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FIT FOR THE FUTURE

A paper by Dale Sinclair, a healthcare architect with AECOM

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ALONG WITH MUCH OF THE BUILT ENVIRONMENT, THE UK'S NATIONAL HEALTH SERVICE ESTATE IS FACING THE NEED TO ACCOMMODATE RAPID CHANGE. ARCHITECT AND HEALTHCARE EXPERT DALE SINCLAIR SETS OUT SOME SUGGESTED STEPS TOWARDS FUTURE FITNESS.

CONTENTS

INTRODUCTION

As an expert in healthcare design, with over 30 years' experience as an architect, I share the profound concerns of many over the National Health Service (NHS) estate and how it needs to respond to rapidly accelerating change.

Undoubtedly, the NHS estate of the future will bear little resemblance to today's struggling model. Some may say this is stating the obvious. Yet, even today, hospitals are being built that will not be fit for purpose in 15 years' time. You can rarely go a day now without reading about a revolutionary innovation in wellbeing and healthcare. As a result, we cannot continue to design the buildings and infrastructure of the future without careful consideration and close collaboration with an extensive range of stakeholders.

This paper is intended as a thought piece to help those individuals commissioning buildings: to scan the horizon; anticipate and meet impending challenges; and begin a dialogue to ensure diverse buildings and infrastructure equipped for the years ahead.

It is reassuring to know that many are already working to create new models of care. To reflect this, the paper includes a story based sometime in the future. At points, it may seem surreal to some. Yet every part of the story is based on the use of technologies that exist today. The future is now, and NHS assets and estates' strategies need to be shaped accordingly through collaborative and strategic long-term thinking.

A NEW HEALTHCARE ECOSYSTEM

Today (2017/18), the NHS in the United Kingdom has a net expenditure of £118 billion per year. Its per capita costs have increased from £1,868 to £2,057 in just five years. And admissions to hospitals have grown by 28 per cent in the last 10 years.

The continuation of this trend is neither sustainable nor acceptable for the UK government and society as a whole. It is widely acknowledged that significant change is required to reverse these trends and move towards a more person-centred, health-based future.

Technology and demographic changes are transforming the world around us. No profession is immune, including my own — which faces a painful journey, moving from traditional paper-based, face-to-face processes to digital design-to-construction environments. We are using immersive technologies such as virtual reality (VR) and augmented reality (AR) to reimagine the design process, while robotics, 3D printing and other innovations are reshaping construction.

In healthcare too, for example, new technologies are shifting the focus from in-patient to more out-patient focused transactions and onwards towards care in the community. These innovative solutions cannot be adopted in isolation. If the NHS is to achieve significant savings, they must work in tandem with a re-designed and re-imagined NHS estate. Here, primary care, mental health facilities, care homes, ambulance and pharmacy services will all be conceived as elements of a new healthcare eco-system, where technology and new estate strategies work hand-in-hand to deliver better healthcare outcomes at considerably reduced cost.

Simply put, technology will fundamentally alter asset demands. Consultants, doctors, GPs, nurses and others involved in current models of care will need to change clinical behaviours and consider how care can be transitioned to, and undertaken, in new environments. The buildings we design are developed to last for many years, and there is an urgent need to consider how technology will influence patients' interactions with the NHS estate in this new brand new world.

The buildings that align with new models of care need to be reconceived as a whole if we want to have a sustainable NHS framework in the future. This means we must move beyond the current asset base of acute hospitals and GP surgeries, placing a stronger focus on how technology might influence a new generation of NHS buildings and infrastructure.

With change accelerating, it is time to pause. Current NHS assets might successfully and incrementally absorb and implement technological advancements; but, progress so far, suggests that this would result in estates unfit for use in years to come.

We must embrace the bigger picture, using our design skills to re-imagine the NHS estate of tomorrow in line with the likely technologies of the future. Design is not restricted to physical buildings. It comes in many forms: the design of new technologies, apps and equipment. Equally important is the design of the new clinical processes, and the buildings and operational processes that will wrap around them.

Images:
Virtual reality (VR) and augmented reality (AR) immersive technologies

THERE IS AN URGENT NEED TO CONSIDER HOW TECHNOLOGY WILL INFLUENCE PATIENTS' INTERACTIONS WITH THE NHS ESTATE.

FUTURE FOCUS — CONSIDERING THE NEW PATIENT EXPERIENCE

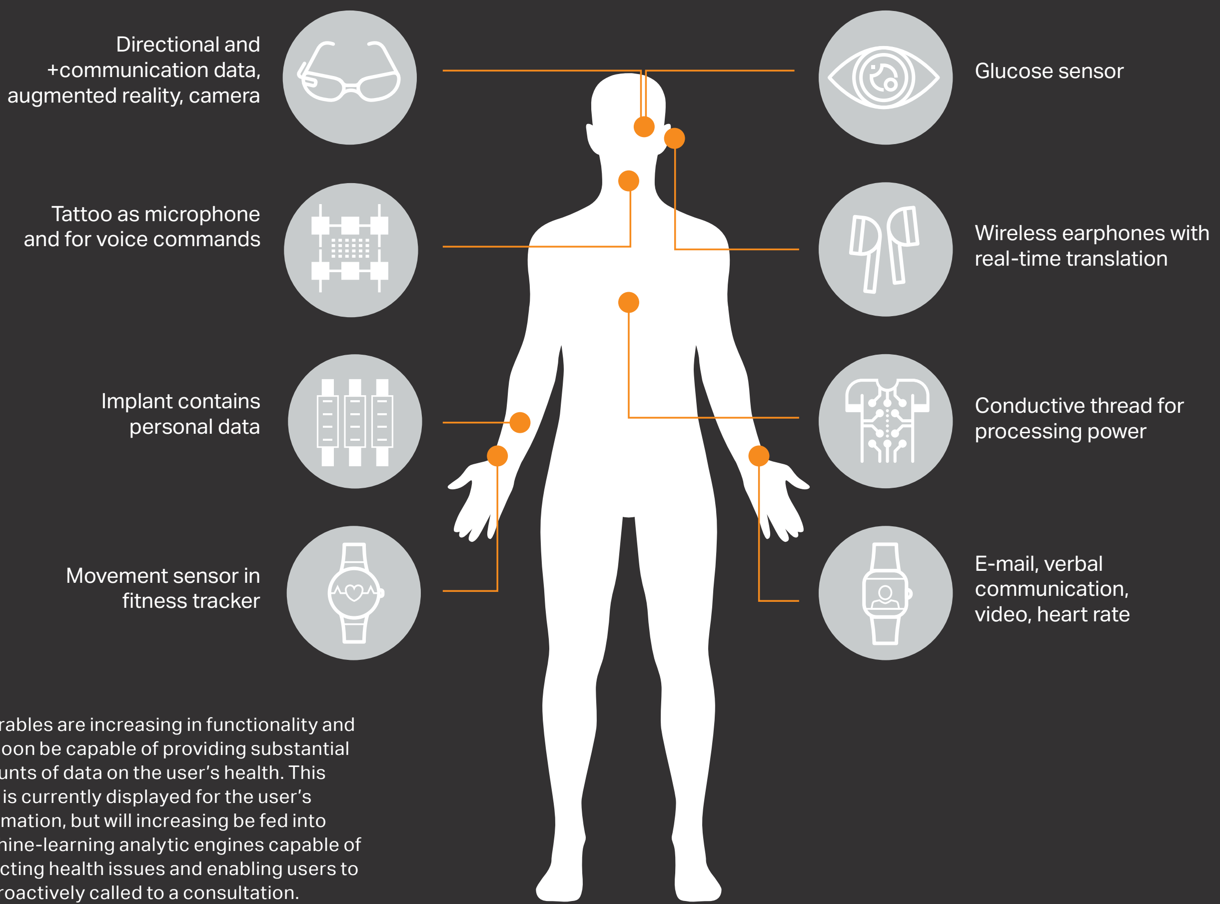
Let's consider how the future will look.

Wearable technology has transformed healthcare, as detailed in Figure 1. The vast majority of UK citizens wear the "NHS watch" developed in conjunction with a global design brand. It records and transmits vital statistics to the cloud: pulse, blood pressure, temperature and breathing rate. AI analyses the data, detecting any trends that merit further analysis.

Preventive healthcare measures have radically transformed the NHS. Back in 2017, the demand on accident and emergency services (A&E) had increased significantly compared to the previous decade. Today, demand is down 60 per cent. With an emphasis on prevention, new GP surgeries are being developed in collaboration with a major gym brand. The population is healthier, and helping to promote the sustainability of the NHS

> WEARABLE TECHNOLOGY HAS TRANSFORMED HEALTHCARE

Figure 1: Wearables will be commonplace in the near future



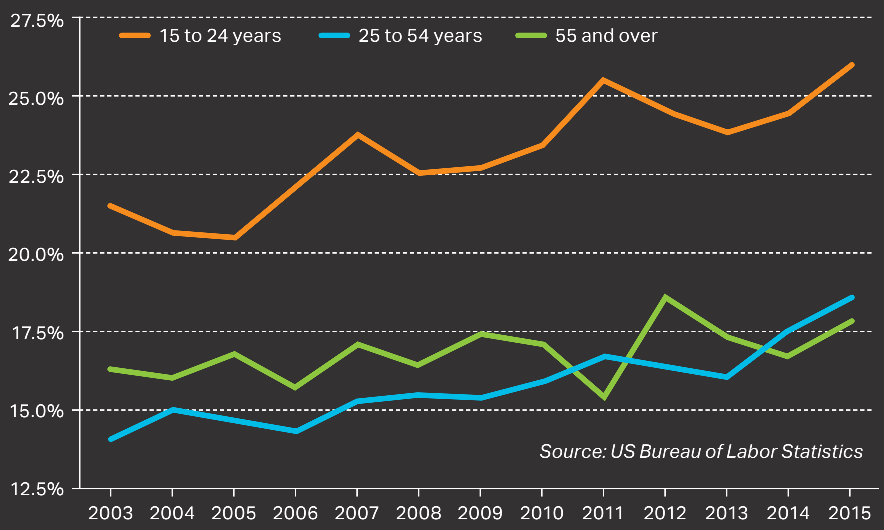
Wearables are increasing in functionality and will soon be capable of providing substantial amounts of data on the user's health. This data is currently displayed for the user's information, but will increasing be fed into machine-learning analytic engines capable of detecting health issues and enabling users to be proactively called to a consultation.

With data encouraging the population towards healthier lifestyles, web-based tools such as surveys and questionnaires help deliver better healthcare outcomes, providing links to new weekly menus or training programmes that shift aspirations from a 10 kilometre run towards a marathon.

Significantly reduced A&E costs have enabled the NHS to provide more annual diagnostic assessments for the over-30s, previously limited to private healthcare programmes. The NHS estimates that early diagnostics like these have significantly reduced costs.

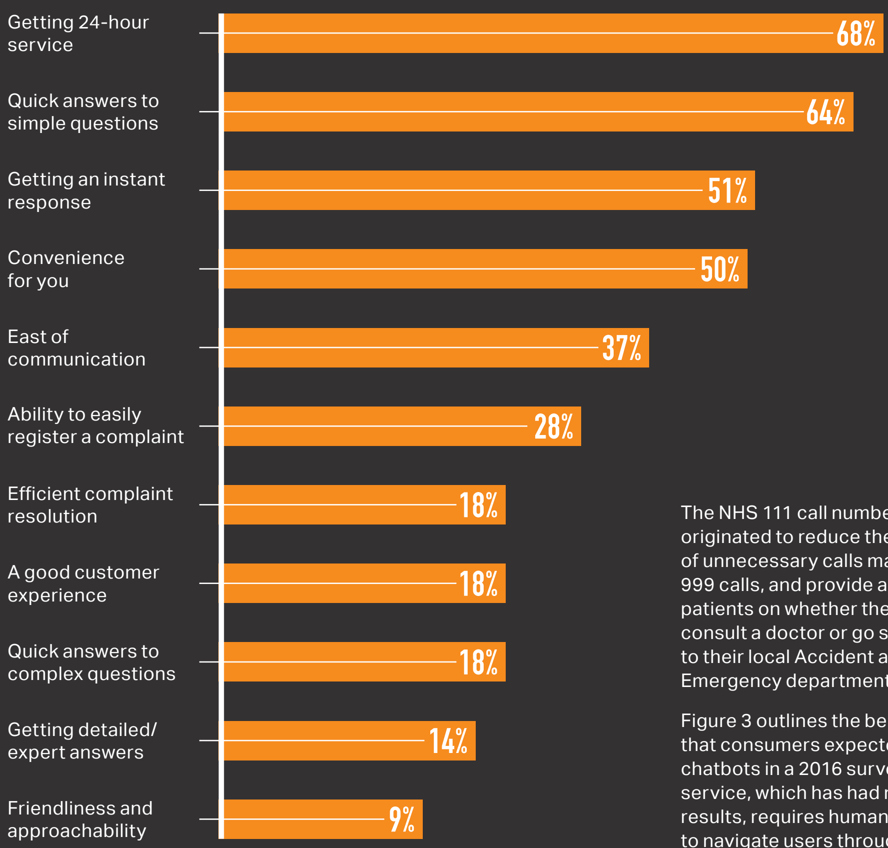
Figure 2: A fitter future society?

Percentage of population engaged in sports and exercise on an average day, by age, 2003-15



Although some trends point towards increased obesity, Figure 2 suggests that the 15 to 24 age group shows a substantial uptake of exercise. Reduced reactive healthcare costs would unlock investment in further preventative measures such as gym memberships or annual diagnostic assessments that are currently limited to private healthcare patients.

Figure 3: Consumers' expected benefits from chatbots



Source: myclever Agency 2016

The NHS 111 call number was originated to reduce the number of unnecessary calls made to 999 calls, and provide advice to patients on whether they should consult a doctor or go straight to their local Accident and Emergency department.

Figure 3 outlines the benefits that consumers expected from chatbots in a 2016 survey. The service, which has had mixed results, requires human operators to navigate users through a number of pre-defined questions and steps.

Chatbots are increasingly being leveraged to provide a computerised voice service or text interface that employs machine learning to assist the customer interface.

The Huffington Post reports on the use of the medical diagnosis app, Your.MD, that uses technologies such as machine learning and natural language processing to learn from every conversation it has. Telemedicine is also helping doctors, providing faster and more up-to-date information.

CHARLIE'S JOURNEY

INITIAL CONTACT – MEET CHARLIE

When data from Charlie's wearable suggests a potential illness, a chatbot conversation is immediately triggered. During the video conversation, via Charlie's phone, the bot asks a number of carefully crafted questions, based on the initial data analytics, to secure additional information and harvest new data via facial recognition analysis.

The aim is to identify possible symptoms that the initial data or questioning could not reveal. The bot determines that further information is required and asks Charlie to attend a local diagnostic centre.

DIAGNOSTIC CENTRES

With more accurate diagnostics for the simplest of ailments, and the introduction by a global online retailer of secure drone deliveries of prescription and over-the-counter drugs, high street pharmacies are selling fewer drugs. In response, they are incorporating plug-in NHS diagnostic centres into their businesses.

Charlie has arranged an appointment on an app and is able to walk in. A nurse takes a number of samples (robots are not trusted with needles yet). Handheld devices are increasingly being used to provide instant analysis and diagnostics, and the blood is analysed immediately.

The last time this happened, Charlie was diagnosed with a cold and the pharmacist was able to provide an over-the-counter prescription. This time the blood test is inconclusive, and Charlie is asked to attend a consultation.

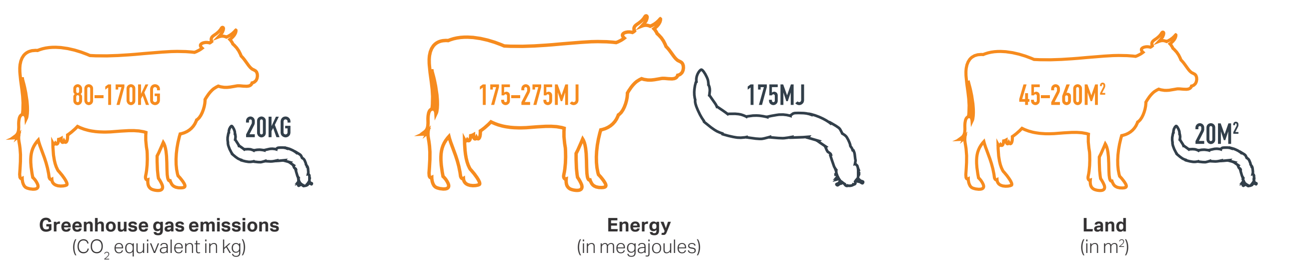
Fortunately, this diagnostic centre has consultation booths. Charlie secures an appointment in 30 minutes time and, meanwhile, browses the pharmacy's organic food area — including its new locust-based snack section (see Figure 4 below).

New healthier lifestyles will incorporate fruit and vegetables grown and sold in city centre hydroponic farms or new sources of protein such as insects.

Technology has allowed GPs to transform the way in which they provide their services. Around 30 per cent of GPs are based in a new generation of low-energy, carbon-neutral bricks and mortar buildings. A further 30 per cent are in the new diagnostic centre plug-ins. While the remaining 40 per cent of NHS GPs work remotely, as the use of video-conferencing and other digital tools mean face-to-face transactions in the consulting room are no longer essential.

Consultations are also faster due to the data now available to the doctors, enabling artificial intelligence (AI) to provide a high probability of the likely prognosis as well as the option for real-time translations into many languages. →

Figure 4: Environmentally friendly
What does it take to produce 1kg of protein? (Beef compared with mealworms)



Source: www.entomoveproject.com

Approximately, five per cent of NHS doctors are now based in the Lake District and work from home, with many walking and cycling in the morning and consulting with patients in the afternoon and early evening to meet peak demand.

In response, the NHS has set up a training centre in Windermere, where GPs meet monthly to share knowledge and notes on a face-to-face basis. Although the training centre has cost £2 million to construct, this use of home-based doctors has avoided £30 million of capital expenditure, as well as the associated staffing and maintenance costs.

Due to new immigration rules, it has also been difficult to retain overseas doctors trained in the UK. As a result, the NHS opened GP centres in Delhi, Mumbai and Kolkata. This strategy enables the NHS to call on the skills and experience of overseas staff.

It is a win-win arrangement. The doctors can be based closer to their families, and premises and staff costs are lower. Each centre has hundreds of doctors who link to patients in the diagnostic plug-ins, 24 hours a day.

A MORE COMPLEX DIAGNOSIS

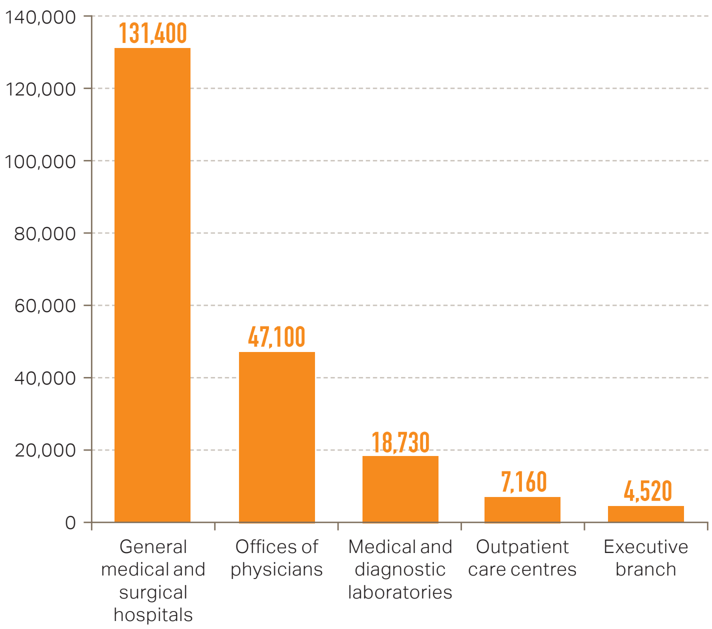
The consultation reveals further concerns and the need for more complex diagnostics. Charlie is booked into the local diagnostic outpatient centre for an imaging appointment the following day. It might also be necessary to see a specialist.

Due to its reduced size and cost, equipment no longer needs to be shared between in-patient and out-patient areas, allowing the proliferation of diagnostic centres with a new generation of imaging and other crucial tech (see Figure 5 below).

These centres, which have been designed using digital libraries and modular manufacturing processes, can be delivered to a new site within weeks of the NHS placing an order and be operational in two months.

The buildings are adaptable and easily extendable. For example, a new imaging module can be easily added or the buildings relocated to another site to provide a better balance of catchment areas. In addition, the new design-to-construction processes have brought down the capital costs of buildings like this by 25 per cent.

Figure 5: The number of radiologists working outside hospitals



Source: US Bureau of Labor Statistics

The size and cost of equipment is falling, allowing equipment to be located beyond acute hospitals — where it has been historically shared between in- and out-patient facilities. For example, Figure 5 illustrates the number of radiologists working outside hospitals.

The current dimensions of a CT scanner suggest a future where equipment can be relocated or moved around the country and shared. The NHS has been using scanning trucks for a number of years. Future equipment may rotate around more and smaller, diagnostic centres.

One example of this is a CT scanner shared by four centres on a monthly rotation. Doors and corridors will need to be sized accordingly, with the potential for using smart sensors to automate the opening of doors.

The build and facilities management (FM) costs per square meter of a diagnostic centre are less than an acute hospital. Moving equipment into compact buildings saves money and puts it closer to the point of care.

A CAT SCAN

The next day, Charlie attends the diagnostic centre and walks straight into the scanning room for a CAT scan. The image is immediately reviewed by a specialist software package and, based on machine-learning diagnostic tools and predictive analytics, a report is sent to a clinical expert for further analysis and ratification.

This specialist worked at the Leeds Cancer Centre for 15 years, but is now semi-retired and lives in Kuala Lumpur, working from home four hours a day for the NHS.

The diagnosis is ratified by the specialist, and Charlie receives a text message advising him that the results have been received and a face-to-face conversation is required.

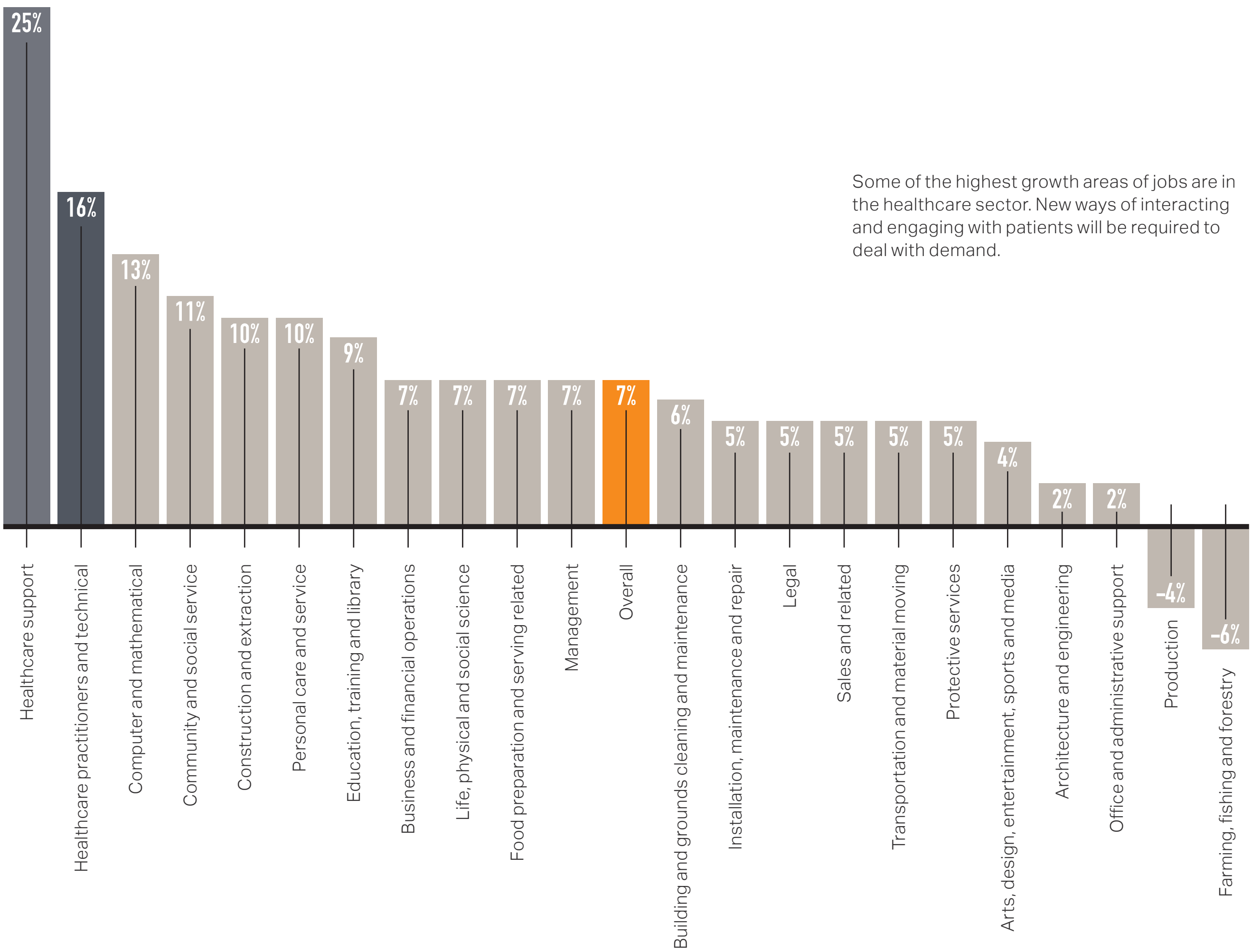
The option of a human or robotic consultant is provided, with Charlie choosing the latter. The diagnostic centre has a number of suites where distressing news can be conveyed to patients. The calming environment in these rooms has been adapted over time, informed by comparisons of the different reactions of patients using artificial intelligence and machine learning.

The room selector is able to choose the most calming environment for Charlie's prognosis to be given.

Given the circumstances, Charlie reacts well to the news and is given time to absorb the diagnosis. Charlie requests a conversation with the counsellor who is on standby to monitor what is happening. Fortunately, the nearest centre of excellence for this particular condition is in Charlie's home city.

The consultant has recommended that Charlie goes there immediately, and one of the hospital's autonomous vehicles is dispatched to the diagnostic centre. The counsellor accompanies Charlie. →

Figure 6: Job growth by occupational group
Median projected job growth, 2014-24 (per cent)



Some of the highest growth areas of jobs are in the healthcare sector. New ways of interacting and engaging with patients will be required to deal with demand.

Figure 7: Robots and humans working together to improve the patient experience
Telemedicine assistants will aid doctors and facilitate communication with staff and patients

In 1996, the average practicing registered nurse in the US was 42.3 years old, which is nearly 10 years older than the average age in the workforce in general. As a result, over 10 per cent of all occupational back injuries in the US are caused by moving and assisting healthcare patients.

Relatively little attention has been given to measuring and reducing the frequency of handling patients. Robotic nurses could help reduce back-related injuries of nursing staff and also be used in care homes and other facilities.

TREATMENT

Autonomous vehicles have transformed this particular NHS estate. There is no longer any parking on site. Instead, the NHS has developed this space to accommodate buildings that are leased to pharmaceutical companies working with the local university on a number of research projects. This has provided significant revenue and stronger ties between the trust's teaching department and the research and development teams of the university and associated private sector companies. The estate has changed in other ways too.

The continual shift towards less invasive operations in the out-patient facilities attached to many diagnostic centres (some adjacent to remaining and refurbished GP surgeries) and the use of home diagnostics have radically reduced the bed requirements in larger acute hospitals.

Consequently, part of the NHS flexible campus strategy includes standalone patient hotels (see Figure 8). These replace the more commonplace scenario of ward blocks over diagnostic and treatment podiums. Rooms can be rented by relatives and friends.

Diagnostic and treatment areas are designed in more flexible, narrower four-storey "wings" — allowing more daylight into theatres and other spaces, improving the wellbeing of staff and patients alike. Healthcare technical notes and healthcare building notes have been updated to reflect a new generation of clinical spaces based around the NHS grid. This enables manufacturers to develop modular rooms that can be selected from a catalogue by the design team. Walls and doors have been designed to allow quick adaptation of clinical areas, as shown in Figure 9. →

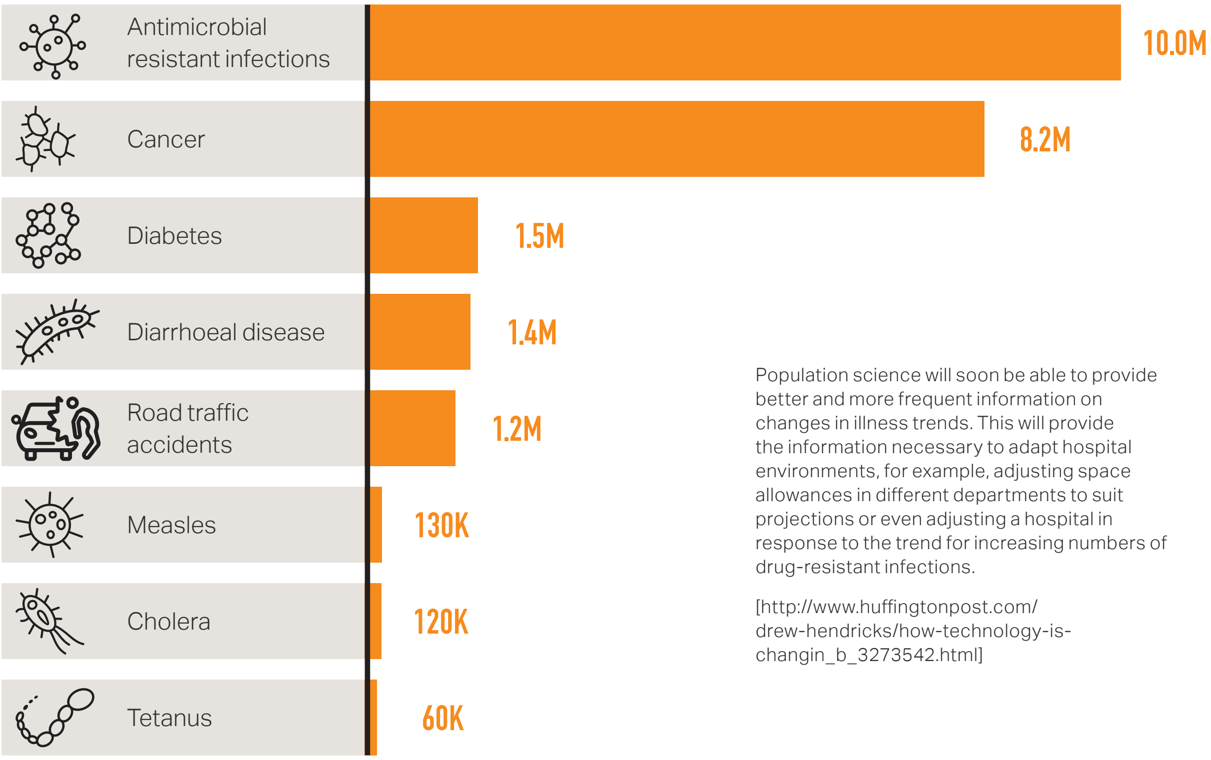
Figure 8: Patient experience - The patient hotel

- Switchable glazing to balance observation and privacy
- Nursing stations and other spaces adaptable for different future use
- Rooms fitted out with various sensors to enhance patient experience
- Robotic nursing assistants linked to room sensors and on call for various functions
- Automatic doors and security sensors: intruders, roaming, autonomous beds/wheelchairs

Figure 9: Adaptive diagnostic and treatment spaces

- Narrow plan to maximise daylight and future potential uses
- Integrated teaching spaces with VR technologies and real-time links to any operating theatre in the world
- Spaces must be capable of rapid adaption requiring careful location of medical gases and new movable wall technologies
- Doors will be crucial:
  - Switchable glazing to allow visibility or privacy
  - Larger to facilitate the relocaion of large items of portable equipment
  - Automated for safety and to accommodate robotic assistants and autonomous beds and wheelchairs
  - Security enabled to prevent intruders or roaming

Figure 10: Deaths from drug resistant infections set to sky rocket



Population science will soon be able to provide better and more frequent information on changes in illness trends. This will provide the information necessary to adapt hospital environments, for example, adjusting space allowances in different departments to suit projections or even adjusting a hospital in response to the trend for increasing numbers of drug-resistant infections.

[http://www.huffingtonpost.com/drew-hendricks/how-technology-is-changin_b_3273542.html]

FLEXIBLE LABORATORIES FLEXIBLE DIAGNOSTIC SPACE FLEXIBLE PATIENT HOTELS

Figure 11: The NHS Estate of the Future
Oxford University Hospital NHS Foundation Trust

Each clinical wing is allocated to a specialist hospital, for example, women and children, eye and cancer. Every wing has its own central atrium space acting as a hub for consultants, nurses, patients and visitors and allowing them to meet face-to-face for informal conversations. Escalators and staircases are provided to minimise lift use and offer a more dynamic patient experience.

To maintain the flexibility of the buildings, larger equipment such as linear accelerators, is constructed in a two-storey concrete building that sits below the public square. The square acts as a focal point, with easy access to the entrances of each hospital, and serves as a hub for public transport and cyclists who can enjoy a café with shower facilities.

One wing of the hospital has already become surplus to the trust's requirements. Thanks to its flexible design, it is now operating as the research and development facility for a major charity, enabling greater connectivity with the latest research, thinking and innovations. This charity has designed its modular-lab layouts around the NHS grid to allow for further opportunities like this in the future.

The vehicle takes Charlie to the entrance of the patient hotel. Autonomous vehicles have also been used in conjunction with "mini" entrances to bring patients closer to the point of care, reducing the need for elderly and mobility-impaired patients to be moved around inside buildings.

Wayfinding schemes were removed from hospitals many years ago, with handheld devices acting as a navigation tool inside the hospital for the many autonomous vehicles, beds and wheelchairs shuttling patients around the estate.

Charlie goes straight to the room. It is comfortable, and feels more like a hotel, but behind many of the wall panels lie medical gases — as detailed in Figure 12. Charlie rests in preparation for an operation the next day.

Before it is time for his meal, he walks out of his room and has a quick chat with the patient in the next room who has just had a 3D-printed lower arm fitted (see Figure 13).

He then orders a meal, before fasting must commence, choosing to pay extra for external catering to be delivered in lieu of the in-house offerings.

Figure 12: Smart patient rooms

- Sensors used for various activities including fall monitoring, turn mangement and movement of patients
- Robotic assistants used for lifting patients, providing advice and dispensing drugs — predictive AI minimising dignity issues
- Apps used to call medical staff, control room temperature, lights, entertainment and monitor medical gases and drips
- Stats transmitted to a local server using Bluetooth technologies and accessed by handheld devices with automated alerts to clinical teams
- Switchable glazing in lieu of curtains to balance visibility and privacy — linked to sensors

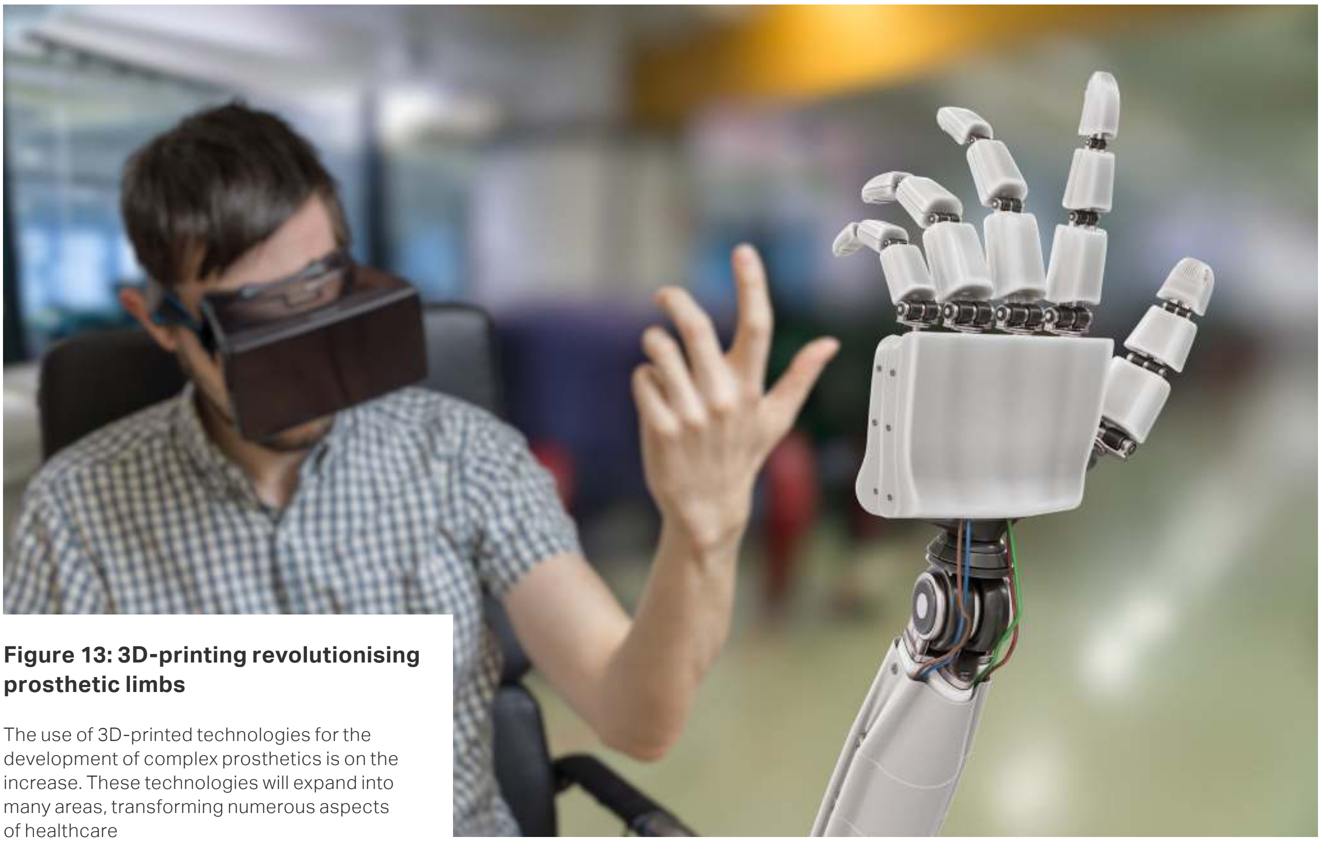


Figure 13: 3D-printing revolutionising prosthetic limbs

The use of 3D-printed technologies for the development of complex prosthetics is on the increase. These technologies will expand into many areas, transforming numerous aspects of healthcare

SURGERY

The next day Charlie is prepared for the operation. The senior consultant running the surgical team should be attending an annual clinical conference overseas, but the hospital has recently invested in different technologies, including telepresence facilities, that allow regular communication with other specialist centres across the globe. The local acute hospital is a teaching hospital with close ties to the neighbouring university and a number of research and development organisations. By embedding teaching and research facilities into the clinical spaces, a number of innovative clinical breakthroughs have been made, and enhanced by the global knowledge-sharing community.

Although the operation is overseen by an experienced in-house clinical team, the surgeon with the greatest experience for this particular operation is based in Denver. The operation is timed for 9am in Denver (4pm BST). This particular operation is rare with procedural complexities.

However, the semi-automated robot has undertaken this operation many times before, as has the operator in Denver. The last big reduction in deaths during operations occurred when Atal Gwande's checklists were adopted many years ago. Now these processes have been automated, and the use of global super-specialists has reduced fatality rates in surgery even further.

The operation is successful and Charlie rests in the specially-designed recovery area within the patient hotel. Charlie's vital statistics are monitored remotely and when the software gives the green light, the autonomous bed is off, using one of the specialist bed-only lifts and connecting via an underground link back into the patient hotel.

The room sensors detect when Charlie wakes up and a robotic assistant is dispatched to give the good news that all went well. A nurse connects Charlie with a sensor pack. Via Charlie's home wi-fi, these sensors will provide signals back to the hospital in real-time for the next 72 hours. If there is any concern with these signals, Charlie will be contacted and an automated vehicle immediately dispatched.

This might take Charlie to the hospital, but is more likely to go to a local diagnostic centre where a GP will be on standby.

Charlie is ready to leave and is allocated an autonomous vehicle downstairs. Charlie notices that some of the adjacent patient hotels are designed differently. With wards detached from the diagnostic podiums, the Trust has been able to take a range of approaches. It was concerned that the trend for fewer in-patient beds — driven by less invasive operations, faster recovery times and greater use of clinical diagnostics and sensors from home — would result in empty ward blocks, and they have been proved right. With a reduced need for bed spaces, the Trust has converted one ward tower into staff accommodation.

These studio flats have been popular with junior doctors, allowing them to take their first step on the housing ladder. They were transformed in collaboration with a local developer, and are equally owned by the Trust — with stringent legal conditions preventing their sale to non-NHS staff. The Trust is proposing to convert another tower into key-worker housing, generating much needed accommodation for staff with families. It is also considering whether to convert a third tower into a hotel, due to the demand for accommodation in the area. They are delighted that the flexibility of their masterplan has allowed these many incremental, and beneficial, changes to occur over the years.

Figure 14: Using virtual reality

A number of immersive technologies are being used by designers to enhance the presentation experience for clients. This includes tools such as Microsoft Hololens, which is also being used to transform medical education.

In the future, this technology will be capable of use in operating rooms, with surgeons seeing through anatomical structures such as blood vessels before open organs, allowing them to perform more precise excisions.

Medical students can study anatomy using virtual reality and can carry out operations on virtual dissection tables. These technologies will increasingly be used to enhance the educational experience — giving students insights from 360-degree cameras worn by surgeons.

New technologies will enable rare operations to be broadcast around the world in real-time. Examples include the Anatomage anatomy visualization system enabling virtual dissection; ImageVis3D, simple and interactive software for visualization; and 4DAnatomy, a cloud-based, interactive, dissection-simulation resource.

Figure 15: Continuing innovation in robotic surgery
Robotic surgery has arrived, coming in many guises with equipment manufacturers such as Da Vinci Robotics developing many products. Their systems currently require human interventions, but this will become increasingly less so. For more complex operations, the surgeon does not need to be in the operating room.

A robot can combine robotics and image-analysis technology, and can draw blood from a patient. In the years ahead, it will perform real-time analysis of the blood. RIBA (Robot for Interactive Body Assistance) is used for patients who need assistance in care homes. Its Japanese version, the Robear is shaped as a giant, gentle bear with a cartoonish head. They can lift and move patients in and out of bed into a wheelchair, help patients to stand, and turn them to prevent bed sores as many times as required. A TUG robot is capable of transporting 453 kg of laboratory specimens, medication or clinical equipment. California-based Sense.ly has developed a virtual nursing assistant, Molly, to follow up with patients post discharge.

In the future digestible and wearable sensors will be the norm. Biometric tattoos can transmit medical information discreetly. RFID chips can be implanted under the skin to transmit data and act as an identification device.

Sensors will transmit data including temperature to neurological symptoms, providing alerts to local diagnostic centres and allowing ambulance services to respond to strokes in real time, within the crucial early window that can make the difference. The Rogers Group are developing many sensors.

If wearing thin e-skins or having embedded sensors are not appropriate for a particular patient, a new generation of medical tricorders will be capable of diagnosing any diseases and give individuals more choices over their own health. Instead of waiting for the verdict of medical professionals, patients will control their own health. Such devices include Scanadu, which is an early-stage mobile medical device to empower patients, or Viatom Checkme — which traces ECG, and measures body temperature, pulse rate and rhythm, oxygen saturation, systolic blood pressure, physical activity and sleep.

To support this wave of smart sensors, there is a depth and diversity of many AI starups in the healthcare industry. Sentrian, backed by investors including Frost Data Capital, analyses biosensor data and sends patient-specific alerts to clinicians. London-based, Babylon Health recently raised $25 million from investors including Google-owned DeepMind Technologies to develop an AI-based chat platform.

RECOVERY

Charlie cycles over to see a grandparent. They recently moved into their new flat, which is part of a development for a new retirement community. These developments are exempt from stamp duty (a tax paid back in 2017 when purchasing a new property), to encourage elderly residents to release larger houses back into the housing market. In this community, the properties are intelligently fitted out. Sensors can detect movements with voice-activated alarm systems, and can measure activity levels, drug taking and sleeping patterns.

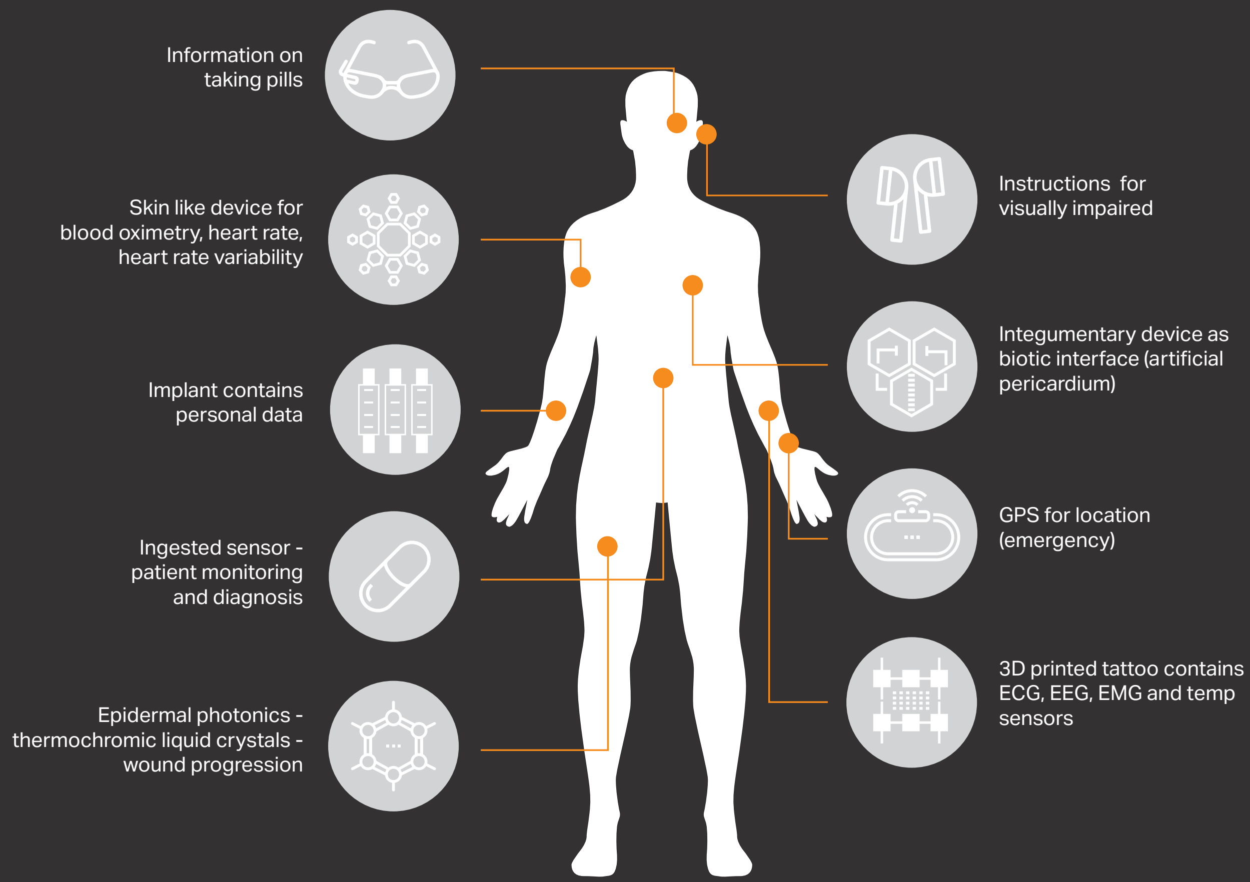
When required alerts can be sent to relatives, robotic assistants, care home staff or even directly to the emergency services.

Residents are comforted that they can have the right care at the right time, while retaining the ability to live at home for the rest of their lives.

These facilities have reduced the need for in-patient beds spaces previously occupied by the elderly. The facility's gym is shared by a number of NHS physiotherapists, helping many residents to improve their mobility.

Charlie's grandparent is delighted with the visit. Charlie makes sure that the recovery sensors are being picked up by the development's wi-fi system. Charlie relaxes. It has been an incredible journey over the last two days.

Figure 16: Different applications of medical sensors



Source: AECOM

Figure 17: New assisted living possibilities

- Pull cord/alarm beacon
- Door bell (video link)
- Door sensors (security/roam)
- Smoke/CO_2 sensors
- Temperature/humidity sensors
- Window/door sensors
- Flood detector
- Movement detector (fall alarm/curtains)
- Pressure mats (bed/chairs)
- Camera

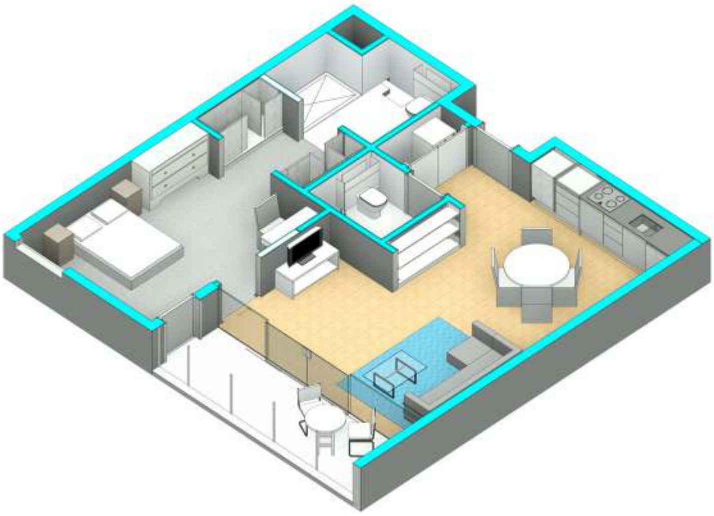
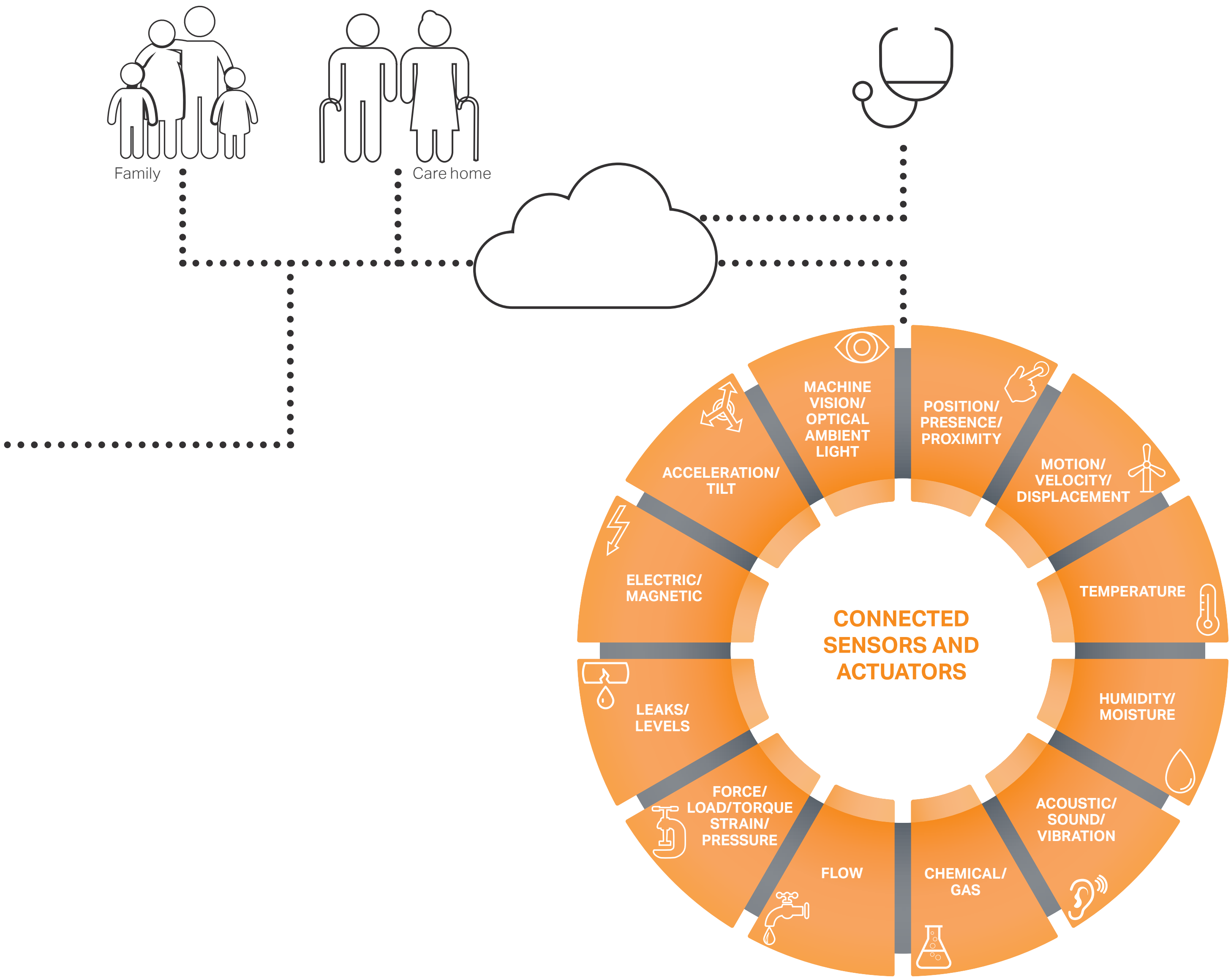


Figure 18: Connected devices and rules



CONCLUSION

In conclusion, the NHS brand is global. A redefined NHS allows the broader UK health economy, estimated at £55 billion per annum, to benefit from the UK's renewed leadership: redefining how a health ecosystem is delivered to society.

Charlie's clinical journey started with the sensors in a watch and ended with a different type of sensor to monitor his recovery. The new technologies referenced throughout the paper underline the need for a major holistic re-think of the NHS estate.

Good design in its many guises, from watches to flexible wards and clinical areas, will become the backbone of a redefined, proactive NHS infrastructure and new, more sustainable NHS estate with technological innovation at its heart. An NHS fit for the future that is once again the envy of the world: sustainable through design.

THE NEW TECHNOLOGIES REFERENCED THROUGHOUT THIS PAPER UNDERLINE THE NEED FOR A MAJOR HOLISTIC RE-THINK OF THE NHS ESTATE.

WITHOUT LIMITS

Imagine it. Delivered.

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