SIEMENS
Ingenuity for life

Your guide to The Sir William Siemens Challenge

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iForge

SIR WILLIAM SIEMENS CHALLENGE | MindSphere LIVE

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1 The Brief

Can you create something that's never been done before? Now's your chance to prove it. Working in a team of multi-disciplined engineers, you must build an automated device that brings to life the data collected by MindSphere – the cloud-based Internet of Things (IoT) operating system invented by Siemens.

The expertise among you will vary from mechanical and electrical to computer science, civil and related fields of engineering. Some of you will be good with data and will write a parser to translate the information we give you – revealing its meaning. Others in your team will be better at designing the structure of your device and powering it. But all of you must work together to agree upon the concept and how to execute it. To achieve the perfect outcome, by the end of this challenge your team will have...

- Parsed and analysed MindSphere datasets into a digestible format that the whole team can understand.
- Designed a concept based on that data, which gives meaning to your creation.
- Different features of your device – whether they move, produce sounds or light up – must represent different sets in your data, e.g. fan speed representing room temperature (see prototype video). However, the more original you are with your concept, the better.
- Built something that's intelligently engineered and performs in a unique way.
- Used a PLC (i.e. Raspberry Pi) to program your device, so its actions showcase the datasets you've uncovered – bringing them to life.
- Collaborated and worked hard to understand and complement each other's roles.
- Solved problems you've encountered and demonstrated your adaptability.

However, there are certain rules you must abide by in the build-up and during the event, so as not to lose points or risk disqualification.

2 The Rules

2.1 The Kit

Packed full of essential materials and components, you'll receive a huge assortment of kit which will give you the flexibility to build most table top devices you're able to dream up. **Please note, you must fill out a form at the event stating the exact materials you intend to use. Any kit you take, but fail to use will result in points being deducted from your team. We will be sure to remind you of this on the first day of the competition.**

Here are the quantities so you can start coming up with ideas and think about how much kit is required.

Motors & Drivers

5x Servo Motor Tower Pro MG996R
5x Servo mounting brackets
1x Servo Pan tilt kit
5x Servo metal horn
3x Nema 17 Stepper (2A, 2.8V)
3x Nema 17 Bracket
3x 5mm Mounting hub
3x Stepper Motor Driver (A4988, 2A)
1x DC Motor 12V 100RPM 583 oz-in
2x DC motor driver 13A 5-30V
1x DC motor mount
1x 6mm mounting hub
4x Push Pull Solenoid 12V JF-0826B or JF-0530B

Transistors

12x FDP7030BL N channel mosfet 60A 30V

Power

2x Bench power supply 6A, variable voltage
1x Buck Voltage Regulator adjustable 5-30V 5A
1x Buck voltage regulator adjustable 3A
4x Step-Up Voltage Regulator adjustable 4A
1x Lipo Battery 3.7v 1S 1C
1x LiPo Charger
3x Capacitors 1000uf 25v
3x Capacitors 100uf 25v
1x Resistors pack 1/4W (300x - 30 values)
100x 100 ohm resistors 1/4W
10x Light dependant resistors
7x Diodes 1N4004
5x Diodes FR207 2A 1000V
5x Diodes SR2100 2A 100V
2x Heatsink 3pcs set
10x Standard terminal blocks 5mm

LEDs

3x Addressable LEDs strip WS2812B 5V 60 LEDs/meter - 5 Meters
200x Super bright LEDs 5mm
3x 3W RGB LED
3x 3W Warm white LED

ICs and Breakouts

3x TPIC6B596N 8-bit Shift register 5V
1x 74AHCT125 - Quad Level-Shifter (3V to 5V)

Belts, Gears, Pulleys

1x 1x GT2 Timing belt 10mm x 2m
2x GT2 driver pulley 20T
2x GT2 Idler pulley 20T
1x Closed loop GT2 belt 1000mm
1x Closed loop GT2 belt 200mm

Structure

10x M3 x 20mm standoff spacers
2x 5mm bearing block
1x MakerBeam Kit
1x MakerBeam Hinge & Bearings & fixing set (10)
1x MakerBeam hinges pack
1x MakerBeam Tslot Nuts (25 pack)
1x MakerBeam corner Cube (12 Pack)
2x Lead screw + Rails set 200mm
4x 8mm Shaft rod 500mm
1x Lazy Susan 140x8.5mm

Controllers

1x Teensy 3.2
1x Raspberry Pi 4 model B
1x Raspberry Pi PSU
1x Raspberry Pi mini fan
1x Micro sd Card 16GB class 10 with Raspbian Stretch installed
1x Raspberry pi Display touch screen
1x Nodemcu ESP8266 WiFi Chip

Audio

1x X Mini Speaker re-chargeable

Sensors

2x Hall Sensor TLE4905L
4x Magnets 9mm cube N52 neodymium

Other

10x Steel Marbles
1x Solderless breadboard 830 holes

Cables

2x Micro USB cable for micro controllers and chargers

Materials

2x Laser grade plywood sheet 900x600mm 3mm thickness
2x Laser grade plywood sheet 900x600mm 6mm thickness
2x Clear Perspex sheet 900x600mm 3mm thickness
2x Clear Perspex sheet 900x600mm 6mm thickness
1x Wire rope 1.5mm x 8m
10x Wire rope crimps
20x Corner brackets
10x M8 160mm bolts
30x M8 Nuts
40x M3 6mm
40x M3 10mm
40x M3 20mm
40x M3 40mm
100x M3 nuts
100x M3 Locking nuts
100x M5 Locking nuts
40x M4 screws for mounting hub and linear bearings 10mm
10x M5 30mm bolt
10x M5 60mm bolt

Consumables

Solder
Glue sticks
Screws (multiple sizes) 4/5mm x 50/70mm and 2.5mm x 10mm
Cable ties (multiple lengths)
Electrical wire 7/0.2 (1.4A 1000V) (2x Red, 2x Black, 2x Yellow, 2x Green)
Electrical wire 16/0.2 (4A 1000V) (1x Red and 1x Black)
PCB prototyping boards(20x8.5cm)
Dupont jumpers 10cm
Heat Shrink 1.6mm & 4.8mm
PCB header (400)
Assorted nuts and bolts (multiple sizes)
Wood glue (i.e. gorilla glue) or similar
Epoxy
Insulating tape

2.2 £100 Bonus Budget

Extra parts MUST be ordered by 31st October. No more than 3 items per team and everything must be available for next-day delivery from Amazon.co.uk. Cost of delivery needs to be included within the allotted £100. Failure to comply will result in items being deducted from your order, so as not to exceed the budget.

2.3 Tools and Facilities

Your team will have access to the Diamond Building's state-of-the-art engineering workshop: the iForge. You'll have all the essential tools and machinery to create simple and complex parts. Here's what will be available to you on the day.

Hand tools

3x Cordless drill
3x Mini screwdriver set
3x Screwdriver set
2x Wood saw
3x Metal cutters
6x Soldering iron
6x Fume Extractor
3x Solder sucker
1x Heat Gun
3x Hot Glue Gun
3x Multimeter
3x Wire stripper
3x Wire cutter
1x PCB spot face cutter
2x Calliper
1x Hacksaw
Clamps – various sizes

Power tools and machinery

1x Band Saw
1x Table Saw
1x Pillar drill and bits selection
1x Laser Cutter

2.4 Your Device

You must only use the materials and tools provided to build your device – as well as any approved kit we've purchased on your behalf using your £100 bonus budget. Dimensions of the device must be no bigger than 600x900mm. We recommend slightly smaller as this is the maximum sized base you will be given to rest and transport it on. However, there will be more workspace for your laptops, components and miscellaneous items.

Other than this, so long as it passes a risk assessment, be as creative with your build as possible.

2.5 Risk Assessment

Before building your device, you must write up a risk assessment. We will provide a basic form relating to the tools available on-site, but you must produce one detailing the features of your invention and the potential consequences, or lack thereof. If deemed safe enough, we'll sign this off and building can begin.

2.6 The Data

We will be handing out your data on a secure USB drive on the first day of the competition. This has been collected by thousands of sensors installed across The Diamond Building at the University of Sheffield – each measuring different activities and conditions, such as computer usage and CO2 levels.

The data format will not be revealed until the event. It will be too comprehensive and complex to read with the naked eye, so you'll need to write some code capable of parsing it on the day.

2.7 Programming

All devices must be controlled by a program written by members of the team during the weekend of the competition. No exceptions. Pre-written code is not allowed and devices must run autonomously with the aid of a PLC, e.g. Raspberry Pi. They can't be purely mechanical, electronic or kinetic.

2.8 Laptops

Those of you planning on writing programs and using CAD software may prefer to bring your own laptops, which we recommend. Laptops will be available to borrow at the event, but there are limits to the programs they are able to download.

2.9 Teams

This challenge consists of 12 competing teams from 17 different UK universities. It's seven people per team and every team will have an equal balance of digital and engineering specialists. All team members must agree on their concept, as well as the device they intend to build and how it performs. We want to see teamwork.

2.10 Workspaces

All workstations must be kept free of rubbish in accordance with Health and Safety. Building should be confined to the iForge and Light Structures areas. However, please feel free to move throughout the building when discussing ideas, using computers or taking a break. Our university support staff can direct you to some good spots for eating and relaxing.

2.11 Support Staff/Troubleshooting Tools and PLCs

Siemens will have engineers and trouble-shooters on-hand to discuss any issues that arise during your build. They are allowed to guide you on how to approach the overall challenge, but won't interfere with your decisions or help with the building of your device. However, they can point you towards resources explaining how to use tools, components and PLCs.

3 Event Agenda

Friday 15th November

15:00 - 16:00	Registration at The Diamond
16:00 - 17:00	Induction for equipment in the lab
17:00 - 17.30	Opening ceremony
17:30 - 17:30	Hacking starts
19:30 - 20:30	Dinner
23:00 - 23:00	Manufacturing close (iForge)
23:00 - 23:30	Pizza
01:00 - 01:00	Close

Saturday 16th November

08:00 - 08:15	Arrive at The Diamond
08:15 - 09:00	Breakfast
09:00 - 09:00	Manufacturing
13:00 - 14:00	Lunch
18:30 - 19:30	Dinner
22:30 - 23:00	Pizza
23:00 - 23:00	Manufacturing close (iForge)
01:00 - 01:00	Close

Sunday 17th November

07:00 - 07:15	Arrive at The Diamond
07:15 - 08:00	Breakfast
08:00 - 13:00	Manufacturing (final push)
13:00 - 15:00	Presentations, judging and lunch
15:00 - 15:30	Closing ceremony

4 Judging Criteria

Building something totally original is essential to impressing our Siemens' judges. We're also very eager to see adaptability, collaboration and problem-solving skills. But the winning team will also combine the data-driven, engineering and creative elements of this challenge (as outlined below) better than any of its competitors. We'll have some questions regarding your device's concept, performance and aesthetics, which you'll need logical explanations for when presenting. Here's what we'll be looking for:

4.1 Data

Parsing of data:
How effectively have you been able to process the countless layers of data collected by our MindSphere network? Have you built a programme capable of organising it into individual sets, which reveal their individual meaning? What does the data represent and what is it saying about conditions in The Diamond Building?

Rationale behind data selection:
Once you've isolated individual datasets, they should present a choice of data sources throughout the Diamond Building, including sensors reading 'humidity levels' or 'power consumption'. Which data will you choose to represent with your device? Does your data selection match up with the concept behind your device? See our prototype video for examples.

4.2 Engineering

Electrical/mechanical:
Quite simply, how well built is your device? How much of the standardised kit has been used and how intelligently has it been integrated with your team's additional purchases? Is the set-up efficient and does it perform as it should, autonomously, with the aid of a rationally programmed PLC?

Structural:
How well thought-out is the structural integrity? What's it trying to achieve? Is it designed to support less than ordinary weight, or simply supposed to be visually striking? Is the structure key to making this a unique device, or is it just essential to fulfilling the mechanics behind it? What forces does it exploit? Does it incorporate kinetic energy? There are so many possibilities, none of which should be accidental – so give us your rationale.

4.3 Creative

Concept linking to data source:
How does your device demonstrate the activity recorded in your selected data, e.g. the varying levels in humidity? Our prototype is a perfect example. But you don't have to build a scaled down example of The Diamond Building itself. There's plenty you can create to effectively portray your data findings. It just takes some planning and imagination.

Aesthetics/output:
Let's be honest, you signed up to build something cool. So what's interesting about your device? Is it the sleek design? Is it the way it manipulates sound or light? Maybe it's a subtle yet intriguing invention, or perhaps it was built to deliver a high-energy performance?

4.4 Resourcefulness

Sustainable design is crucial to a brighter future. When considering the kit required to build your device, you must minimise waste as much as possible. So you will be given a form upon which you'll write ONLY the kit that will end up being a part of your device. The more parts you select that go unused, the more likely our judges are to deduct points from you and your team.

4.5 Summary (Things to Think About)

As we'll be assessing you on your collaboration, adaptability, problem-solving, use of data, engineering skills and creativity, please ensure you're able answer the following questions when talking/presenting to our judges:

- How did you work together as a team?
- What challenges did you face and how did you overcome them?
- How would you explain your product and the data used?
- How can you prove all engineering disciplines were considered throughout the challenge?
- What process did you go through to come to your final concept?
- What technologies did you use and how did you use them? (Please mention coding)
- What did you learn?
- What would you have done differently looking back?

5 Technical Resources

You've seen the kit list. Now, here's some extra handy information about the specs and uses of the equipment included. There are 'How to...' guides for the PLCs (Raspberry Pi, Teensy etc.), recommendations on currents and voltages components should run on, and assembly instructions for many of the essentials – just in case you need a little extra help. There's no harm in taking our tips on-board. In fact, we encourage you to take a look so your device works as it should.

MG996R servos specs
http://www.towerpro.com.tw/product/mg996r/

Servo pan tilt kit assembly guide
https://www.robotshop.com/media/files/pdf/lynxmotion-pan-and-tilt-assembly.pdf

Nema 17 stepper motors (17HS19-2004S1)
https://www.omc-stepperonline.com/nema-17-stepper-motor/nema-17-bipolare-59ncm-84oz-in-2a-42x48mm-4fili-w-1m-cable-and-connector.html
NOTE: The steppers motors have to be driven at 12V-24V, using the current limiting functionality on the A4988 stepper drivers. Limit the current to 2A max. See details on the A4988 stepper driver's link (below). The A4988 operate at 8V-35V, so you must drive the steppers at 8V minimum anyway. Use the step-up voltage regulators to drive the steppers at a higher voltage using the 12V PSU if necessary.

The A4988 acts as a chopper driver (high voltage but limited current). More info below.
http://www.linearmotiontips.com/what-is-a-chopper-drive-for-a-stepper-motor/

Nema 17 brackets mechanical drawing
https://www.robotshop.com/media/files/zip/documentation-3338.zip

5mm mounting hub mechanical drawing (steppers)
https://www.pololu.com/file/0J665/1998-5mm-m3-hub-dimensions.pdf

Stepper motor driver A4988
https://www.pololu.com/product/1182
NOTE: We suggest using the AccelStepper library to drive the stepper motors with the supplied A4988 drivers.

In order to use the AccelStepper library with the A4988 (only 'step' and 'dir' pins), please see examples on this page (examples 3, 4, 5 and 7).
http://www.schmalzhaus.com/EasyDriver/Examples/EasyDriverExamples.html

Cytron DC motor 1100RPM 12V
https://www.robotshop.com/uk/12v-100rpm-583-oz-in-brushed-dc-motor.html
https://www.robotshop.com/media/files/images2/12v-100rpm-583-oz-in-brushed-dc-motor-desc-dime.jpg

Cytron DC motor driver 13A - MD13S
https://www.robotshop.com/media/files/pdf/MD13S_User-Mannual.pdf

DC motor mount mechanical drawing
https://www.robotshop.com/media/files/pdf/mechanical-drawing-1084.pdf

6mm mounting hub mechanical drawing (DC motor)
https://www.pololu.com/file/0J667/1999-6mm-m3-hub-dimensions.pdf

Push pull solenoid
https://www.banggood.com/JF-0826B-12V-DC-10mm-Hard-Magnetic-20N-Push-Pull-Electromagnet-Frame-Solenoid-p-1130239.html?

How to drive solenoids with a micro controller (circuit diagram)
http://playground.arduino.cc/uploads/Learning/solenoid_driver.pdf

FDP7030BL N channel MOSFET 60A 30V
http://www.mouser.com/ds/2/149/FDP7030BL-1008136.pdf

Buck voltage regulator adjustable 5-30V 5A
https://www.ebay.co.uk/itm/Constant-current-voltage-5-30v-5A-buck-regulator-with-Display-UK-Stock-/191592089525?hash=item2c9bc747b5:g:QAsAAOSwstxVa3yK

LM2596 buck voltage regulator adjustable 3A
https://www.ebay.co.uk/itm/LM2596-DC-DC-Switching-Adjustable-Step-Down-Voltage-Regulator-Converter-3V-40V/162289623433?hash=item25c9372189:m:mfnqbLbvaO6JOj7AXxfgPMQ

XL6009 step up voltage regulator adjustable 4A
https://www.ebay.co.uk/itm/XL6009-DC-DC-Voltage-Step-Up-Boost-Converter-replace-LM2577-3-32v-input-UK-Fast/400858208676?hash=item5d5502d9a4:g:ADoAAMXQstJTlgtv

Light dependant resistors guide
https://learn.adafruit.com/photocells/using-a-photocell

Small LiPo charger and 5V booster
https://hobbycomponents.com/shields/870-wemos-d1-mini-lithium-battery-shield

FR207 2A 1000V Diodes
http://www.farnell.com/datasheets/1693119.pdf?_ga=2.201070830.1779851752.1537608713-699437738.1509543304&_gac=1.195416286.1538296351.CjwKCAjwlqLdBRBCEiwAPxTGaXINGN4JwaNYzljv7niGQZATD9GaHwtv4oOsOu9oZeJQJb5KULGWNUaAsjHEALw_wcB

SR2100 2A 100V Diodes
http://www.eicsemi.com/DataSheet/SR220_2100.pdf

1N4004 1A 400V diodes
http://www.onsemi.com/pub/Collateral/1N4001-D.PDF

Standard terminal blocks mechanical drawings
http://uk.farnell.com/camdenboss/ctb1202-2bk/terminal-block-wire-to-brd-2pos/dp/1716993

WS2812B 5050 RGB LED strips (Neopixels)
https://learn.adafruit.com/adafruit-neopixel-uberguide/the-magic-of-neopixels

Tips and tricks on soldering LED strips
https://learn.adafruit.com/roll-up-video-light/prepare-led-strips

Neopixel bus library (necessary for the ESP8266)
https://github.com/Makuna/NeoPixelBus

NOTE: the preferred method to drive neopixels with the ESP8266 board is the NeoEsp8266Dma800KbpsMethod as explained in the Wiki. This uses the RX pin as output to drive the LEDs.
https://github.com/Makuna/NeoPixelBus/wiki/NeoPixelBus-object

It is also possible to use the Raspberry PI
https://learn.adafruit.com/adafruit-neopixel-uberguide/python-circuitpython#python-installation-of-neopixel-library-17-9

It is also possible to use the Teensy 3.2
https://github.com/adafruit/Adafruit_NeoPixel

For the Teensy, the OctoWS2811 library can be used
https://www.pjrc.com/teensy/td_libs_OctoWS2811.html

Also the FastLED library can be used
https://github.com/FastLED/FastLED
https://www.pjrc.com/teensy/td_libs_FastSPI_LED.html

And, the Adafruit simplified library as well...
https://learn.adafruit.com/adafruit-neopixel-uberguide/arduino-library-installation

Super bright 5mm LEDs
https://www.ebay.co.uk/itm/LED-5mm-or-3mm-Superbright-Clear-Diffused-Choose-Colour-Mix-Pack-UK-Seller-/152508668100?var=&hash=item23823998c4:m:mGd94m0bGnzHoJN-jR9dKYg

3W RGB LEDs
https://www.ebay.co.uk/itm/3w-RGB-3-chip-6-Pin-LEDs-PCB-20mm-Heat-sink-1-5-and-10-beads-Red-Green-Blue/271859322781?hash=item3f4c140f9d:m:m0K2J50cAHKezxwz9iVizSA

3W warm white LEDs
http://www.ebay.co.uk/itm/1W-3W-10W-High-Power-Heatsink-PCB-LED-1st-Class/281769990142?epid=1653484094&hash=item419accd7fe:m:m_7aUnUxhCs0PJwtFwe78Gw

TIPC6B596N 8bits shift register 5V
http://www.ti.com/lit/ds/symlink/tpic6b596.pdf
https://learn.sparkfun.com/tutorials/shift-registers

Code examples on how to use a shift register for 7 segment displays
https://learn.sparkfun.com/tutorials/large-digit-driver-hookup-guide#example-two-large-digits

How shift registers work
https://www.youtube.com/watch?v=6fVbJbNPrEU

GT2 belt and pulleys
(Link below is only one possible example of how to assemble components. Product in the link is not supplied in kit).
http://ooznest.co.uk/3D-Printer-CNC-Kits-Bundles/Linear-Actuators/Mini-V-Linear-Actuator-Kit

5mm bearing blocks
https://www.technobotsonline.com/5mm-bearing-blocks-pk-2.html

MakerBeam Kits
https://www.makerbeam.com/makerbeam-makerbeam-regular-starter-kit-black.html
https://www.makerbeam.com/makerbeam-t-slot-nuts-for-makerbeam-25p.html
https://www.makerbeam.com/makerbeam-corner-cubes-12p-clear-for-makerbeam.html
https://www.makerbeam.com/makerbeam-hinge-bearings-for-makerbeam-5p.html
https://www.makerbeam.com/makerbeam-hinges-for-makerbeam-8p-4p.html

Teensy 3.2
https://www.pjrc.com/store/teensy32.html
https://www.pjrc.com/teensy/first_use.html
https://www.pjrc.com/teensy/projects.html
http://www.michelepanegrossi.com/Data/SWSC/HowToParseStringsArduinoTeensy.ino

Arduino IDE support
https://www.pjrc.com/teensy/teensyduino.html
https://www.pjrc.com/teensy/td_download.html

Raspberry Pi 4 model B
https://www.raspberrypi.org/products/raspberry-pi-4-model-b/
https://www.raspberrypi.org/documentation/remote-access/ssh/README.md
https://www.raspberrypi.org/documentation/remote-access/

Raspberry Pi Display Touch Screen
https://coolcomponents.co.uk/products/raspberry-pi-7-touch-screen-display
https://www.raspberrypi.org/documentation/
https://www.raspberrypi.org/documentation/hardware/display/README.md

NodeMcu WiFi board (ESP8266)
http://www.esp8266.com/
https://learn.adafruit.com/adafruit-huzzah-esp8266-breakout

NOTE: to use the NodeMcu board with the Arduino IDE follow instructions on this page (It is necessary to install an additional board manager URL).
https://learn.adafruit.com/adafruit-huzzah-esp8266-breakout/using-arduino-ide

Arduino core resources page for ESP8266 (hardware and Arduino core software info).
https://arduino-esp8266.readthedocs.io/en/latest/index.html

NOTE: The Adafruit Huzzah is simply a breakout board for the ESP8266 chip. The NodeMcu is exactly the same thing and libraries can be used in the same way on both devices. The NodeMcu has different pin names (D1 - D8). After installing the ESP8266 support in the Arduino IDE, select NodeMCU 1.0 (ESP-12E Module). This will allow you to use the D1-D8 names for the pins.

We can implement a communication system between the Raspberry Pi and the NodeMcu using OSC (Open Sound Control) over the network. OSC runs on UDP.

OSC library for the ESP8266
https://github.com/CNMAT/OSC

NOTE: The ESP8266 can be setup as a WiFi Access Point/Router. It can generate a network and route up to 4 devices. Look in the ESP8266WiFi examples after installing the board support in the Arduino IDE.

WiFi manager library for the ESP8266 (more useful features and takes care of a number of settings).
https://github.com/tzapu/WiFiManager

Examples on communication between Teensy and RPi via Serial or OSC (originally coded in OpenFrameworks).
http://www.michelepanegrossi.com/Data/SWSC/SerialAndOSCExpleOF.zip

Hall effect sensor TLE4905L
http://www.produktinfo.conrad.com/datenblaetter/150000-174999/153775-da-01-en-HALL_SENSOR_TLE_4935L.pdf

Wire rope crimp tool
https://www.youtube.com/watch?v=RfLY6mOBzJ0