Slide 1 - Introduction (Garry)

Good afternoon, and thank you for allowing us to present our concept to you today. We are excited to be here. My name is Garry Clawson and I am a 2nd year student currently on the BSc(Hons) Computer Science program at the University of Lincoln. My team partner Callum Thompson, is a 2nd year BSc(Hons) student on the Games Computing program, also at the University of Lincoln. *(Slight pause)*

Airflow within buildings is not something that is historically thought about outside of air conditioning or heating. Once a building is designed and built, managing airflow is particularly difficult due to the static nature of the space, especially if a dynamic delivery of airflow is required.

Airborne diseases such as COVID-19 have now brought the movement of air, particularly person-to-person movement of air, to the forefront of the public's mind, especially when indoors. Our submission intends to present one solution to the management of indoor airflow to reduce COVID-19 like transmissions, to mitigate this public concern.

Slide 2 - How Covid-19 shaped our submission (Garry)

Airborne transmission is a major route to infection of a Covid-19 like disease. We have all seen how indoor environments need to be carefully managed to ensure the safest possible space.

However, this has so far been by changing our behaviours, using additional tools such as PPE or even completely cutting ourselves off from one another. For high risk people this is the only way they can shield themselves, however, we can learn from the past where traditional hospitals had large windows and tall ceilings to help remove pathogens.

Helping today's space constrained hospitals remove airborne pathogens is one such route to reducing reliance on individual behaviours and minimising the impact that airborne disease transmission can have.

Slide 3 - Why is airflow management important (Garry)

The Center for Disease Control & Prevention as well as the World Health Organisation, have prepared a significant set of statistics regarding COVID-19 transmission. They show that two main avenues of non contact delivery are via droplet and aerosol over short and long ranges respectively. However, importantly, the CDC also notes that air currents as well as air humidity play a large part in the propagation process itself.

As well as the distance that an airborne disease can travel, the duration it can persist as an aerosol was also noted to be around 3 hours. The CDC further goes on to state that once propagated, if an airborne disease is left to fall onto surfaces such as floors or bins, they can then proceed to survive from 4 hours to 2-3 days. This airborne duration, coupled with being able to manage humidity of between 50% - 80% provides an ideal opportunity to minimize airborne proliferation of a SARS like disease.

This high level analysis shows that if it is possible to identify, move and ultimately discharge contaminated air, quickly from an internal space, it could be advantageous to not just the health of the occupants but also the wider operation of the hospital itself.

Slide 4 - Concept Overview - Wearable Technology (Callum)

Wearable technology today is ubiquitous and ranges from watches, bracelets to even personal implants. This technology has been extended to help monitor and manage a person's health and to help guide improved lifestyle choices such as the 10,000 steps per day challenge. However, this technology has not yet been extended to help dynamically control or inform the built environment around you.

Identifying a concern is not enough. Wearable technology needs to be able to mitigate any concern by dynamically controlling your surroundings. Localised air conditioning systems are again pervasive within indoor environments and are generally managed as part of a BMS (Building Management System). However, what they do not do is respond to a user directly, they only respond to the environment on a given set of parameters of which a user is set within.

Further, using data provided by wearable technology and linking to localised extraction at the bedside or in corridors, we can extend the concept of managing airborne particles throughout a building infrastructure.

Slide 5 - Concept Overview - Leveraging Azure (Callum)

Giving a BMS the ability to utilise streaming personal and sensor data to dynamically manage a localised environment turns the current BMS idea on its head, and lets the building command the resources it needs rather than the users dictate what services the building needs.

Azure services would facilitate IoT devices and support the flow of air through a building to ensure minimal exposure to airborne particles at any one time. It would manage when certain doors or windows are open (to what degree or speed), what extraction or air conditioning is on to mitigate any spread of a disease. Along with wearable technology it would not only be possible to identify a source of contamination but also the possible spread to ensure rapid response where required.

Employing ML and AI also turns a static building into a dynamic building; determining what areas need the most attention (for cleaning say) and which areas do not. Current static monitoring does not allow a distributed connected network to learn or leverage from each useful data point, nor does it allow real time adjustments due to demand changes in that environment. It just allows air conditioning to be on or off, or heating to be low or high. There is no current intelligence built in.

Many of the technologies are readily available although may not yet be used in the way we require or support IoT technology. Manufacturers do not yet facilitate IoT connectivity in their extraction solutions for instance. The Philips Wearable BioSensor only currently measures vital signs or step count but not a user's internal diaphragm movement or breathing cadence which may indicate a cough or sneeze. Air conditioning systems are connected to a BMS but are generally managed in clusters or zones in a defined space, not individually managed to a local need or in response to a continually changing environment.

Linking wearable technology, air control services as well as building resources into a single theme we can begin to conceptualise how a new style of airflow management can be developed.

Slide 6 - User Interaction - People First (Callum)

The concept uses an ‘Always On - Always There’ philosophy and requires no direct user interaction. To ensure that a user can be connected at all times a wearable device such as the Phillips Biosensor is employed. This Biosensor would recognise a person's orientation as well as extended features such as the ability to detect a cough or sneeze. This sensor would also support internal GPS that can be implemented within ceiling lights using Phillips Visible Light Communication (VLC) technology.

As a user moves throughout the building, a real time environment map is constructed through the use of Digital Twins and ingested data to support Stream Analytics, ML & AI services. This map is built up with a users’ breathing rates, coughs, sneezes and general air circulation through the dynamically changing space.

The image shows a snapshot of a building where IoT devices map the airflow in real time via sensor technology. The red zones are ‘high’ contamination’ areas and the green are ‘low’ contamination areas. The *new* purpose of the BMS is to *understand* what a contaminated area is and how to then move the contaminated air out as safely as possible with the use of pathfinding algorithms such as A-Star for example.

One result of this implementation is that a hospital building can then manage contamination concerns in real time without human interaction. This would ensure that spaces are more effectively used, process efficiency is increased, and NHS staff and patients are more properly supported.

Slide 7 - Concept Architecture Design (Garry)

The concept architecture employed is subdivided into 4 key zones that show the flow and hand off of information. IoT and edge device messages are ingested at the front end through the IoT Hub to support automated activity, digital twins and anomaly detection.

The environment analysis is completed by the Azure Cognitive Services as well Azure streaming analytics to support the Edge while serverless functions feed back to IoT devices and feed forward to the Event Hub, Event Grid and Logic App to manage the core operation of the system.

Data visualization is utilised by integrating HoloLens for direct user interaction as well as a wider analysis through PowerBI. The services are all woven together by a *pay-for-what-you-use* structure ensuring massive scalability without the upfront cost.

Slide 8 - Implementation - Key Services (Garry)

The key to this concept is not complexity but extensibility. Deploying the simplest solution to manage the key concerns will yield more immediate benefits than a narrow but deeply deployed system. To this end several Azure resources have been employed.

The **Azure IoT Hub** is used for ingesting large quantities of data from IoT devices in the hospital building as well as from user wearables. The IoT hub will be used to ensure the full connection of all IoT devices while being flexible, scalable and secure. The ability for the IoT hub to also push updates to devices allows concept extension to Edge ML but just as importantly, to ensure you can also update firmware. The Hub will act as the central information broker from the outside world as well as linking the digital twin and Azure data factory for seamless on and off premises data storage.

The **Azure Digital Twin** technology is deeply ingrained to support intelligence from sensor logic; continually improving the effectiveness of the hospital in real time. This digital mirror of the real world allows for scenario development, problem resolution as well as extended data visualization.

Azure Custom Vision through the **Azure Cognitive Services** is deployed to analyze any ‘out of standard’ spaces such as beds not in the right place or misplaced equipment. This is to aid in determining any potential contamination threats. For instance, if a patient sneezes in an empty room, using cognitive services we can identify the contamination zone and create the required event trigger, however if that person then leaves the room, the next room user will not know that a piece of equipment may now be contaminated. Azure Cognitive Services help mitigate this scenario and initiate the required response to efficiently and safely manage this situation.

Azure Machine Learning is used to optimize the deployment of the building management system and to continually improve the intelligence of how air flow moves within the hospital infrastructure. The Machine Learning service will be critical in enabling the fine tuning of the air flow systems depending on what scenario is presented such as busy corridors, open windows or a densely populated space, to then manage the movement of contaminated air.

The **Azure Logic App** will support the automated scheduling of tasks for each of the air conditioning and air extraction devices, as well as the building fabric. The Logic App could also populate a traffic lighting system to show Red/Amber/Green spaces and automatically command resources for clean up or further service requirements.

We would like to now show you a live demonstration of this concept, at a very high level, we have built using Azure.

DEMONSTRATION (Garry)

(Click simulation button)

On the face of it this may look like a simple static web page, however there is more here than meets the eye. The web app itself is a .NET core web app fully hosted on Azure cloud web services deployed on a UK south server.

In the background each simulation creates 12 sensor readings to simulate the contamination levels for each room on the map. These telemetry readings are sent and then ingested by the IoT hub. A serverless trigger function then takes these messages and stores them as a collection in a CosmosDB where we then also use a HTTP trigger to create the RESTful API to expose the data to the outside world. This exposed data has been cleaned up to sit in the correct json format we then need in our application.

We then query the API for the json using RestSharp, parse it with NewtonSoft to select only the readings we want to see in the code behind, and then push these sensor readings across to the HTML/JS front end, where we present them as coloured circles in their respective rooms. These colours represent a threat level from low through high but they could easily represent triggers for airflow controls. Each press of the simulation button completes this round trip.

(Scroll down on website to show A)*

Now we know a contamination threat exists, how do we manage it? One opportunity previously mentioned could be with the A* pathfinding algorithm or something similar. Here is an example of what that may look like when mapped to a hospital floor layout taking into account populated areas.

We built this demonstration in a few days using available training materials and microsoft support documents. We hope we have given a deeper sense of Azure and how the previously detailed services could be deployed. But more importantly, demonstrated an initial high level feasibility of our concept on Azure.

Slide 9 - Implementation - Primary Use Case (Callum)

The primary focus of the concept is to intelligently visualise, respond and safely remove airborne pathogens. This is not possible by just using an air conditioning system that is not contextually aware of the environment. Using IoT with the power of Azure and coupled with digital twin technology allows the building to become augmented into a living environment.

To do this, the monitoring of room occupation levels is vital and this is achieved through the KinectDK linked to the Azure Cognitive Services with Azure AI. KinectDK allows real time visual analysis to identify what has changed or capture where in a room a user has been. Wearable BioSensor technology compliments this by allowing discrete personal data to be overlaid with the visual world. HoloLens technology can then augment low/med/high risk zones and provide real time airflow visuals to support the user in navigating spaces, to ensure minimal possible disease exposure.

Integrated IoT devices managed via the IoT Hub with Azure machine learning identifies a crowded space and if any anomalies are present. This allows every space to be monitored against a known normal and scored. Where this normal changes events via the Event Grid or Event Hub can be fired. Temperature and humidity changes can therefore be managed *on the fly* to ensure the best conditions for the removal of Covid-19 like diseases; especially in rooms which are not actively sanitised but often visited, such as a family room.

Finally, once an event has been triggered we can begin to effectively triage and bring the space back to the original standard. A live building can manage its own resources using the Logic App; this means decontamination can take place '*where needed - when needed*'.

In an environment that is constantly changing, having a static resource schedule for clean up is no longer effective or efficient. This concept turns that paradigm on its head and the 'living building' behaves similar to an immune system, creating T-Cells in the presence of an unknown body, tackling issues where and when required.

Slide 10 - Implementation - Secondary Use Cases (Callum)

The secondary focus of the concept is security, fault monitoring and cost management. In many instances a door could be jammed (blocked) and this has to be managed manually. The Azure DataLake linked with PowerBI allows general services to be managed as well as responses deployed.

Lighting systems upgraded to support internal GPS can map where users are and ensure contaminated spaces are not inadvertently accessed. Azure Streaming Services will be used to detect anomalies in streaming or *hot* data. Using thousands of IoT devices this can take advantage of micro conditions within the hospital itself. This ranges from having the right tools at hand to allowing stock and costs to be managed.

Slide 11 - Cost and Feasibility (Callum)

The average cost when deploying a traditional BMS is between $2.50 - $7.00 per square foot. For a 300,000 square feet hospital, which is around 120 beds, that would cost at least $750,000. This very high cost means that the ROI takes four or more years to recover the cost of installation.

Deploying with Azure you only pay for what you use which reduces this ROI considerably. It is important to also recognise that this ROI time is based on easily measurable data, for example energy savings. It does not consider savings from the added health protection to patients and staff from the proposed airflow management concept.

With a system such as the NHS within the United Kingdom, which is funded by taxpayers, it is even more crucial. It does not just save the NHS money as uninfected staff or patients have less chance of catching viruses through airborne transmission, but they also remain a contributing member of society.

It is an unfeasible expectation for existing infrastructure to be teared down and rebuilt with a fully integrated BMS. It would not just be extremely expensive, but it would also be a strain on health services with the reduction in capacity. A way to overcome this would be to do a phased refit, also known as a retrofit. The benefit of this is from the lower risk of disruption to operations and the spread of costs over a longer period of time. Retrofitting would also allow staged deployment as well as validation supported by Azure digital twins.

Slide 12 - Conclusion & Questions (Callum)

This concept has focused on using Azure as an artificial ‘immune system’ that can visualise, respond and expel contaminated air in an automated intelligent way. We have identified and discussed several services that we have used and we have demonstrated a high level example of our concept.

However, this is just the tip of the iceberg; with the power of Azure imagine what more can be done if we also allow the building to ‘share its experiences’ and more broadly communicate to the users inside.

Thank you for your time today. We hope you have found our presentation compelling. We are happy to take questions.

(Open for questions)