Annex 6

Innovate UK

Final Report

FINAL REPORT – EXECUTIVE SUMMARY

ORGANISATION	DESIGNABILITY CHARITY
PROJECT TITLE	CHIRON
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EXECUTIVE SUMMARY

1. What was the intention of your project (summary)?

We envisaged an intelligent modular robot system comprising a range of actuators, that grows with us and learns our needs and preferences while we are well, and is able to adapt, expand and learn as our care needs emerge. Our vision is for a CHIRON in every home.
The mission was to move away from a disability/need-centric model of care to a preventative and supportive model of care that aims to extend our independent living capacity, disrupt the pathway to institutionalised care and enable people to stay independent for longer. It aims to support them to undertake their own personal care tasks, remain mentally engaged and extend their years of healthy and fulfilling life, Ultimately it aims to significantly enhance people's later life options beyond the current dependency model that has a tendency to objectify older adults.
The project intended to harness the current and emerging ability of robotic systems to handle materials and objects with high levels of accuracy and sensitivity, linked to sensory feedback and vision as a modular set of devices and software that can be mixed and matched by the customer to enable independent self-care and domestic tasks or care worker to enable assistance to an increased number of customers.
Key attributes of a successful system include operational safety in unpredictable situations, adaptability in dynamic environments, intelligence for making autonomous decisions based on perception of the context and user state, reliability to operate without manual intervention, and ability for multi-modal interaction to enable use by people with different communication and mobility difficulties. The CHIRON modular robotic system was intended to be:

1. Reconfigurable and interoperable as an ecosystem of software and hardware components.
2. Online and configured for machine learning and competent straight out of the box.
3. Compatible with the existing external ecosystem such as smart wearables, home automation, occupancy detectors, mobile care apps.
4. Accessible to friends and family and keep them informed about your wellbeing.
5. Respond feedback from you, the customer, using both audio and advanced vision systems to ensure that all support being provided is safe, consensual and dignified.
6. Controlled by spoken languages and gestures and be updated with the latest advances in communication methods for people with dementia or learning disabilities.
7. Extendable to have sufficient sensory and mechanical feedback in the future (safety for close human/robot interaction) to help people turn, move, transfer, sit, stand and walk.

2. What does your final solution consist of?

The project developed a proof of concept overhead care assist robot that uses standard gantry systems to provide a rigid Z (X and Y) positioned end effector. End Effectors were designed to assist people in moving from sitting to standing and to fetch and carry objects and are extensible to multiple additional tasks. The system puts RolaTube (a Storable Tubular Extensible Member) to a novel use to provide the Z extension and Rotite connectors to deliver the interchangeability and interoperability of end effectors. The system has been constructed with consideration given to current safety and regulatory standards for assistive robots, with a view to ensuring that it would be safe to be used with people in the future.
Voice activation using Amazon ECHO, Google Home and the Softbank Pepper robot has been utilised, together with touch screen tablet control interface. The system has been set up in the Bristol Robotics Laboratory Assisted Living Space; there is a Sit to Stand robot in the bedroom area and the Pick and Place system is in the kitchen dining area. Both systems can be easily demonstrated and have been evaluated by a sample of older adults whose feedback helped to make improvements to the interactivity with the system and the design of the interfaces.
It should be stressed that the project outcome is a "proof of concept" and that much work needs to be carried out before the system reaches a Minimum Viable Product stage and then there will be significant testing that will need to be undertaken to obtain regulatory

approval. These include:
BS EN ISO 13482-2014 Robots and robotic devices - Safety requirements for personal care robots
BS EN 62366-1-2015 Medical devices - Part 1: Application of usability engineering to medical devices (IEC 62366-1:2015)
Lifting Operations Lifting Equipment Regulations 1998 (LOLER)

The solution that we have developed is unique and world leading, patent pending 'An overhead robotic system to support independent living' P003448GB00.

3. How did you go about developing and prototyping your solution?

The engineering design and development was undertaken primarily by Designability Charity, and the Bristol Robotics Laboratory, with the Shadow Robot Company working on the software and gripper. Key input to the engineering teams was provided by the care partner, Three Sisters Care and SHABA. Telemetry Associates provided support for project management. Three Sisters Care helped the project develop use cases of the needs of older adults from a set of their clients (The Pioneer Group). Significant work was required to define what form the solution might take and these activities covered the first two quarters of the project. The outcome of requirements activity was the design of a gantry mounted robotic system, with control over the X and Y positioning, and a semi-rigid retractable Z vertical axis. The Z axis utilised a RolaTube, a Storable Tubular Extensible Member (STEM) in an innovative way to deliver the vertical movement. The design work was shared between the engineering organisations with Designability developing the geometric solution and the RolaTube, BRL developing the control system and drives for the X and Y axes and Shadow developing the interconnection and interoperability. Most of the software was developed using open source Robot Operating System (ROS). BRL developed the human-robot interfaces, which enable user interaction through a range of modalities, voice, touch and force feedback. Shadow developed the sensing systems and the control software to traverse the space of the test areas. This used a four-camera 3d vision systems to track position and identify presence of obstacles in the space to be avoided.
By the end of Q6 the project had a working prototype of the X,Y and Z movement and control systems, with proprietary Rotite end-effector mechanical coupling.
By Q7 there were two prototypes; A Sit to Stand (STS) assist system with X and Y axis control and positioning, utilising a Designability designed the STS end effector incorporating force sensing and feedback developed by BRL, as well as a Pick and place (PAP) X,Y,Z control and positioning system, with Shadow designed rotatable gripping device.
At project end both of these two proof of concept prototype systems have been demonstrated as working.

4. What did you learn from this project?

Knowledge
There was a very large body of knowledge collated in understanding care-related activities to explore gaps and barriers to incorporation of intelligent technologies, in smart homes and in robotics. It was noted that disseminating this knowledge across a multidisciplinary team of engineers, designers, industry groups and social care providers is not straightforward. However the CHIRON consortium has acquired more experience and channels for effective dissemination, as this continues to be realised through the organisation of talks to a range of stakeholders, as well as writing of white papers and research publications after the end of the project.
Expectations
The work required to develop the engineering, control, human robot interface and safety systems represents a considerable engineering challenge. There are also significant safety and ethical issues that need to be considered in the test and evaluation phases. It is

important that health and social care partners recognise this and expectations around delivery and availability of the systems are managed accordingly.

Market and Business Case

We learnt from the Business Case work, that there is a significant market for what the project has created provided it can be streamlined, cost reduced and turned into a consumer product. We also know that the work that still needs to be done is likely to require around £10 Million on development funding and that to reach a saleable product will take at least 3 years and while we can point to a NPV of about £50 Million if sales commence in 2022 and are taken out to 2030 (at 12% discount rate). Alongside this the potential end user savings of the current 250 thousand elderly people requiring carers could see their costs lessened by £22 thousand per year (or £60 per day). (Total 5.5 Billion per annum for the UK)

Market Requirements

We also know that a marketable product must be easy to set up, not require significant structural fixing (as this will contravene Leaseholder and Landlord contracts and significantly curtail the potential market) and that ongoing maintenance and support for the systems will need to be built into the delivery model.

Funding Gap

The major issue is the work needed to take the current proof of concept system through to a pre-production prototype. Feedback we have received is that at this early stage, the technology is considered to high risk for venture capital and therefore further government funding is likely to be required in order to realise the potential of the technology.

5. What are the next steps to commercialising and scaling your solution?

It is acknowledged that there is still significant work to be done to bring the product to market and that the CHIRON project partners do not have all the required skills and capabilities to do this. The work required will need further funding and we perceive that the product requires clinical and performance validation and safety-related development to bring it closer to market and begin to attract VC Funding. Angel investment will be of too low value to be of major use and again will be looking for a return on investment earlier than can realistically be achieved.

We also recognise that the total investment needed to reach market is beyond that which single Innovate UK grant could provide. We are therefore taking a pragmatic approach with an understanding that funding will need to come from via staged investments from a combination of research council grants, central government, investors and commercial partnerships.

We have developed a package of marketing and promotional materials, and having researched the market and identified potential early adopters, have rebranded the system as JUVA.

We plan to:

1. Enter a bid into Innovate UK’s January 2018 sector competition: Strand 2, Emerging and Enabling technologies to deliver further engineering developments and safety critical software development.
2. We will actively seek additional grant sources to allow us to complete the additional work packages with the aim of delivering a minimally viable product by 2020-21
3. Establish a new consortium of partners with the required expertise to take the product to market. From within this consortium we will aim to create a commercial entity that is well placed to seek VC funding within 2-3 years. Ideally this consortium will include a commercial partner with manufacturing and route to market.
4. We have already expressed interest in participating on KTN Investment events going forward and will be exploring whether there are elements of the project which have viability for segmented investment with an early exploitation opportunity
5. Explore alternative methods of funding such as social investment and crowdfunding

6. Develop relations with existing medical device manufacturers, housing providers and social care organisations to identify the most effective early adoption sites, synergistic opportunities and initial routes to market.
7. Explore additional market segments for the product aside from the aging sector. We perceive that there are significant opportunities within hospital secondary care and also long term care for people with high physical needs. The secondary care hospital market is of particular interest as it is a controlled environment that faces acute pressures on funding and staffing. There are also opportunities within areas such as therapy and rehabilitation.
8. Continue to disseminate our learnings across applicable channels to maintain interest and momentum.

The Business case (deliverable 6.4) has clearly detailed the potentially valuable business opportunity from the work done by the CHIRON Project and the CHIRON consortium is keen to ensure the project is scaled and the product commercialised.

Describe 1 or 2 case studies illustrating the disruptive impact and consumer demand generated by your solution.

Our state of the art document reviewed the economic and market context for CHIRON.

The demand for care will significantly exceed supply - 1.7 million people in the UK will require care by 2030.
The average yearly cost of an individual in residential care will reach between £42,000 to £48,000 and for non-residential care will be £9,000 to £14,000 by 2030.
Private self-paying market is increasing as local authority funding decreases.
Annual UK public expenditure on long-term care will increase from £11.3 to £31.1 billion by 2032, with private expenditure due to rise from £7.3 to £22.4 billion in the same period.
Allowing an individual to stay in their homes and avoiding residential care has an estimated cost saving of £20,000 annually per person for the public sector.
The number of people requiring (residential and non-residential) care will increase substantially from 1.4 million in 2011 to 1.7 million in 2030.
What we know from Section 2 on 'Workforce Shortages' is that the demand for care will significantly outstrip supply.

Age UK has estimated that 1,004,000 older people between 65 and over have unmet social care needs – (Having a bath or a shower, Dressing or undressing, Getting in and out of bed, Using the toilet, Eating, including cutting up food) there were roughly 31 per cent of older people with difficulty in carrying out activities of daily living (Age UK, 2014). They looked into ELSA (Wave 6, Marmot, M. et al. (2014). English Longitudinal Study of Ageing: Waves 0-6, 1998-2013) and extracted the volume of unmet needs among respondents aged 65 or over. From this they estimated the number of people with difficulties with ADLs by number of difficulties and how many of these have unmet needs. There were 920,000 people with 1 to 3 difficulties requiring up to 3.5 hours of care, 40,000 with 4 needs requiring 10 hours of care and 42,000 requiring 30 plus hour of care per week.

The table below shows a summation of the clinical frailty levels mapped against how many hours care these people need, as well as a rough estimate of the costs people will pay per year in case in relation to their level of need (Source 3SC). Estimates of the number of people affected have been included, based on the Age UK analysis.

Table relating care need to clinical frailty level with estimated number of people in need.

Clinical Frailty Level	**Hours Care per week**	**Cost of Care per year estimate in £**	**Estimated numbers of people affected**
Clinical frailty level 4 – issues around not being able to garden, help with cooking	5	3,600	920,000
Clinical frailty level 5 – needs mobility rails, cycling an issue, on medications	7.5	5,500	
Clinical frailty level 6 – mainly stays at home, cannot garden anymore, eyesight bad, danger of dehydration as difficult to go to toilet	12	8,700	40,000
Clinical frailty level 7 – Stroke, housebound, risk of pressure sores, requires support getting to toilet, transfers from wheelchair to toilet a problem.	18	13,100	42,000

Clinical Frailty level 8 – Heart attacks and stroke, arthritis, asthma, danger of pressure sores, diabetes, medication, doubly incontinent	168	52,000	

The Market for Assistive Robotic Technology for Care
A 2010 study (RAS 2020 Robotics and Autonomous Systems, July 2014, RAS-Special Interest Group of Technology Strategy Board) forecast that annual UK public expenditure on long-term care will increase from £11.3 to £31.1 billion by 2032, with private expenditure due to rise from £7.3 to £22.4 billion in the same period. There is a clear need to develop new assistive robotic technologies that allow people to live for longer in their own homes.
The Department for Business, Innovation and Skills, has highlighted that the UK is in a prime position to achieve a 10 per cent share of a robotics and McKinsey have suggested that autonomous systems and applications of advanced robotics could generate a potential global economic impact of $1.9 trillion to $6.4 trillion by 2025.

The project also carried out a detailed business case and this was provided as deliverable D6.4. Below is an excerpt illustrating the potential market size.

The population of the UK today is approximately 66 Million of whom around about 8% (5.28 Million) are more than 75 years old. This number will rise to around 76 Million by 2050 of whom around 15% (11.4 Million) will be over 75%.

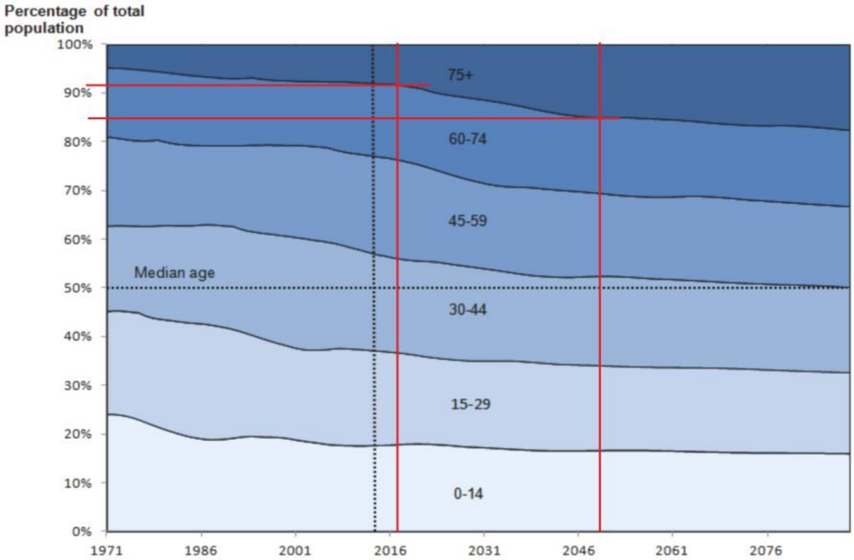

Figure 2. Percentage age distribution, UK, year ending mid-1971 to year ending mid-2089 (Source ONS)
Our gross estimate is based on 5% of the people over 75 (264,000) requiring care by two people for tasks such as lifting, toileting, getting up and washing, at a cost of £128.00 per day (for 4 hours each) and, with CHIRON use, only one carer for less time (say 3 hours), the net saving could be around £70 per day. With a population needing intensive care of 264,000, CHIRON could save £6.75 Billion per year. (And twice that by 2050).
The promise of CHIRON/JUVA is that it can help people be independently mobile, not having to rely on carers for sit to stand transfers and mobility if they are able to load bear. It can also support physical tasks for those who have significant problems with mobility, and help with tasks such as fetching and carrying items, and with more development, cleaning, laundry and food preparation and serving such that one carer can easily manage people at home who are highly dependent and give them far more personal attention. By doing this, the economics for people staying at home are greatly improved. The JUVA System has the potential to save both money and carers and help people remain at home.

JUVA USE CASE	2017	2050
Number of people over 75	5,280,000	11,400,000
5% of those people needing 2 carers for lifting	264,000	570,000
Cost per patient of 2 Carers for 4 hours per day each	£128.00	£128.00
Cost per patient with CHIRON and 1 carer 3 hours per day	£48.00	£48.00
CHIRON Net Saving for 1 Patient per annum	£21,900	£21,900
CHIRON Carer cost saving per day/patient	£80.00	£80.00
CHIRON Net Saving per day/patient	£60.00	£60.00

Table 1. Use Case calculations

The JUVA System could meet this potential need and save significant amounts of cost in doing so.
However, not all the identified number of 75 year olds and over will wish to dispense with their carers however according to Skills for Care, on any given day there is a shortage of 90,000 carers in the UK. However a marketable JUVA system is unlikely to be available before 2020 and even then it will only be in prototype form and used for testing, certification and marketing.
The analysis done within the project provides some indication that there would be a ready market for the concept. We have based the analysis above on an annual lease for CHIRON/JUVA of around £140 per week (a payback of about 3.5 years) on a system that would cost the leasing company about £25k. We would expect an 8 year life or more for the system.
We would expect the JUVA system to grow into the market and by 2030 achieve sales of at least 11,000 per annum (with an 8 year life, this rate of manufacture would still only meet half this potential market demand and there would be other markets and significant exports).
Note: the alternative to having 2 carers at home is to move people into care homes which would be still more expensive at between £846 and £621 per week. (Source Competitions and Markets Authority).

Section 1: Project Intention should include (Max 2 A4 Pages):
The background and context should describe the problem/challenge you are seeking to address

The Vision: We envisaged an intelligent modular robot system comprising a range of end-effectors capable of delivering support for a range of activities of daily living. We have a vision of "CHIRON in every home". It was anticipated that eventually CHIRON would grow with the end-users changing needs and learn their needs and preferences while they were still well, and be able to adapt, expand and learn as their care needs emerge. The Mission: To move away from a disability/need-centric model of care to a preventative model of care that aims to extend our independent living capacity and disrupt the pathway to institutionalised care.

The **concept** was for CHIRON to enable people to stay independent for longer, supporting them in undertaking their own personal care tasks, remaining mentally engaged and generally extend their years of healthy and fulfilling life and to significantly alter people's later life options beyond the dependency model that has a tendency to objectify older adults.

It was anticipated that CHIRON would harness the current and emerging ability of robotic systems to handle materials and objects with high levels of accuracy and, linked to sensory feedback and vision, with sensitivity.

We envisaged CHIRON as a modular set of devices and software that could be mixed and matched by the customer to enable independent self-care and domestic tasks or with a care worker to enable assistance to an increased number of customers.

Key attributes of a successful system would include operational safety in unpredictable situations, adaptability in dynamic environments, intelligence for making autonomous decisions based on its perception of the context and user state, operational reliability without manual intervention and the ability for multi-modal interaction thus enabling use by people with different communication and mobility difficulties.

We foresaw that CHIRON would be a modular robotic system that was:

1. reconfigurable and interoperable as an ecosystem of software and hardware components.
2. transferrable into other Chiron embodiments across other places you might visit.
3. online and configured for machine learning with your personal Chiron competent straight out of the box.
4. compatible with existing external ecosystem eg. smart wearables, home automation, occupancy detectors, mobile care apps.
5. accessible to friends and family who could be kept informed about the patient wellbeing.
6. responsive to feedback from you, the customer, using both audio and advanced vision systems to ensure that all support being provided is safe, consensual and dignified.
7. controlled by spoken languages as well as gestures and future proof for the latest advances in communication methods for people with dementia or learning disabilities.
8. extendable to have sufficient sensory and mechanical feedback in the future (a safety layer for close human / robot interaction) to safely help people turn, move, transfer, sit, stand and walk.

At the outset of the project we had many ideas but no pre-existing solution of how we would create CHIRON. We knew most of the required technologies existed in some form; we therefore proposed to both invent and adapt. Three Sisters Care provide care services to elderly and disabled people, which informed the customer brief and use cases, putting user centred design at the very core of our project. These use cases would draw on previous work on Robotic assistants carried out by Bristol Robotics Laboratory (MOBISERV, IDRESS Projects) and the capabilities of Designability and the Shadow Robot Company, to create and integrate a range of devices that make up CHIRON system.

We also intended to build on Innovate UK's previous project accomplishments, for example integrating with AUTOPIC, an autonomous strawberry picker using a Shadow specialised gripper. We were also open to inviting international partners, already making strides in modular robotics such as Roombots in order to carve out a future international market.

To ensure continued user feedback the Pioneer Group, would be engaged throughout the 24-month project, using the facilities provided by the Assistive Living Lab at BRL, a custom built studio apartment with kitchenette. We aimed to achieve long term commitment from our Pioneer customers, so that CHIRON could eventually be tested within Pioneers' own homes.

We envisaged a new market for CHIRON as a consumer product aimed at people with good health, poor health or a known future need for healthcare support who would purchase/lease the basic components, for example, a person newly diagnosed with Parkinson's might just want a wall mounted arm to help get out of bed in the morning, in the knowledge that in 5 years, that arm will be upgraded and expanded to help them dress or move around the home. In cases such as dementia, stroke and other neurological conditions, concerned children would purchase CHIRON to either delay their parents' decline into dependence or support therapies to enhance independence. We also considered that there would be a final group of active older adults, who are simply keen to maintain their independence as they age. With the help of CHIRON, these early adopters might never have to specify care needs, and the notion of 'care' as we know it today could become obsolete.

With this in mind, we set out in the early stages of the project to understand the State of the Art – The Environment as a number of the required technologies existed in some form; we proposed to invent, adopt and adapt processes, designs and systems from multiple sources and therefore will needed to research and understand the relevant technologies that may be available to utilise in delivering our CHIRON system. We also had to understand the environment into which our CHIRON system will be introduced. This included the needs and aspirations of the end users, carers and family together with the economics and strategies of all the stakeholders in the wellbeing ecosystem. This work comprised WP2 of the project which gathers together everything to do with the state of the art, discovers what has been done before and the IP issues surrounding specific technologies. This will be primarily covered by WP2 - The Environment: State of the art and people, Economics & Strategies, IP and literature searches, Standardisation review. It is seen that this WP had a number of work areas for this work package which evolved as the project progressed.

The project had a very strong body of expertise in robotics, assistive technologies and care-related products to be harnessed to deliver a set of modular CHIRON component. These would be a mix of new specific actuator/end-effector/sensory and vision systems and adaptations of existing robotic and other technology. Specific attention was paid to interoperability, interconnectivity, usability and integration of the components, with a focus on developing easy to use connectors that are strong, reliable and safe under normal operating conditions. This was work done as part of WP 4 Engineering, Robotics and Systems. This WP would operate iteratively with WP5 and draw on needs and requirements specified in WP2 and WP3.

To understand the Needs and Necessary Solutions we would draw on the expertise of Three Sisters Care who provide care services to people with impairments and older adults with assistive care needs. Working with these user groups, we intended to draw on the capabilities of Designability, Bristol Robotics Laboratory and Shadow Robot Company to create and integrate a range of devices to create CHIRON. We also build on Innovate UK's previous accomplishments, in DALLAS and previous ALIP projects as well as other sources such as SETHA and Housing LIN. This work comprises WP3 Needs and Necessary Solutions which develop the functional specifications and environmental and user requirements for the CHIRON system. Of necessity that work package required widespread external consultation as well as internal debate and discussion. The project would use both the resources of this WP to explore, consult and resolve the needs for personal care and help against the capabilities of the technology. It was intended that we would create an Advisory Board to deliver this consultation.

Section 2: The final solution should include (Max 2 A4 Pages):
.A brief description of the solution, and how this addresses the scope of the challenge. Describe the proposed solution and the assessed impact it had. Describe how the solution is innovative, and why or how it will succeed in the market. Identify and numerically justify the market potential of this product i.e. the market size over a given period of time.

<u>The Challenge</u>

People living with mid, moderate or severe physical impairments will require some assistance in order to live independently. The principal difficulties which must be overcome include: reduced upper limb strength and co-ordination, making it difficult to fetch and carry objects; and reduced lower limb strength making it difficult for the person to get out of a chair, move around, stand unsupported while dressing or going to the toilet, and transferring from a bed to a chair or onto a toilet, for instance.

<u>Some solutions</u>

Many overhead support systems are known which provide assistance to less-able-bodied individuals, and typically comprise an overhead gantry to which is attached a hanging frame via which assistance equipment can be attached. The hanging frame is mounted via a strengthened fabric strip which depends from a trolley on the gantry. Typical assistance equipment may include handle bars to provide a user with a walking aid around the location, all the way up to a full-body sling for transferring individuals with severe impairments around the location. The fabric strip provides a simple mechanism by which z-axis, that is in-use vertical, actuations relative to the user, can simply be reeled or unfurled using a motor to alter the height of the assistance equipment. The problem with such arrangements is that, although they are relatively mechanically simple and cost-effective, the fabric strips are prone to swinging in-use, and therefore force sensors cannot be readily incorporated into their housings to provide smart control of the assistance equipment. The position of the handles or harness at the end of the strap cannot be accurately controlled and the whole system must me manually controlled by a care assistant.

<u>The CHIRON Solution</u>

The CHIRON systems provide a novel overhead support system which is capable of movement and positioning along the both X,Y horizontal and Z vertical axis, The system is fully computer controlled, thus enabling the user to operate the system independently.

The physical system comprises an overhead gantry mounted in a horizontal plane; and a robotic support device engaged with the overhead gantry. This comprises of: a closed loop controlled motorised vertical drive that is extendible and retractable along the vertical axis; a user-interaction support element coupled to an end of the drive output element which is distal to the vertical drive means; and a rigid extendible coupling in a plane perpendicular to the vertical axis, a first end of the extendible coupling being fixed relative to the vertical drive means, and a second end of the extendible coupling being fixed relative to the end of the drive output element. Having an extendible coupling that is substantially rigid in the lateral direction, allows for a robust robotic support device to be constructed. The drive output element uses a bi-stable reeled composite material and/or storable tubular extendible member. A specially designed connector on the lower end, allows attachment of a range of end effectors for different functions, make the system modular.

Force sensors are used to determine the loads applied to the robotic support device in the vertical axis, this permits the system to determine whether applied loads can be safely borne. Additional lateral force sensors are used to monitor loads in the X and Y axis, lateral to the vertical axis.

Four video/IR depth cameras mounted around the Z axis are used to determine the position of the end effector and user, allowing automatic sensing and control. Based upon data of their position and/or condition, these inform the actions required to be taken by the robotic support device, which can then act accordingly. Safety standards for personal care robots define both a monitored and protected space with the operating environment. The robot must stop immediately if a new object is detected within the protected space.

Considerable work was undertaken to integrate data from the video cameras, force and other sensors. Individual elements of the sensing and control system were developed using open source Robot Operating System (ROS) software, running within a CHIRON operating system. This allow dynamic route planning, with avoidance objects within the operating space, these are prerequisites to ensure safe operation of the system. The team at Shadow were able to provide an emulator or virtual CHIRON system, which enabled the software development team to evaluate the performance of different sensors and the control software, while the mechanical engineers were still working on the hardware.

We evaluated and tested a number of embodiments of the control system – the human robot interface. Control of the system is by means of a touch screen computer tablet and/or voice control using proprietary interfaces, such as Google Home and Amazon Alexa.

The system is designed to provide assistance to a user, getting up from a chair – sit to stand (STS). In this instance the end effector is a support frame. The handles on the frame include a grip sensors, which provide additional control of the X,Y,Z drive. The system is programmed provide optimal closed loop biomechanical support for each individual user.

We have also developed a second modular end effector, comprising of a mechanical gripper adapted to grip and/or release objects for the user. By means of voice or touch screen control, the user may instruct the system to select, pick, fetch and place objects, from any position within the room.

We have used a Rotite mechanical coupling that would in future allow automatic selection and exchange of the end effectors. We envisage that third party providers could provide end effectors offering different functions, such as cleaning, or person ‘lift assist’, for example.

The X and Y axis supports are constructed from a proprietary commercially available overhead track system. This is attached at intervals to load bearing points on the ceiling, or if this is not possible, to pillars installed in each corner of the room. The overhead rail uses a proprietary commercially available track system. The CHIRON proof of concept system is installed separately in a living area and a bedroom. Manufacturers of ceiling mounted hoists provide track sections that operate through a cut out in a doorway to allow operation in multiple rooms.

The proof of concept system has been demonstrated to the CHIRON Advisory Board, potential Industry partners (ETAC, Innovate UK Pitchfest) and Health Professionals (Royal United Hospitals Trust – Occupational Therapy and Medical Physics, Royal Society of Medicine, Southend Health and Social Services, Association of Retirement Community Operators). Feedback has been overwhelmingly positive. One industry partner commented that ‘there has been no innovations in patient movement and handling for the last 20 years’. If we were able to demonstrate the system, it ~~would~~ generate a very high level of demand.