusion and create a network to advance knowledge about ways of fostering social inclusion. The effect will be to facilitate and support connectedness for persons with dementia and their communities, reduce social exclusion, isolation and stigma, while also helping to shape and prioritize outcomes for resilience by supporting others (such as family, carers and the community) understand what matters to them most.
      - Requirement
        - {OL1} The system should contribute to the implementation of strategies developed as a part of the evidence based toolkit of resilience strategies
  - Level 2 CGA & MPI {OL2}
    - Level 2. CGA & MPI: To make service robots a tool that facilitates Comprehensive Geriatric Assessment and the evaluation of a Multidimensional Prognosis Index.
      - Requirement
        - {OL2} The system should facilitate CGA
        - {OL2} The system should facilitate the evaluation of MPI
    - MARIO positions itself as a tool to help policy makers and the medical community to manage the increasing costs and additional stress placed on the health care system associated with the wide, heterogeneous and complex aging population. The promotion of interventions capable to increase the independent living are a must and a certainty which are reflected in literature and policy. In the realization of interventions that promote independent living, one of the more accepted and validated approaches is the CGA that is a multidimensional, usually interdisciplinary, diagnostic process intended to determine an elderly person's medical, psychosocial, and functional capacity problems. The CGA addresses the following needs and in the MARIO Level 2 Innovations a service robot will be used to facilitate:
      - Requirement
        - {OL2} The System should contribute to cost management
        - {OL2} The system should Reduce stress in the system of care
        - {OL2} The system must increase the level of independent living.
    - Evaluation of the patients
      - Requirement
        - {OL2} The system must facilitate the monitoring and diagnostic processes that form part of the CGA
    - Improvement of the communication inside the team who is in charge of the care
      - Requirement
        - {OL2} The system must contribute to communication within the care team.
    - Project and check the rehabilitation plan.
      - Requirement
        - {OL2} The system must be able to contribute to the assessment of the rehabilitation plan
    - These service-robot enabled innovations will lead to improved diagnostic accuracy, optimization of medical treatment and health outcomes, the improved function and quality of life, reduced costs and improved long-term care management. As part of the evaluation, MARIO will be used to collect information that enables the integration of many different domains of data into a single score that can represent synthetically the health status of a person. This score is called a Multidimensional Prognostic Index (MPI) and IRCCS is deeply involved in the development of methods within its hospital and community dwellings to make this score accurate and useful. The capacity of a robotic home system to detect autonomously early changes in the health status of a subject tanks to this index and within the CGA approach can be very important especially for older subjects. This is the core of MARIO Level 2 Innovations
      - Requirement
        - {OL2} The system will lead to improved diagnostic accuracy, optimisation of medical treatment and health outcomes, improved function and quality of life, reduced costs and improved long term care management.
        - {OL2} The system must be able to contribute to the integration of assessment data leading to an assessment of health.
        - {OL2} The system must be able to detect changes in health based on the methods within the CGA approach.
  - Level 3 4Connect+ Modules {OL3}
    - Increasing Mario's flexibility, modularity and utility.. Figure 2:MARIO Project Concept 4Connect+, touching and talking Figure 2 shows the main concepts of the Level 3 Innovations. They are the integration of Mario Level 1 and Level 2 Innovations into the Kompai platform which makes the robot the mechanism to deliver these innovations and to connect the user to his/her care provider and/or the medical community. In addition, Modules are developed to create linkages to community social services, to the user's personal social network and to the user's personal interests. The "+" in 4Connect+ indicates the linkage to the developer community made possible by Mario serving as platform capable of receiving and implementing new robot applications. For the iPhone, applications became a disruptive innovation that changed phones as we knew them and harnessed talent worldwide. For Mario, we aspire to the same. Users will be able to interact with Mario in two ways, via a touchscreen and by voice. The work builds on ROBO's already excellent platform Mario makes it better and allows it to do more.
      - {OL3} Requirement
        - {OL3} The system must be able to connect the user to their care provider.
        - {OL3} The system must be able to connect the user to the medical community
        - {OL3} The system must be abel to connect the user to the community social services
        - {OL3} The system must be able to connect the user to their own personal social network
        - {OL3} The system must be able to connect the user to their personal interests.
        - {OL3} The system must be able to accept new applications developed by 3rd party developers.
        - {OL3} The system must be able to interact with users using a touch screen {TECHNICAL}
        - {OL3} The system must be able to interact with users using speech.
  - Level 4Breakthrough ICT Advances: {OL4}
    - Moods and Expressions, Semantic Analysis and Ambient Sensor Interaction. Using data from the MARIO service robot platform, other ambient sensors strategically placed in the living environment, and research from Level 1 and Level 2 related to the needs of persons at risk or having dementia, MARIO will build a new generation of robots able to communicate with humans on a natural language basis as well as to detect, interpret, and express emotional expressions, and to react to such interactions with a behavior, which adapts and evolve dependently on the environment they live in, i.e. ambient sensors, and the specific humans they interact with. In other words, MARIO robot will be able to get familiar with their human companions by establishing specialized relationships with them. MARIO robots novelty also resides in their openness and networked nature: They learn and evolve thanks to their specific with-humans relationships, but they also exploit a general encyclopedic background knowledge from the Semantic Web. Moreover, they share what they learn with the other MARIO robots, hence creating a knowledge-sharing virtuous cycle that during time makes them more and more "cultivated" at their starting phase as well as beyond it.
      - {OL4} Requirement
        - {OL4} The system must be able to gather data from ambient sensors in the living environment.
        - {OL4} The system must be able to communicate with users using natural language
        - {OL4} The system must be able to detect the emotional expressions of the user.
        - {OL4} The system must be able to interpret the emotional expressions of the user
        - {OL4} The system must be able to make emotional expressions.
        - {OL4} The system must be able to react to the user's emotional expressions.
        - {OL4} The system must be able to adapt and evolve its behavioural responses to the user's emotional expressions depending on the living environment.
        - {OL4} The system must be able to establish a personal and specialised relationship with the user (and with multiple users on an individual basis).
        - {OL4} The system must be open
        - {OL4} The system must be networked
        - {OL4} The system must be able to access and exploit knowledge from the "Semantic Web"
        - {OL4} Multiple instances of the system must be able to share learned knowledge between them in order to bootstrap behaviours.
        - {OL4} The system is expected to improve its performance over time through learning.

- **Scope**
  - The scope calls for focus on service robotics "in assisted living environments." MARIO responds through the front line activities of the NUIG nursing division, IRCSS hospital, and community social services division of STOCKPORT which in total provide care and assistance to over 3200 persons in assisted living environments. The project begins and ends with activities in these environments. With respect to outpatient support programs and community social services to persons at risk to the effects of loneliness or dementia, the project has outreach to approximately 100,000 older persons with identified conditions.The scope also calls for "multi-disciplinary research... that builds on past results." With respect to this, aside from the end users, the consortium includes two robot companies, two software development companies,an exploitation partner, an RTO robotics lab, an RTO semantic and ontology unit and two university departments focused on ambient sensing, ICT, and the treatment of data. In total, research activities build upon over 15 past projects (later described) and to include ROBO's 30+ years of robotics innovations. Lastly the scope calls for the development of solutions characterized by their "modularity, cost-effectiveness, reliability, flexibility...applicability to realistic settings, safety and accepatability to end-users."Mario responds to this first through the use of use of near state of the art robotic platforms that can be made available to the market post project completion quickly with Mario adaptations. Second, a key component and indication of MRIO is to use robots as platforms that can support and receive "robot applications." this will empower developers, promote creativity and increase the robots flexibility and usefulness. Lastly, Mario conducts a deep effort into intelligent interface, useful functionalities(4Connect+), mutual care as a base concept, considerable research into ontology and semantic analysis to improve accuracy and machine learning to allow Mario to learn and personalize to its end user and care providers over time. In total, these efforts will dramatically increase its acceptability to end users.
    - Requirements
      - {SCOPE} The system must be modular
      - {SCOPE} The system should be cost effective
      - {SCOPE} The system should be reliable
      - {SCOPE} The system should be flexible
      - {SCOPE} The system should be applicable in a real environment
      - {SCOPE} The system should be safe
      - {SCOPE} The system should be safe
      - {SCOPE} The system will provide an intelligent interface for users
      - {SCOPE} The system will be able to accept addition applications
      - {SCOPE} The system will utilise the concept of "mutual care"
      - {SCOPE} The system will utilise learning to improves performance
      - {SCOPE} The system will utilise an ontology and semantic analysis to improve its performance
      - {SCOPE} The system will personalise to the user and care providers over time.

- **Expected Impact**
  - The Mario proposal is in line with the call expected impact and will endeavour to achieve:An assessment methodology that provides evidence for the benefits of service robotics developed.From design through development and through validation, Mario will involve relevant stake holders directly in the project and expand its outreach via a stakeholder community outside of the project. Through the use of ICT to conduct comprehensive geriatric assessment (which connects all stakeholders involved in providing care with common access to information and management planning) and service robots to assists with the evaluation of a multidimensional prognosis index,admissions and days spent in care institutions will be reduced. In addition, by increasing the resilience of persons at risk, time spent living at homes will be prolonged.Mario will significantly improvement the quality of life of older persons and of their care providers. For persons at risk to dementia, it will serve as a tool to increase resilience. For persons with perceptions of loneliness, Mario will act as a companion and in a convincing way by incorporating mutual care and machine learning concepts. For all end users, Mario will provide connectivity to the community, care providers, family and friends and personal interests. Users and care providers will have access to information, diagnosis tools, and treatment possibilities not previously available.By coupling the leading service robot Kompai with rigorous research into resilience, dementia, CGA,and MPI and coupled with new semantic analysis and behavioral capabilities, Mario will position the consortium for global leadership in advanced solutions supporting active and healthy ageing.
    - {IMPACT} The system will act as a convincing companion to the user
    - {IMPACT} The system will utilise learning and the "mutual care" concept to enhance its interaction with the user
    - {IMPACT} The system will provide connectivity to the community, to care providers, family, friends and personal interests for the user.
    - {IMPACT} The system will provide users and carers with access to information, diagnostic tools and treatments.
    - {IMPACT} The system will utilise learning and semantic analysis to enhance behaviours.

- **Specific Challenge**
  - The core aspect of the specific challenge for this call is "...an ageing European population is at greater risk of cognitive impairment, frailty and social exclusion. Mario directly addresses this core aspect through its focus on the cognitive aspects of loneliness, isolation and dementia. The challenge continues to identify the need to"develop new breakthroughs for active and assisted living based on advanced ICT solutionsIn Mario new breakthroughs include (amongst others) multi-faceted interventions delivered by service robots to build resilience, change perceptions of loneliness, and effect cognitive stimulation the use of service robots to facilitate the conduct of comprehensive geriatric assessment and to help patient assessment through a multidimensional prognosis index via direct and indirect data a "4connect+" platform that links service robots and their users to the community, care givers,their own social network, interests and developers who can design new applications to improve robot functionalities through time. It is noteworthy that the cumulative effect of these new breakthroughs also contribute to addressing the"sustainability of health and care systems" specified in the challenge.
    - Requirements
      - {SC} The system will be able to carry out CGA
      - {SC} The system will be able to carry out MPI
      - {SC} The system will be abel to utilise multiple sources of data
      - {SC} The system will allow new applications to be developed.
      - {SC} The system will connect he user to their community, care providers, their social network and interests.

- **STOs**
  - STO1: Health and Assessment
    - **Background**
      - Our research work in MARIO aims to identify the best ways service robots can help building resilience for PWD by working in a coordinated manner with PWD, carers and community, using their knowledge at all stages to ensure the intervention best meets the needs and priorities of PWD.
      - Many people with dementia live meaningful lives and retain many abilities if a supportive psycho-social environment exists12. However PWD report that dementia affects their confidence to engage in social activities leaving them isolated. In addition, caring for the PWD places great demands on the carer. Carers report a lack of support, information and skills13. These problems can result in PWD being placed in residential care prematurely which has significant economic and health costs. The Alzheimer's Society UK (2013) estimate that reducing isolation and developing resilience through Dementia Friendly Communities (DFC) will contribute to keeping people at home saving around £999 per person per year.
      - Resilience is a "behavioural process" built on strengthening personal attributes and external assets such as supportive relationships and community resources which can lead to improving outcomes for PWD14. Resilience can be taught, learnt and fostered15 irrespective of cognitive impairment16. Finally, resilience training focuses on modifiable intra- personal skills and protective factors aimed to increase the person's "hardiness" to remain psychologically and physically healthy (resilient) in the face of adversity. Psycho-social interventions that strengthen resilience by focusing on the personal attributes and external assets of PWD show much promise17. To be effective these interventions must be multi-facetted targeting the PWD, family and community. In addition, evidence of the effectiveness of many psychosocial interventions are inconclusive.Most are small-scale, short-term observational studies with high risk of bias, compounded by poor reporting, inadequate detail on the nature of the intervention, the stage of dementia or the inclusion criteria. Furthermore, interventions have focused on the PWD or their carer or both18 none used tested interventions that focused on the triad of PWD, carer and the community at large.
    - ***Ambition***
      - Our analysis of potential uses for MARIO robots suggests that a significant advance is needed in robotic capabilities to interact and communicate with this population. One area of improvements we introduce relates to the need to supply robots with the "mental" capabilities to understand how they are perceived by human users and PWD in particular, allowing them to perform socially and physically appropriate behaviours that PWD will find helpful. The introduction of MARIO robots will not solve all societal problems of PWD. However, they can begin to address the shortage of skilled labour in the caring professions, assist carers to be more efficient, and allow them to focus more on the human-to-human aspects of their work. At the moment, older and disabled people rely on family, or on carers who are paid privately or by the state, to support them in many aspects of their daily lives. Wages for carers are low, and there are widespread concerns about poor standards of care impacting on the human rights of older citizens. The recruitment of foreign labour into the European caring professions does not solve this problem. We consider that the need to physically act in support of people's welfare, coupled with the limited resources of the European care systems, implies that more need for more advanced automation of care and assistance in the home such as this introduced by MARIO.
        - {STO1} The system needs to understand how it is perceived by users in a way that enhances appropriate behaviour
        - {STO1} The system needs to perform socially and physically appropriate behaviours that are helpful to the user.
        - {STO1} The system should be to reduce the workload on care staff increasing their efficiency.
        - {STO1} The system will enhance physical interaction and the automation of care processes and assistance.
      - In MARIO we will build an innovative resilient based intervention targeting PWD, carers and community, which will improve the outcomes of PWD so that they can continue to participate in a meaningful way and live well within their community for as long as possible. However no resilience based intervention specific to PWD exists currently so it is therefore that we consider that we contribute to the improvement of bringing the technology readiness in this area from TRL 1 where basic principles have only been observed to TRL 5 that offers validation of a technology in a relevant environment such as we intend to do with the MARIO pilots.
        - {STO1} The system must improve the outcomes of the user and help them participate in a meaningful way, living well in their community.
        - {STO1} The system is expected to extend the time before a user needs to enter care
        - {STO1} The system improves the user's resilience
    - ***Objectives***
      - To make service robots a tool for the medical community in the diagnosis, treatment, rehabilitation and prevention of persons suffering from loneliness, isolation, dementia and their effects.
        - {STO1} The system must provide information about the user to the medical community
      - To identify the best ways robots can assist the of building resilience for Persons with Dementia by working in a coordinated manner with PWD, care providers and communities
        - {STO1} The system must operate in coordination between the user, care providers and the community
      - To introduce service robots as a tool for comprehensive geriatric assessment (CGA) enabling the multidimensional evaluation of subjects (MPI) considering the domains of cognitive, nutrition, comorbidity, basal and instrumental activities of daily living.
        - {STO1} The system must be a too for carrying out CGA.
        - {STO1} The system must be a tool for enabling the evaluation of users using MPI.
        - {STO1} The system must interact cognitively with the user
        - {STO1} The system must be able to monitor and assess the food intake of the user
        - {STO1} The system must be able to monitor and assess the health of the user
        - {STO1} The system must be able to monitor and assess the daily living processes of the user
      - To facilitate independent living and active ageing through robots as one solution to isolation and loneliness and their damaging effects via connectivity to others, mutual care and mental stimulation.
        - {STO1} The system must provide mental stimulation to the user.
        - {STO1} The system must provide connectivity between the user and others.
        - {STO1} The system must be able to interact with the user with "mutual care"
      - To develop the Caregiver Module as part of Mario's "4Connect +" that links the patient, data, robot and caregiver community together to realize the health and assessment functionalities.
        - {STO1} The system will have a care giver module that relates the patient, health data and the caregiver community to the robot behaviours.
  - STO2 Sociology and Behavior: To address the needs of persons at risk and/or suffering from loneliness, isolation and dementia with customized service robot solutions.
    - Background
      - Increased costs related to the ageing population raise grave concerns about the sustainability of the health care system due to the parallel increase of dependency status expenses. Moreover, the evaluation of elderly patients represents a complex universe difficult to evaluate and manage as a unique body. One possible answer is an early detection of impairments in a specific area or domain allowing carers to act prematurely and trying to change the disease trajectory. The Comprehensive Geriatric Assessment (CGA) represents one of the most used and validated approaches to evaluate the elderly subjects. Patients receiving CGA are more likely to be living at home and less likely to be functionally or cognitively impaired as confirmed in a recent Cochrane review19. In the community setting, CGA has been shown to result in improved outcomes, over routine care, in the day hospital setting and community hospital-based early supportive discharge20. In the previous years we have developed and widely validated a Mortality Prognostic Index (MPI) for older persons which is based on and becomes part of the CGA approach21. The customization of this approach for different illnesses and conditions has been a wide body of research at IRCCS and substantial work has been conducted specifically on patients with dementia (previous reference)and on older persons in community assisted living environments22. To provide clarity, one instance of an MPI assessment survey as part of a CGA approach is included as Appendix B.
    - ***Ambition***
      - Reading this survey, one can begin to think about what parts and questions a service robot could help answer and how the survey process at large might be adapted. To our knowledge, MARIO will be the first instance globally that a robot model will be developed that is capable of performing autonomously a CGA directly on elderly patients without assistance and can subsequently determine the health status (MPIR). One of the most fascinating aspects of the proposed research and developed module is that it will permit the monitoring continuously the different aspects or domains constituting the concept of health, so we can spot the general health status of a subject over time. This should allow the implementation of preventive program strategies, very easily seeking to limit or even impede substantially life, costs and independent living. The results of the project should be translated into a more wide area of interest involving health policy maker and social worker in a constructive dialogue to create new models of care for this specific population at risk of early institutionalization and hospitalisation. Many are the difficulties and limits that we can encounter in the development of this module and among these: the user acceptability, privacy issues, data safety, interaction methods, technologies limits, architectural limits but we think that almost all, based on the consortium experience, are surmountable. In the literature there aren't studies assessing the sam issues but, in a wider vision, many studies on ICT technologies have their difficulties in proving intervention efficacy in the health and social field23 and one important issue is the need for a more precise characterization of the patients that can benefit from the application of this technology. More recently a review24 highlighted that the most important issues to an efficaciously applications of ICT on health context seems to be: the gap in communication between technology and health science researchers; that research often fails to translate into practice because study designs do not extend past real-world context and are often focused on the caregiver rather than the elderly and finally that transferring technology into the home from organizational settings to support independent living in older adults presents contextual challenges due to the less controlled nature of the home setting. MARIO will fill the gap and its holistic approach should reach the objectives and be translated in real life solutions.
        - {STO2} The system will be able to autonomously perform parts of the CGA assessment
        - {STO2} The system will be able to autonomously assess the health status of the user.
        - {STO2} The system will be able to carry out long term and continuous monitoring of the health status of the user.
        - {STO2} The system must be acceptable to the user
        - {STO2} The system must address privacy issues
        - {STO2} The system must address data safety issues
        - {STO2} The system will provide a more precise characterisation of the user
        - {STO2} The system must operate in both care and home environments
    - ***Objectives***
      - Identify and implement interaction schemata that can lead to the establishment of a rich set of human/robot interaction routines. This will include and build upon the concept of Mutual Care which at its core has the concept that two-way relationships are fundamental to acceptance.
        - {STO2} The system will engage in a "mutual care" interaction with the user.
        - {STO2} The system will establish a rich set of interactions with the user
      - To develop robot motor (follow, exploration, navigation) and communication (mood, gesture, eyes) capabilities that more effectively addresses the emotional needs of the targeted end users.
        - {STO2} The system will be able to follow the user
        - {STO2} The system will be able to explore its environment
        - {STO2} The system will be able to navigate around its environment.
        - {STO2} The system will be able communicate with the user and effectively address their emotional needs using mood, gesture and eyes
      - To identify and develop customized interaction and communication capacities (e.g. gestures and the capacity to interact with the human companion through a situation-based natural language comprehension/production system) appropriate for PWD.
        - {STO2} The system will be abel to communicate to the user using a situation based natural language system appropriate to a PWD
        - {STO2} The system will communicate with the user using gestures.
      - To enable MARIO robots to adapt their behavior to the user during operation over time.
        - {STO2} The system is able to adapt its behaviour to the user over time
      - To develop the Community Module as part of Mario's "4Connect +" links the targeted end user to their community and social support services.
        - {STO2} The system is able to connect the user to their community
        - {STO2} The system is able to connect the user to social support services
      - To target also the community via social marketing to foster systemic change in the understanding and behaviour of community members thus promoting positive actions for dementia
      - To develop the Family & Friends Module as part of Mario's "4Connect+" links the targeted end users to their personal social support network.
        - {STO2} The system is able to connect the user to their personal social support network
  - STO3 Robot Utility: user base by making Mario solutions modular, cost effective and useful:
    - ***Ambition***
      - The Mario project aims to integrate in a single platform a series of capabilities that represent the state of the art in robotics but that so far have been developed and demonstrated in isolation. If successful, this will represent a significant progress in robotic personal assistant research development31 and in human-robot interaction32. Indeed, we believe, that the integration of behavioural, social, and cognitive skills constitutes a crucial prerequisite for systems that need to cooperate with humans in a robust and effective manner. First at all, Mario aims to be an autonomous robot that can operate robustly and effectively without external intervention for long lasting periods of time. This implies that Mario will not only display a series of behavioural skills that can be triggered by the user but also a capacity to autonomously initiate behavioural activities (e.g. monitoring or user engagement behaviour) depending on the circumstances. Secondly, Mario will integrate into a single system a rich set of interaction capabilities that will enable it to coordinate with its user through either verbal and non-verbal interaction modalities (i.e. gestures recognition, attention gathering behaviours, emotion expression and recognition). Overall, this will enable us to progress our understanding of the role of the integration between action, social, and cognitive skills for the development of intelligent systems33. Finally, Mario will be designed as an adaptive system capable of modifying its behavioural and social skills while interacting with the user. Within this vision, meanings that are shared between the robot and the user are expected to arise from the combination of verbal and nonverbal interactions and from the adaptive tuning of the association between the environmental and social context and the afforded actions.
        - {STO3} The system will be integrated onto a single platform
        - {STO3} The system must integrate behavioural, social and cognitive skills.
        - {STO} The system must operate robustly
        - {STO3} The system must operate autonomously for long periods of time
        - {STO3} The system must be able to exhibit a set of behavioural skills triggered by the user
        - {STO3} The system must be able to initiate behavioural activities.
        - {STO3} The system must be able to engage in both verbal and non verbal interaction with the user, including gesture recognition, attention gathering behaviours and emotion expression and recognition
        - {STO3} The system will be able to modify its behaviours through interaction with the user
        - {STO3} The system will be able to modify its social skills through interaction with the user
        - {STO3} The system will build up "meanings" that are shared with the user through interaction and from the adaptive tuning of the association between the environment and social context and the afforded actions.
      - The concept of "robots as platforms" will be utilised in MAIO. Software developers will be able to build new robotic applications that can be downloaded from Mario robots. This will promote creativity and will increase robots flexibility, utility and usefulness. There are a few examples of robotic application stores that are either still in the research phase (e.g. RAPP project36) or they have already done their first attempts in the market (e.g. Robot App Store37, NAO app store38). In MARIO we aim to advance the state-of-the-art in this area in several ways: The first innovation is the methodology that MARIO will apply for evaluating and accessing the extent to which the developed applications support the independent living of the elderly. None of the existing state-of-the-art application stores have applied a methodology for evaluating applications in terms of improving elderly isolation and loneliness. MARIO aims to support software community to build applications targeted to older people. This will enhance the variety of applications developed thus will improve the functionalities of the MARIO platform as a whole. The second innovation is the ability of MARIO robotic applications to interact with ambient sensors located in the home or in the environment of the robot. None of the existing application stores have considered and are able to establish connections with third party devices (e.g. sensors). The ability for a developer to create an application that will interact with sensors ca increase the functionalities of the applications and can enhance the variety of application ideas. The third innovation is the ability of MARIO applications to receive new information from the MARIO Ontology Network. This will enable MARIO robots to connect with the web and increase their knowledge and enhance their interaction with humans. These robotic semantic interaction abilities will increase the functionalities of the robotic applications developed since developers will be able to utilise the ontology knowledge to produce new smart applications for robots.
        - {STO3} The system must be able to download new applications.
        - {STO3} The system must be able to access ambient sensors in the environment
        - {STO3} The system must be able to access the "MARIO Ontology Network"
        - {STO3} The system must be able to increase its knowledge by accessing the MON.
        - {STO3} The system must be abel to enhance its interaction with the user through accessing the MON.
      - Innovation Potential MARIO will continue important sector wide progress on the development and penetration of service robots into assisted living environments. The impact of the advances in MARIO are that these service robots will become a more useful tool for older persons, their families, care givers, community planners, and the medical community. Herein lies the innovation potential. MARIO will give these stakeholders the ability to do new things with service robots. For community social care providers such as STOCK, MARIO represents an entirely new way to connect to and to provide for the well being in its community. For IRCCS, robots facilitating CGA and MPI evaluation opens entire new areas of development, research and patient care options. For NUIG, Mario does the same with respect to PWD and building resilience. Two innovative features of Mario have high innovation potential impact. They are the interaction with ambient sensors and linkage to the developer community through applications. Both of these open infinite possibilities about new ways MARIO can be used and things that MARIO can be made to do. For these reasons, innovation potential is seen by end users as one of the strongest aspect of the proposal submission.
        - {STO3} The system must operate in an assisted living environment
        - {STO3} The system must be able to execute different applications in different environments.
    - ***Objectives***
      - To make Mario capable of downloading new robot applications (similar to the iPhone) which serve to harness the talent of the developer community and to give the robot wide possibilities for new functionalities and personalization.
        - {STO3} It must be possible to personalise the system
        - {STO3} The system must be able to download new applications.
      - To create a web-based robot application repository from which robots can download applications and which links end users to the developer community
      - To create a first set of Mario robot applications that take into account the special needs of older persons and those at risk or suffering from loneliness, isolation and dementia. To integrate these into the "My Interests" or "MyMario" Module of the 4Connect+ platform.
        - {STO3} The system will contain a "My Interests" module
        - {STO3} The system will contain a "MyMario" Module
      - To enable MARIO to interact with and make use of ambient sensors located in the home or environment of the robot to improve robot monitoring capabilities between the robot and person and meanwhile making possible new applications and functionalities
        - {STO3} The system will be able to interact with and make use of ambient sensors located in the environment.
        - {STO3} The system will make use of ambient sensors to help monitor the user.
      - To support the incubation of MARIO in an open source community such as Apache, also as integration with existing semantic open source projects (Stanbol,Marmotta).
  - STO4 Semantic interactions: To develop robot semantic and cognitive interaction abilities
    - ***Ambition***
      - Ontologies within the robotic domain have started entering the core technology, as witnessed by the recently created IEEE standard committee standard for Ontologies for Robotics and Automation34. The purpose of the standard is to provide an overall ontology and methodology for knowledge representation and reasoning in robotics and automation, together with the representation of concepts in an initial set of application domains. However, there is no standard ontology yet that can be used as a base for robot semantics in MARIO. Therefore, our project will design those ontologies with the MARIO concept and use cases as requirements. The ontologies will guide the process of representing, extracting, enriching, exploiting knowledge relevant for robots in an assistive, situated context. Mario offers the unique opportunity to radically progress beyond the current state of the art not in in six clear areas of innovation:
        - {STO4} The system will use ontologies to help it use and process knowledge about the assisted living environment.
      - The first innovation with respect to the state-of-art will be the integration of robot semantics (sensors, behavioral patterns) with existing structured (e.g. databases) and unstructured (e.g. text) data, leveraging on current data integration practices such as the Linked Data principles, W3C semantic web standards RDF, SPARQL, and RIF, semantic-web-oriented machine reading (see below), ontologies, etc. This is in order to ensure that background knowledge, extracted knowledge, incoming data from sensors, behavioral patterns, assisted patient and indoor spaces data, etc., will be all semantically interoperable, typically through SPARQL endpoints that can be accessed in different ways.
        - {STO4} The system will integrate multiple sources of data and multiple methods of data integration to build semantically interoperable data.
      - A second, related, advancement - is an "entity-centric" knowledge management: each entity and its relations have a public identity that provides a first "grounding" to the knowledge used by robots (while stiltedness and embodiment of robots' knowledge would be another, deeper, level of grounding). Such identity is given by resolvable URIs that use simple Web and Internet protocols to provide useful knowledge as a representative of real world entities. Such knowledge is then embodied in the behavior of robots, so approximating the way humans make use of socially-constructed knowledge to improve their interaction.
        - {STO4} The system will utilise resolvable URIs to identify entities and their relations.
        - {STO4} The system will be able to relate entities and URIs to their real world entities.
        - {STO4} The system will be able to utilise and embody the entities and their relations into behaviours to improve interactions.
      - A third advancement is the introduction of semantic-web-oriented machine reading/listening in robots. An existing machine reading component, FRED35 will be extended and improved to that aim. FRED is a tool that extracts knowledge from text ("reads") and represents it into well-connected RDF graphs with a formal semantic interpretation. Extracted knowledge includes named entities, entity typing, sense disambiguation, concept taxonomies, events with their participants, arbitrary relations, negation, modality, tense. FRED links the extracted knowledge to existing data (linked data) and ontologies, so providing the entity-centric grounding to unstructured data and their relations as well. It will be extended also to support listening by reusing off-the-shelf speech recognition tools. The internal architecture of FRED makes it cable of reusing any natural language processing component (e.g. it currently supports deep parsing, discourse representation structures oriented to events and situations, semantic roles lexicons, etc.), and providing a formal, linked, and grounded semantics to their input.
        - {STO4} The system will be able to parse text and carry out a formal semantic interpretation of it.
        - {STO4} The system will be able to use the formal semantic interpretation of parsed text to enhance its knowledge through integration.
        - {STO4} The system will be able to ground the semantic interpretation of text in entities.
      - A fourth advancement for this project is the development of a Mario Ontology Network (MON) using (possibly extending it and being involved within the IEEE Standard Association) the Ontologies for Robotics and Automation mentioned at the beginning, which could appear during the project. As a methodology, the lightweight and well tested eXtreme Design will be applied based on the requirements and data structures emerging from the implementation of MARIO. MON will be evolvable by integrating ontologies emerging from interaction with assisted human, sensors or with other robots. MON will also be interconnected with the sentiment analysis framework, which will deal with moods and expression recognition and will provide a semantic structure of the extracted opinions, all integrated to the 4Connect+ platform MARIO will deliver.
        - {STO4} The system will use a specially designed Ontology network.
        - {STO4} The system will align to emerging ontology standards for robotics.
        - {STO4} The system will be able to evolve the Ontology by integrating new information gained through interaction with the user, the environment and other robots.
        - {STO4} The system will have a "sentiment analysis framework" able to recognise the user's moods and expressions.
        - {STO4} The system will be able to integrate the semantic framework and the sentiment framework
      - A final, fifth innovation is the ability to advance robot knowledge by learning new (or fine-tuning existing ones) ontology patterns from its experience with users and the robot network eventually in place. E.g., the patterns and expressions generated and produced by the described components will be fed back to the cognitive system in order to address emotional needs of the targeted end users in compliance with the sociology and behavior objectives of MARIO.
        - {STO4} The system is able to advance its knowledge by learning new ontology patterns from interaction with the user and the network of robots
        - {STO4} The system is able to advance its knowledge by fine tuning its ontology patterns from interaction with the user and the network of robots.
        - {STO4} The system will use its ontology and stored knowledge to address the emotional needs of the user in accordance with the sociological and behavioural objectives of the system.
    - ***Objectives***
      - To develop a MARIO Ontology Network (MON) covering, e.g. the actions the robot is involved in, the ambient sensor network, context recognition, elderly needs, etc., which will enable robots to cope with their spatial environment, and to communicate with each other as well as with their human companions;
        - {STO4} The system will utilise an ontology that covers the actions of the system, the ambient sensors, the context of operation, and the user needs.
        - {STO4} The system will utilise the ontology to cope with the spatial characteristics of the operating environment
        - {STO4} The system will utilise the ontology to communicate with the user
        - {STO4} The system will utilise the ontology to communicate with other systems.
      - To enable MARIO robots to evolve their knowledge and adapt their behavior according to, and dependently on, their specific with-human interactions;
        - {STO4} The system will be abel to evolve its knowledge and adapt its behaviours dependently on user interactions.
      - To connect MARIO robots with the Web (especially the Web of Data) and make them able to reuse it as background knowledge for improving their with-human interactions;
        - {STO4} The system must be able to connect to the web and utilise web based knowledge to improve user interaction.
      - To make MARIO robots able to recognize/discover relevant interaction and behavioral patterns, e.g. indicating loneliness perception;
        - {STO4} The system must be able to recognise and discover interaction and behavioural patterns relevant to its overall task.
      - To enable MARIO understanding and reacting to natural language interaction and emotional behaviours.
        - {STO4} The system must be able to recognise and respond to natural language interaction with the user
        - {STO4} The system must be able to recognise and respond to emotional behaviours.
  - STO5 Privacy, Ethics and Data Management: To eliminate potential concerns regarding data privacy, security and ethics and instead to turn this aspect into a strength and competitive advantage
    - Background
      - Assistive robotics and socially interactive robotics raise specific ethical issues, both in relation to their interactions with end users, and in relation to the social impact and wider social significance of their use. In relation to the MARIO project, the combination of privacy and safety concerns relating to the robot and its applications and the social and cognitive vulnerabilities of elderly persons with dementia (PWD) raises particular ethical challenges. Previous results of EU projects addressing ethical issues in relation to robotics included the EURON RoboEthics Roadmap39 the FP6 project ETHICBOTS40 and specifically regarding assistive care of the elderly "ICT & Ageing: European Study on Users, Markets and Technologies project" One core concern is the ever present issue of privacy, both in relation to data privacy of the potentially complex and intrusive personal data collected by the robot, and also in relation to the user's experienced privacy, specifically regarding robots that perform safety monitoring functions. Ethical work on assistive and social robots has also highlighted a range of concerns regarding the human-robot relationship, including the question whether the replacement of direct human care by robots is ethically objectionable whether the social experience of a relationship with social robots is intrinsically problematic or whether there is a need to integrate ethical principles into the design of such robots. The importance of value-based design has been highlighted, both in relation to the importance and complications of following the principles of privacy by design as well for the importance of a comprehensively ethically informed approach to design.
    - ***Ambition***
      - The MARIO project aims to provide such an integrated value-based approach to the design, trial and evaluation by means of embedding an ethical framework at the core of the project. In addition to particular attention to privacy concerns, the project will integrate the concerns of end-users and their carers and family throughout all stages of the project. This approach aims to remedy an essential shortcoming in the field of robotics for the elderly that a recent review article highlighted, namely the neglect of user perspectives regarding the development and use of those robots thereby addressing not just an essential requirement of good design, but also an important human rights concern regarding the rights of PWD. This is particularly challenging in relation to the target group of PWD, where cognitive capacity challenges need to be met in sensitive and innovative ways to facilitate informed consent and participation as well as supported decision making. The approach to the targeted involvement of PWD and their carers and families in the MARIO project will provide a transferable model of best ethical practice that has the potential to contribute significantly to the implementation of ethical and human rights compliant practice in the field. Finally, the evaluation of the innovative multidimensional approach to achieving social inclusion of PWD delivered by the NUIG team will be underpinned by awareness of ethical concerns regarding the balance between potential socially beneficial and problematic effects of the introduction of human-robot interaction in the care of PWD. To perform such an ethical analysis within the framework of the MARIO project has significant potential to advance the ethical debate on the issue which, while frequently addressed in abstract, is rarely realised in relation to concrete examples of social effects of human robot interaction.
        - {STO5} The system design will encompass ethical concerns
        - {STO5} The system will provide data privacy for users
    - ***Objectives***
      - To deal with ethical issues by exploring data structures, algorithms, applications and software technologies that empower end users to have input into the types of usage of their own individual data through principles of dynamic informed consent.
        - {STO5} The system will employ a ethical approach to the design of data structures and system design.
        - {STO5} The system will embody the concept of "dynamic informed consent"
      - To develop and implement an ethical framework that addresses ethical concerns about data privacy and meets data protection and security requirements for sensitive personal data, to be applied with a corresponding data access mechanism
        - {STO5} The system will be designed using an ethical framework when considering data privacy, data protection and access mechanisms for private user data.
      - To identify any evidence arising from the user experience of the robot-human interaction that could support ethical claims and concerns, and in light of the available evidence in the project and ethical literature balance the ethically advantageous and problematic aspects of the replacement of human support by service robot support.
      - To develop a core repository for all MARIO interactions that serves as a central access point enabling users to perceive an integrated personal information sphere by allowing overview, understanding, access and management.
        - {STO5} the system will have a core repository for user interactions.
        - {STO5} The system will provide users will ability to examine the interaction repository.
        - {STO5} The system will allow users to access and manage the information repository.
      - To develop metrics for trust and privacy, withdrawal functions for disclosed data and the integration of legal policies surrounding data management and accompanied by user guidelines.
  - STO6 Leadership and Progress: To achieve IMPACT in robotics, their use for independent healthy living and progress in the challenge area of loneliness, isolation and dementia
    - To engage and involve stakeholders and end users from the project beginning to its end in the design, development, and implementation of MARIO solutions via diverse pilot activities.
    - To go beyond the consortium by levering multipliers such as developers, the open source community, partner exploitation networks and channels and a stakeholder community.
    - To execute a communication campaign to the general public and targeted stakeholders that builds awareness, achieves branding, and facilitates post project uptake.

Proposal Requirements

(OL1) Requirements

- [OL1] System must build resilience in the user as a result of behavioural processes.
- [OL1] The system must enhance the user's connectedness
- [OL1] The system must enhance social interaction
- [OL1] The system must catalyse demential research capacity
- [OL1] [Unclear is the system required to maximise or is it the application of the system that maximises] The system must maximise effectiveness in highly personalized patient centric care
- [OL1] The system must work across Europe
- [OL1] System must strengthen PWD's resources for coping with challenges.
- [OL1] System must act as a base for developing interventions.
- [OL1] System must empower the user
- [OL1] System must empower the user's carers
- [OL1] System must empower the community the user is in
- [OL1] System should enhance a positive self-concept and attitude
- [OL1] System should promote acceptance of "changing self".
- [OL1] System should affirm the concept of a person centred environment.
- [OL1] System should enhance social support networks and community support.
- [OL1] The system should contribute to the implementation of strategies developed as a part of the evidence based toolkit of resilience strategies

(OL2) Requirements

- [OL2] The system should facilitate CGA.
- [OL2] The system should facilitate the evaluation of MPI
- [OL2] The System should contribute to cost management
- [OL2] The system should Reduce stress in the system of care
- [OL2] The system must increase the level of independent living.
- [OL2] The system must facilitate the monitoring and diagnostic processes that form part of the CGA
- [OL2] The system must contribute to communication within the care team.
- [OL2] The system must be able to contribute to the assessment of the rehabilitation plan.
- [OL2] The system will lead to improved diagnostic accuracy, optimisation of medical treatment and health outcomes, improved function and quality of life, reduced costs and improved long term care management.
- [OL2] The system must be able to contribute to the implementation of assessment data leading to an assessment of health.
- [OL2] The system must be able to detect changes in health based on the methods within the CGA approach.

(OL3) Requirement

- [OL3] The system must be able to connect the user to their care provider.
- [OL3] The system must be able to connect the user to the medical community
- [OL3] The system must be able to connect the user to the community social services
- [OL3] The system must be able to connect the user to their own personal social network
- [OL3] The system must be able to connect the user to their personal interests.
- [OL3] The system must be able to accept new applications developed by 3rd party developers.
- [OL3] The system must be able to interact with users using a touch screen [TECHNICAL].
- [OL3] The system must be able to interact with users using speech.

(OL4) Requirement

- [OL4] The system must be able to gather data from ambient sensors in the living environment.
- [OL4] The system must be able to communicate with users using natural language
- [OL4] The system must be able to detect the emotional expressions of the user.
- [OL4] The system must be able to interpret the emotional expressions of the user
- [OL4] The system must be able to make emotional expressions.
- [OL4] The system must be able to react to the user's emotional expressions.
- [OL4] The system must be able to adapt and evolve its behavioural responses to the user's emotional expressions depending on the living environment.
- [OL4] The system must be able to establish a personal and specialised relationship with the user (and with multiple users on an individual basis).
- [OL4] The system must be open
- [OL4] The system must be networked
- [OL4] The system must be able to access and exploit knowledge from the "Semantic Web"
- [OL4] Multiple instances of the system must be able to share learned knowledge between them in order to bootstrap behaviours.
- [OL4] The system is expected to improve its performance over time through learning.

(MLO) Requirements

- [MLO] System must use multi-faceted interventions
- [MLO] System must deliver progress via a service robot
- [MLO] System must work within assisted living environment
- [MLO] System must be capable of long term interaction with user
- [MLO] System must assist caregivers and staff in carrying out CGA using service robot.
- [MLO] Service robot must be flexible
- [MLO] Service robot must be modular
- [MLO] Service robot must be friendly.
- [MLO] Service robot must be low cost.
- [MLO] Service robot must be near market ready.
- [MLO] System must be able to support 3rd party application development
- [MLO] System must be able to support the download of 3rd party applications.
- [MLO] The system must use machine learning techniques to be more personable, useful and acceptable to users
- [MLO] Apache requirement unclear: The System must run Apache?
- [MLO] The system must have telecommunication capability
- [MLO] The system must be able to host alternative applications.

(RDC) Functional Goals

- [RDC] Seek ways to combat the perception of loneliness
- [RDC] Seek ways to increase resilience
- [RDC] Mitigate the effects and severity of dementia
- [RDC] How can robots be designed to combat the perception of Loneliness, increase resilience and mitigate the effects and severity of dementia.
- [RDC] How can robots be used to assist with CGA and the generation of MPI through data gathering and observation
- [RDC] How can robots be used to create interaction between users and their communities and care givers.

(M) Functional Goals

- [M] Alter the user's perception of loneliness
- [M] Increase the user's resilience
  - Strengthen personal attributes
  - Strengthen external assets
- [M] Improve retention of user's cognitive capacity.
- [M] Reduce social exclusion.
- [M] System to help care givers and staff as well as user.
- [M] Carry out Comprehensive Geriatric Assessment (CGA) to evaluate user.
- [M] Improve care team communication
- [M] Allow checking of rehabilitation plans
- [M] Directly carry out user evaluation
- [M] Indirectly carry out evaluation of behavioural change in the user.
- [M] Contribute to the construction of a Multi-Dimensional Prognosis Index (MPI).
- [M] Contribute to the evaluation of an MPI
- [M] Monitor user's daily living patterns and habits
- [M] Detect changes to the user's daily living patterns and habits

(SCOPE) Requirements

- [SCOPE] The system must be modular
- [SCOPE] The system should be cost effective
- [SCOPE] The system should be reliable
- [SCOPE] The system should be flexible
- [SCOPE] The system should be applicable in a real environment
- [SCOPE] The system should be safe
- [SCOPE] The system should be safe
- [SCOPE] The system will provide an intelligent interface for users
- [SCOPE] The system will be able to accept addition applications
- [SCOPE] The system will utilise the concept of "mutual care"
- [SCOPE] The system will utilise learning to improves performance
- [SCOPE] The system will utilise an ontology and semantic analysis to improve its performance
- [SCOPE] The system will personalise to the user and care providers over time.

(IMPACT) Requirements

- [IMPACT] The system will act as a convincing companion to the user
- [IMPACT] The system will utilise learning and the "mutual care" concept to enhance its interaction with the user
- [IMPACT] The system will provide connectivity to the community, to care providers, family, friends and personal interests for the user.
- [IMPACT] The system will provide users and carers with access to information, diagnostic tools and treatments.
- [IMPACT] The system will utilise learning and semantic analysis to enhance interactions

(SC) Requirement

- [SC] The system will be able to carry out CGA
- [SC] The system will be able to carry out MPI
- [SC] The system will be abel to utilise multiple sources of data
- [SC] The system will allow new applications to be developed.
- [SC] The system will connect the user to their community, care providers, their social network and interests.

STO1: Health and Assessment

- [STO1] The system needs to understand how it is perceived by users in a way that enhances appropriate behaviour
- [STO1] The system needs to perform socially and physically appropriate behaviours that are helpful to the user.
- [STO1] The system should be able to reduce the workload on care staff increasing their efficiency.
- [STO1] The system will enhance physical interaction and the automation of care processes and assistance.
- [STO1] The system must improve the outcomes of the user and help them participate in a meaningful way, living well in their community.
- [STO1] The system is expected to extend the time before a user needs to enter care
- [STO1] The system improves the user's resilience
- [STO1] The system must provide information about the user to the medical community.
- [STO1] The system must operate in coordination between the user, care providers and the community.
- [STO1] The system must be a too for carrying out CGA.
- [STO1] The system must be a tool for enabling the evaluation of users using MPI.
- [STO1] The system must interact cognitively with the user.
- [STO1] The system must be able to monitor and assess the food intake of the user
- [STO1] The system must be able to monitor and assess the health of the user.
- [STO1] The system must be able to monitor and assess the daily living processes of the user.
- [STO1] The system must provide mental stimulation to the user.
- [STO1] The system must provide connectivity between the user and others.
- [STO1] The system must be able to interact with the user with "mutual care"
- [STO1] The system will have a care giver module that relates the patient, health data and the caregiver community to the robot behaviours.

STO2 Sociology and Behavior.

- [STO2] The system will be able to autonomously perform parts of the CGA assessment
- [STO2] The system will be able to autonomously assess the health status of the user
- [STO2] The system will be able to carry out long term and continuous monitoring of the health status of the user.
- [STO2] The system must be acceptable to the user
- [STO2] The system must address privacy issues
- [STO2] The system must address data safety issues
- [STO2] The system will provide a more precise characterisation of the user
- [STO2] The system must operate in both care and home environments
- [STO2] The system will engage in a "mutual care" interaction with the user.
- [STO2] The system will establish a rich set of interactions with the user
- [STO2] The system will be able to follow the user
- [STO2] The system will be able to explore its environment
- [STO2] The system will be able to navigate around its environment.
- [STO2] The system will be able communicate with the user and effectively address their emotional needs using mood, gesture and eyes
- [STO2] The system will be abel to communicate to the user using a situation based natural language system appropriate to a PWD
- [STO2] The system will communicate with the user using gestures.
- [STO2] The system is able to adapt its behaviour to the user over time
- [STO2] The system is able to connect the user to their community
- [STO2] The system is able to connect the user to social support services

STO3 Robot Utility.

- [STO3] The system will be integrated onto a single platform
- [STO3] The system must integrate behavioural, social and cognitive skills.
- [STO3] The system must operate robustly
- [STO3] The system must operate autonomously for long periods of time
- [STO3] The system must be able to exhibit a set of behavioural skills triggered by the user
- [STO3] The system must be able to initiate behavioural activities.
- [STO3] The system must be able to engage in both verbal and non verbal interaction with the user, including gesture recognition, attention grabbing behaviours and emotion expression and recognition.
- [STO3] The system will be able to modify its behaviours through interaction with the user.
- [STO3] The system will be able to modify its social skills through interaction with the user
- [STO3] The system will build up "meanings" that are shared with the user through interaction and from the adaptive tuning of the association between the environment and social context and the afforded actions.
- [STO3] The system must be able to download new applications.
- [STO3] The system must be able to access ambient sensors in the environment.
- [STO3] The system must be able to access the "MARIO Ontology Network"
- [STO3] The system must be able to increase its knowledge by accessing the MON.
- [STO3] The system must be able to enhance its interaction with the user through accessing the MON.
- [STO3] The system must operate in an assisted living environment
- [STO3] The system must be able to execute different applications in different environments.
- [STO3] It must be possible to personalise the system
- [STO3] The system must be able to download new applications.
- [STO3] The system will contain a "My Interests" module
- [STO3] The system will contain a "MyMario" Module
- [STO3] The system will be able to interact with and make use of ambient sensors located in the environment.
- [STO3] The system will make use of ambient sensors to help monitor the user.

STO4 Semantic interactions

- [STO4] The system will use ontologies to help it use and process knowledge about the assisted living environment.
- [STO4] The system will integrate multiple sources of data and multiple methods of data integration to build semantically interoperable data.
- [STO4] The system will utilise resolvable URIs to identify entities and their relations.
- [STO4] The system will be able to relate entities and URIs to their real world entities.
- [STO4] The system will be able to utilise and embody the entities and their relations into behaviours to improve interactions.
- [STO4] The system will be able to parse text and carry out a formal semantic interpretation of it.
- [STO4] The system will be able to use the formal semantic interpretation of parsed text to enhance its knowledge through integration.
- [STO4] The system will be able to ground the semantic interpretation of text in entities.
- [STO4] The system will use a specially designed Ontology network.
- [STO4] The system will align to emerging ontology standards for robotics
- [STO4] The system will be able to evolve the Ontology by integrating new information gained through its interaction with the user, the environment and other robots.
- [STO4] The system will have a "sentiment analysis framework" able to recognise the user's moods and expressions.
- [STO4] The system will be able to integrate the semantic framework and the sentiment framework
- [STO4] The system will utilise an ontology that covers the actions of the system, the ambient entities, the context of operation, and the user needs.
- [STO4] The system will utilise the ontology to cope with the spatial characteristics of the operating environment
- [STO4] The system will utilise the ontology to communicate with the user
- [STO4] The system will utilise the ontology to communicate with other systems.
- [STO4] The system will be abel to evolve its knowledge and adapt its behaviours dependently on user interactions.
- [STO4] The system must be able to connect to the web and utilise web based knowledge to improve user interaction.
- [STO4] The system must be able to recognise and discover interaction and behavioural patterns relevant to its overall task.
- [STO4] The system must be able to recognise and respond to natural language interaction with the user.
- [STO4] The system must be able to recognise and respond to emotional behaviours.

STO5 Privacy, Ethics and Data Management

- [STO5] The system design will encompass ethical concerns
- [STO5] The system will provide data privacy for users.
- [STO5] The system will employ a ethical approach to the design of data structures and system design.
- [STO5] The system will embody the concept of "dynamic informed consent"
- [STO5] The system will be designed using an ethical framework when considering data privacy, data protection and access mechanisms for private user data.
- [STO5] The system will have a core repository for user interactions.
- [STO5] The system will provide users will ability to examine the interaction repository.
- [STO5] The system will allow users to access and manage the information repository.

- Healthcare Outcomes
  - Requirements
    - Impact on Care Givers
      - {MLO} System must assist caregivers and staff in carrying out CGA using service robot.
      - {STO1} The system must operate in coordination between the user, care providers and the community
      - {STO1} The system should be able to reduce the workload on care staff increasing their efficiency.
      - {OL1} System must empower the user's carers
      - {OL2} The system should Reduce stress in the system of care
      - {SC} The system will be able to carry out MPI
      - {SC} The system will be able to carry out CGA
    - User Outcomes
      - {STO1} The system must improve the outcomes of the user and help them participate in a meaningful way, living well in their community.
      - {STO1} The system will enhance physical interaction and the automation of care processes and assistance.
      - {OL2} The system must increase the level of independent living.
      - {STO1} The system is expected to extend the time before a user needs to enter care
    - Information Outcomes
      - {OL2} The system will lead to improved disgnostic accuracy, optimisation of medical treatment and health outcomes, improved function and quality of life, reduced costs and improved long term care management.
      - {OL1} System must act as a base for developing interventions.
      - {OL1} The system should contribute to the implementation of strategies developed as a part of the evidence based toolkit of resilience strategies
      - {IMPACT} The system will provide users and carers with access to information, diagnostic tools and treatments.
      - {OL2} The system must be able to contribute to the assessment of the rehabilitation plan
      - {STO1} The system must provide information about the user to the medical community
    - {OL1} The system must catalyse demential research capacity
    - {OL1} {Unclear is the system required to maximise or is it the application of the system that maximises} The system must maximise effectiveness in highly personalized patient centric care
    - {OL2} The System should contribute to cost management

- User Experience
  - Requirements
    - Impact on the user
      - {OL1} System should promote acceptance of "changing self"
      - {OL1} System should affirm the concept of a person centred environment.
      - {STO2} The system will be able communicate with the user and effectively address their emotional needs using mood, gesture and eyes
      - {STO1} The system must provide mental stimulation to the user.
      - {OL1} System must strengthen PWD's resources for coping with challenges.
      - {STO1} The system improves the user's resilience
      - {OL1} System should enhance a positive self-concept and attitude
      - {STO2} The system must be acceptable to the user
      - {OL4} The system must be able to establish a personal and specialised relationship with the user (and with multiple users on an individual basis).
      - {STO1} The system needs to understand how it is perceived by users in a way that enhances appropriate behaviour
      - {STO1} The system needs to perform socially and physically appropriate behaviours that are helpful to the user.
      - {OL1} System must empower the user
      - {IMPACT} The system will act as a convincing companion to the user
      - {OL1} System must build resilience in the user as a result of behavioural processes.
    - {OL1} System must empower the community the user is in
    - Mutual Care
      - {STO1} The system must be able to interact with the user with "mutual care"
      - {STO2} The system will engage in a "mutual care" interaction with the user.
      - {SCOPE} The system will utilise the concept of "mutual care"

- Knowledge Engineering
  - Requirements
    - {STO3} The system must integrate behavioural, social and cognitive skills.
    - {STO3} The system must be able to exhibit a set of behavioural skills triggered by the user
    - {STO3} The system must be able to initiate behavioural activities.
    - {STO3} It must be possible to personalise the system
    - {STO4} The system will integrate multiple sources of data and multiple methods of data integration to build semantically interoperable data.
    - TECHNOLOGY
      - {STO4} The system will utilise resolvable URIs to identify entities and their relations.
      - {STO3} The system will contain a "My Interests" module
      - {STO3} The system will contain a "MyMario" Module
      - {STO4} The system will be able to relate entities and URIs to their real world entities.
      - {STO4} The system will be able to parse text and carry out a formal semantic interpretation of it.
    - {STO4} The system will be able to utilise and embody the entities and their relations into behaviours to improve interactions.
    - {STO4} The system will be able to use the formal semantic interpretation of parsed text to enhance its knowledge through integration.
    - Ontology
      - {STO4} The system will use a specially designed Ontology network.
      - {STO3} The system must be able to increase its knowledge by accessing the MON.
      - {STO4} The system will use ontologies to help it use and process knowledge about the assisted living environment.
      - {STO3} The system must be abel to enhance its interaction with the user through accessing the MON.
      - {STO4} The system will align to emerging ontology standards for robotics.
      - {STO4} The system will utilise an ontology that covers the actions of the system, the ambient sensors, the context of operation, and the user needs.
      - {SCOPE} The system will utilise an ontology and semantic analysis to improve its performance
    - {STO4} The system will be able to ground the semantic interpretation of text in entities.
    - {STO4} The system will be able to evolve the Ontology by integrating new information gained through interaction with the user, the environment and other robots.
    - {STO5} the system will have a core repository for user interactions.
    - {STO4} The system will be able to integrate the semantic framework and the sentiment framework
    - {STO4} The system will utilise the ontology to cope with the spatial characteristics of the operating environment
    - {STO5} The system will allow users to access and manage the information repository.
    - {STO5} The system will provide users with the ability to examine the interaction repository.
    - {STO4} The system must be able to recognise and discover interaction and behavioural patterns relevant to its overall task.

- Communicaitons and Connectivity
  - Requirements
    - Community Connectivity
      - {STO1} The system must provide connectivity between the user and others.
      - {OL1} The system must enhance the user's connectedness
      - {OL1} System should enhance social support networks and community support.
      - {OL2} The system must contribute to communication within the care team.
      - {OL3} The system must be able to connect the user to the community social services
      - {OL3} The system must be able to connect the user to their care provider.
      - {SC} The system will connect he user to their community, care providers, their social network and interests.
      - {IMPACT} The system will provide connectivity to the community, to care providers, family, friends and personal interests for the user.
      - {OL3} The system must be able to connect the user to their personal interests.
      - {STO2} The system is able to connect the user to social support services
      - {OL3} The system must be able to connect the user to the medical community
      - {OL3} The system must be able to connect the user to their own personal social network
      - {STO2} The system is able to connect the user to their community
    - External Communication
      - {OL4} The system must be networked
      - {MLO} The system must have telecommunication capability
      - {STO3} The system will be able to interact with and make use of ambient sensors located in the environment.
      - {STO3} The system must be able to access ambient sensors in the environment
      - {STO3} The system must be able to access the "MARIO Ontology Network"
      - {STO4} The system must be able to connect to the web and utilise web based knowledge to improve user interaction.
      - {OL4} The system must be able to gather data from ambient sensors in the living environment.
      - {OL4} Multiple instances of the system must be able to share learned knowledge between them in order to bootstrap behaviours.
      - {OL4} The system must be able to access and exploit knowledge from the "Semantic Web"
    - {STO1} The system will have a care giver module that relates the patient, health data and the caregiver community to the robot behaviours.
    - {STO4} The system will utilise the ontology to communicate with other systems.
    - {STO4} The system will utilise the ontology to communicate with the user

- User interaction
  - Requirements
    - Natural Language
      - {OL1} The system must enhance social interaction
      - {STO3} The system must be able to engage in both verbal and non verbal interaction with the user, including gesture recognition, attention gathering behaviours and emotion expression and recognition
      - {OL4} The system must be able to communicate with users using natural language
      - {STO2} The system will be able to communicate to the user using a situation based natural language system appropriate to a PWD
      - {STO4} The system must be able to recognise and respond to natural language interaction with the user
    - {STO1} The system must interact cognitively with the user
    - Emotion recognition
      - {OL4} The system must be able to react to the user's emotional expressions.
      - {OL4} The system must be able to interpret the emotional expressions of the user
      - {OL4} The system must be able to make emotional expressions.
      - {OL4} The system must be able to detect the emotional expressions of the user.
      - {STO4} The system must be able to recognise and respond to emotional behaviours.
    - {OL3} The system must be able to interact with users using speech.
    - {MLO} Service robot must be friendly
    - {STO2} The system will communicate with the user using gestures.
    - {STO4} The system will be able to evolve its knowledge and adapt its behaviours dependently on user interactions.
    - {MLO} They system must use semantic analysis methods to be more personable, useful and acceptable to users
    - {MLO} System must use multi-faceted interventions
    - {MLO} System must be capable of long term interaction with user
    - {SCOPE} The system will provide an intelligent interface for users
    - {IMPACT} The system will utilise learning and the "mutual care" concept to enhance its interaction with the user
    - {STO2} The system will establish a rich set of interactions with the user

- System
  - Requirements
    - {STO2} The system will be able to navigate around its environment.
    - {STO2} The system will be able to explore its environment
    - {MLO} Service robot must be near market ready.
    - {MLO} Service robot must be low cost
    - {STO2} The system will be able to follow the user
    - {SCOPE} The system should be flexible
    - {SCOPE} The system should be reliable
    - Operating Environment
      - {STO3} The system must operate in an assisted living environment
      - {MLO} System must work within assisted living environment
      - {OL1} The system must work across Europe
      - {SCOPE} The system should be applicable in a real environment
      - {STO2} The system must operate in both care and home environments
    - {MLO} System must deliver progress via a service robot
    - {SC} The system will be abel to utilise multiple sources of data
    - {SCOPE} The system should be safe
    - {SCOPE} The system should be safe
    - {SCOPE} The system should be cost effective
    - {SCOPE} The system must be modular
    - {MLO} Service robot must be modular
    - {MLO} Service robot must be flexible
    - {STO} The system must operate robustly
    - {STO3} The system must operate autonomously for long periods of time
    - {STO3} The system will be integrated onto a single platform
  - Adaptation
    - {STO2} The system is able to adapt its behaviour to the user over time
    - {STO3} The system will build up "meanings" that are shared with the user through interaction and from the adaptive tuning of the association between the environment and social context and the afforded actions.
    - {STO3} The system will be able to modify its behaviours through interaction with the user
    - {SCOPE} The system will utilise learning to improves performance
    - {SCOPE} The system will personalise to the user and care providers over time.
    - {MLO} The system must use machine learning techniques to be more personable, useful and acceptable to users
    - {IMPACT} The system will utilise learning and semantic analysis to enhance behaviours.
    - {OL4} The system must be able to adapt and evolve its behavioural responses to the user's emotional expressions depending on the living environment.
    - {OL4} The system is expected to improve its performance over time through learning.
    - {STO3} The system will be able to modify its social skills through interaction with the user

- Ethics and Data Protection
  - Requirements
    - Data Privacy
      - {STO2} The system must address data safety issues
      - {STO2} The system must address privacy issues
      - {STO5} The system will provide data privacy for users
    - Ethics
      - {STO5} The system design will encompass ethical concerns
      - {STO5} The system will employ a ethical approach to the design of data structures and system design.
      - {STO5} The system will be designed using an ethical framework when considering data privacy, data protection and access mechanisms for private user data.
    - {STO5} The system will embody the concept of "dynamic informed consent"

- User assessment and Monitoring
  - Requirements
    - {STO3} The system will make use of ambient sensors to help monitor the user.
    - Health Monitor
      - {STO1} The system must be able to monitor and assess the health of the user
      - {OL2} The system must be able to contribute to the integration of assessment data leading to an assessment of health.
      - {STO2} The system will be able to autonomously assess the health status of the user.
      - {STO2} The system will be able to carry out long term and continuous monitoring of the health status of the user.
    - {STO1} The system must be able to monitor and assess the daily living processes of the user.
    - CGA
      - {STO1} The system must be a tool for carrying out CGA.
      - {OL2} The system should facilitate CGA
      - {OL2} The system must facilitate the monitoring and diagnostic processes that form part of the CGA
      - {OL2} The system must be able to detect changes in health based on the methods within the CGA approach.
      - {STO2} The system will be able to autonomously perform parts of the CGA assessment
    - MPI
      - {STO1} The system must be a tool for enabling the evaluation of users using MPI.
      - {OL2} The system should facilitate the evaluation of MPI
    - {STO4} The system will have a "sentiment analysis framework" able to recognise the user's moods and expressions.
    - {STO1} The system must be able to monitor and assess the food intake of the user
    - {STO2} The system will provide a more precise characterisation of the user

- Proposal Requirements
  - {MLO} Requirements
    - {MLO} Apache requirement unclear: The System must run Apache?
  - {RDC} Functional Goals
  - {M} Functional Goals
  - {SCOPE} Requirements
  - {IMPACT} Requirements
  - {SC} Requirement
  - {OL1} Requirements
  - {OL2} Requirements
  - {OL3} Requirement
    - {OL3} The system must be able to interact with users using a touch screen {TECHNICAL}
  - {OL4} Requirement
    - {OL4} The system must be open
  - STO1: Health and Assessment
  - STO2 Sociology and Behavior:
  - STO3 Robot Utility:
  - STO4 Semantic interactions
  - STO5 Privacy, Ethics and Data Management:

- Application Development
  - Requirements
    - {STO3} The system must be able to execute different applications in different environments.
    - 3rd Party App Development
      - {MLO} System must be able to support the download of 3rd party applications.
      - {OL3} The system must be able to accept new applications developed by 3rd party developers.
      - {MLO} System must be able to support 3rd party application development
    - New Applications
      - {SCOPE} The system will be able to accept addition applications
      - {STO3} The system must be able to download new applications.
      - {MLO} The system must be able to host alternative applications.
      - {STO3} The system must be able to download new applications.
      - {SC} The system will allow new applications to be developed.

Grouped Analysis

- **Time & Calendar**
  - Tell the user what is happening today, what needs to be done and when.
    - **MARIO in their own home to be able to remind them when the shopping needs to be done and bills need to be paid; able to regulate the heating in the house and lock all the doors at night time or at least remind them to lock all the doors; able to select the TV channels that they like via voice commands; alert them when someone is going to visit them eg 'your best friend Tom is coming to see you today'**
    - **MARIO at the start of the day to automatically tell you date and time and year and a list of the day's activities and events planned for that day.**
    - **remember appointments and things to do during the day, acting as a calendar**
    - **Reminders for social events- BINGO, Dementia advocacy group meeting, other social events**
  - Inform the user about the time and date
    - Ability to orientate residents to time ….. and date
  - Remind the user to eat or drink
    - **Reminders to eat and to drink; have photos beside different foodstuffs and drinks so it prompts them what they are**
  - Produce a story of the day based on what has happened to remind the user what they did during the day, who they saw etc.
    - **In the nursing home could he remind you that you had visitors earlier in the day and who they were as sometimes we forget and think no one has visited?**
  - Listen to the user and record and interpret what they say to remember events and make changes to the diary
    - **Able to call out your personal diary to MARIO and he would record it for you.**
  - Make sure the user is following a healthy sleep/wake pattern
- **Communication**
  - Communicate externally to the operating environment with audio and video calling
    - **That MARIo could show a video back to the relatives of themselves in the nursing home and what they are doing.**
    - and the Ability to skype ;
    - **video-call friends**
    - **Able to Skype family and friends through Mario, they call out the number and MARIO rings the person. That family could send videos to MARIO over the wifi and it would then play back the video to the person eg if they were missing a wedding or a family event in Australia that they couldn't attend, getting a life feed to the event would be great.**
  - Allow incoming calls and provide info about who is calling
    - **Store phone numbers and photos of the person attached to the phone number so they are prompted as to who is making the phone call**
    - Is it possible for MARIO to show a 3D image/hologram to the person of their relative when they are talking to them via skype or the phone?
  - Provide local communication to staff about the state of users
    - How will he alert the nurse that something is wrong with a resident if he is away down the ward and the nurse is a distance away? How will he communicate? Could the nurse have a remote in her pocket that bleeps or alerts her when something is wrong with the residents that MARIo is with?
- **Movement**
  - Move around the care home and hospital environments
    - (…)and residents might fall over him? Need to consider how he can move around the nursing home on his wheels!
  - Fail safe motion.
    - What happens if something happens to MARIO, he falls over or crashes into another piece of equipment like the floor polishing device or a commode?
  - Visible or detectable to users so that it is not a trip hazard. e.g. Park safe or audible warning if stuck.
    - what if we accidently knock into him or maybe we could even fall over him?
  - Size compatible with the operating environment.
    - **Marion needs to be able to move around in small spaces as bedrooms are small in the nursing homes. In the proposed pilot sites residents are on average 4 per room and these rooms are small.**
    - The space in each room is small, MARIO could clutter up the place
- **Control**
  - Remote command and control, could be via physical device or interaction such as speech or gesture.
    - Remote control to summons him not just voice activated?
    - Voice activation () key items
    - **(When playing games) but not having to use the pad at the front to do that all the time, could he be activated by voice alone?**
  - Division of command interface according to identity, some commands need carer to give command rather than user. e.g. "Open the front door".
    - **Who controls him us or the nurses?**
    - Who controls him the nurse or the resident?
  - Summon MARIO from across a room
    - **Can we control MARIO? Would there be a remote control that we could use to control him and summons him when we need him?**
  - Clear on/off state and a specific turn on sequence or command
    - **Can we switch him off when we don't want to b annoyed by him? Can we switch him off at night?**
    - Can there be a sleep mode for MARI at night?
  - MARIO state needs to be clearly communicated to the user and auto restart if inactivity detected
    - Who will be responsible for MARIO when he is in the home, what if his system crashes while he is here, how does he reboot?
- **Physical Properties**
  - Physically robust
    - MARIO to have an adjustable height, at the moment concern that he is too small and people with dementia will try and use him as an assistance to get up out of a chair and will knock him over; needs to be robust as they could hit him with their stick on the head or the body.
    - MARIO needs to be robust, we are afraid he will fall over,
  - Recharge its power source
    - When will he recharge his batteries and how long will that take?
  - Adjust its physical confiuration to different user needs
    - MARIO to have an adjustable height, …
    - Can the IPAD be adjustable as at the moment it seems the person has to lean into the screen, could the screen move out more towards them and then back again when they are finished?
- **Interaction**
  - User Interface matches user cognitive ability
    - Restrict the choice on the IPAD icons as too many options will be confusing for people with dementia, it looks like there are 4 options at the moment consider reducing that down to just two; Personalise the icons on the MARIO IPAD.
  - Plays games
    - **want MARIo to be able to entertain them as a group in the nursing home; play games with you maybe do quizzes and crosswords with you**
    - **Have games on it like Golf;**
  - Reads out text, book or newspaper when requested.
    - MARIO to read out local parish newsletters,;
    - **Be able to read a book to them as many have failing sight and concentration is poor**
    - **The robot could announce news headlines**
    - **The robot could recite the rosary**
    - Religion is important for residents. can MARIO say the rosary with them?
  - Take turns and understands social communication in context
    - **Will he start the conversation or will I have to start it ?**
  - Plays music, radio, television or Karaoke appropriate to the time of day or the mood of the individual.
    - (Show) the horse racing.
    - show local football games on his TV screen
    - **MARIo to play soothing music to you at night and to gently wake you in the morning**
    - **be able to play their favourite music; ability to do karaoke in the nursing home for those who want to have a singalong;**
    - **The robot could propose the listening of musical tracks, previously chosen according to the specific individual tastes, to relax the patient**
  - Takes photos and shares them
    - could MARIo take photos of the resident to share with family members?
  - Takes written input
    - Have a writing pad on the IPAD where visitors can record their names and details when they visit?
  - Tells the user where they are if they are lost.
    - Ability to orientate residents to … place …
    - Detachable mobile piece on MARIO that could be taken in their pocket or handbag which would have GPS, face recognition, voice recognition, reminders and prompts calendar; able to call out directions to you as you go to the shop or are in the car in a human sounding voice.
- **Sensing**
  - Able to monitor the environment and detect sensory events and patterns. Smoke, running water, kettle boiling etc.
    - Smoke detector in MARIO
    - Can MARIO have 360 degrees or all around auditory ability to pick up sounds?
    - MARIo must be able to distinguish between day and night
  - Able to recognise people and individuals (face and voice identification)
    - face recognition key items
    - How will MARIO work with more than one resident?
  - Able to detect the motion of people in environment and characterise the motion
    - MARIo needs to have a falls detection; motion sensors on the person?
    - [Detect] That they are moving around in the room or wandering?
  - Able to detect emotional and psychological states of the user in the context of their condition and environment.
    - Sensors to pick up the residents physiological status;
    - Can MARIO identify someone in distress in terms of their emotional wellbeing but not just by pressing the ipad but some type of sensor and then alert the staff?
- **Physical Tasks**
  - Able to move outside
    - **Would like if MARIo could walk outside in the garden with me or along the path of the nursing home**
    - **Could he play a game of bowling with you?**
  - Able to physically interact with the user
    - **The robot could play cards**
    - **Could It help me to do my paintings?**
- **Cognitive Tasks**
  - Remind users where important items are, keys, glasses etc
    - **Remind them where their keys and their purse are.**
  - Remind the user who is in the room who they are talking to
    - **MARIo has face recognition so knows who people are and can prompt you so your not embarrassed when you cant remember**
  - Able to prompt the user about life tasks and the sequence of actions needed to carry out a task
    - **MARIO to remind you what clothes to put on when you get muddled eg put your underwear on first Mary, ….now put on your dress, that red one over there looks nice…how about those red shoes…they would match your dress"**
  - Must be able to identify individual users and recall personal information about them
    - MARIO mush have the lifestory for the person and be individualised to each person.
    - **MARIO has to be able to have in putted the life history/life story of the person, must really know the person; must have their interests and hobbies**
    - **That MARIO becomes their memory bank and stores their memories for them and then prompts them eg tell me again how you met your wife? That was a great holiday in France when your children were young, tell me about visiting Disneyland"**
  - Reminiscence Tasks
    - **The robot could show pictures of the patient and ask him/her if he/she remembers when and where one particular shot has been taken, and who are the people with him in the pictures**
    - **The robot could retrieve events from the life history of the user (e.g. "Dear Tom, do you remember when you were in France…"), elaborate them and interact with the user encouraging him/her to talk about this events proposing also to analyse some pictures (see following point)**
  - Detect the state of the user and recognise emotional or physical states, then carrying out appropriate activities.
    - **Usually patients stay seated on their sofa doing nothing for a long time. When this state is detected by the robot, it could propose engaging tasks to keep him/her active**
    - **That MARIO could detect when they are feeling depressed or lonely and would cheer them up or send out a signal to someone to come and visit them.**
    - **That MARIo would be able to motivate them and deliver words of encouragement eg 'lets do it' "Don't give up" " come on have a go" .**
    - **detect the emotional status**
    - **act as a companion proposing stimulating tasks such as reading news, calling a friend**
    - **Unfortunately, drugs alone don't resolve the course of the illness. It is necessary to perform runs of cognitive stimulation to empower the residual abilities and to slow down the cognitive decay. The robot could perform daily exercises for cognitive stimulation**
- **Healthcare Tasks**
  - Able to detect vital signs
    - **Able to record, vital signs,, person's height, weight,**
    - **If you're a diabetic would he be able to sense when my blood sugar levels are dropping too low and tell me or the nurse**
    - sensors to detect if the blood sugar is low orhigh?
    - MARIO would send information on vital signs to the nurse who would then make the decision on care outcomes not send information direct to the doctor.
  - Able to detect consumption of food and drink
    - **monitor their food and drink intake**
    - **check if he/she eats**
  - Able to detect taking medicine and remind or check with the user.
    - **Sometimes I forget that the nurse has given me my medicine, could he remind me that I have taken them rather than I bothering the nurse?**
  - Able to detect emergency conditions and get help
    - **In Emergencies that MARIO knows if someone is not responding, say they have fallen and are unconscious and will automatically send for help**
    - **video-call the medical center or and his/her relatives in case of emergencies**
    - If a client has a tendency to fall can MARIO check the client's physiological data overtime and then generate a graph where the nurses can see what the reason might be that lead to these falls?
  - Record health patterns through observation to build an individual history.
    - Like the idea of having MARIo undertake the Comprehensive geriatric assessment.
    - **The inversion of the circadian rhythm (sleep-wake cycle) is the more frequent psycho-behavioural symptom in people with MCI, and it represents a serious burden for the caregiver. The robot could record the patient during the sleep and wake him up at the correct time. Proposing activities it could also help not to fall asleep in a period of the day when this could alter the sleep-wake cycle**
  - Able to detect posture and patient position and motion to recognise falls or poor movement
    - **check posture to detect possible falls**
- **Apperance**
  - Spoken Voice more human, louder and slower
    - **MARIO to speak as a human and not sound as it does now like a robot; maybe have the voice of someone they know but for others they thought that a familiar voice would be confusing**
    - **The voice needs to be clear, he needs to speak slowly and a bit loudly so we can hear**
    - Needs to speak like a human not a computer or a sat nav
  - Needs clothes and hair needs to look friendly
    - **Could he have some hair? Can we put a shirt of some clothes on him to make him a bit more friendly looking?**
    - Concerned that at the moment MARIO is unfriendly in appearance and would frighten residents and looks very mechanical, needs to look more friendly and warm
    - **He looks rather frightening, not sure they would like him as he now is, in terms of appearance to be around the nursing home.**
    - **To have more softer or warm features- 'he is like a fridge'**
    - Maybe give him a wig and put a shirt on him
    - **The colour green is very cold on MARIO, could we have a different colour, maybe a brighter warmer colour eg pale blue**
  - Needs to express emotion and make eye contact, interact.
    - **He needs to appreciate humour and 'have a laugh' with us.**
    - Could he smile, express some emotion, appear to make eye contact ? Needs to be able to communicate empathy to the residents.
    - **The robot could wear a hat and have a smiling face so that the patient feels comfortable when it arrives**
  - Needs to be more visible
    - **The robot could have a more noticeable and light colour like orange**
- **Ethics**
  - Must keep personal information private
    - **Will he share private conversations that I have with one family member with another family member? Will he tell my business to someone's?**
    - Will each resident have a personal log in number for MARIO so that he keeps their data safe and distinct from other residents?
    - (CARE Plan generated by MARIO) How safe is this information in terms of storage and security.
    - Privacy and confidentiality of the information stored in MARIO
    - **Will our secretes be safe with MARIO?**
  - Strict controls over access to personal information. Who has access rights? Who owns the information?
    - **Who will have access to the information that we give to MARIo and he has in his memory?**
    - **Where will he hold all his information, on chip in his head?? Who can access my information that he has?**
    - (Confidential Information) How will it be stored safely so that others cannot acces it?
    - (Confidential Information) Who owns that information?
  - (CARE Plan generated by MARIO)
    - Who will have access to this information?
    - Can the information collected by MARIO generate a CARE plan for the resident without the nurses input?
  - Information on MARIO will need to be backed up, how can privacy be maintained?
    - Will the information in MARIo be backed up somewhere, and will it be safe?
  - How can private information be distinguished from non-critical information about an individual. e.g medication vs favourite radio station.
    - Could MARIO have two memories for a resident, in one memory private information is stored and in another memory the social material is stored?
  - How can the balance between ethical care and the use of a robot be implemented?
    - Concern that MARIO might be used to replace nurses in the future .
  - How can support systems and implementation plans be made ethical?
    - **It is difficult that the patient accepts the robot in his/her daily living environment without proper information and instructions**
  - Will the use of a robot stigmatise the user?
    - **It is difficult for a patient to accept a robot that follows the patient outside his/her home. Patients are not happy to be seen with a robot.**
- **Rollout**
  - Important to involved the family members in the launch of MARIO and in advance of his arrival to the nursing home
  - Most staff welcomed the idea of MARIO and keen to see him in person!
  - Probably best to introduce MARIO to the residents with very mild dementia for the pilots
  - **It doesn't transmit emotions and it is important to underline that it has not to replace a real person, but it can be considered just as a valuable tool to reduce the burden of the caregivers**