Microsoft

Microsoft Research

Faculty Summit 2012

ADVANCING THE STATE OF THE ART

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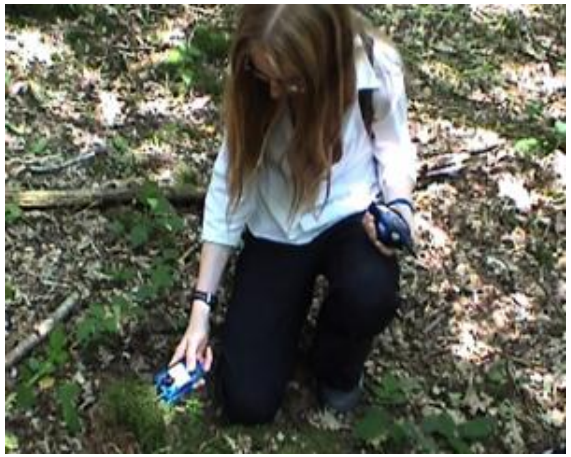
Kerry Hammil, Colin Miller
Microsoft Research

Custom devices in ubicomp research

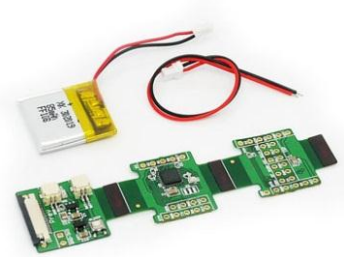


Custom devices

Custom devices often need to be:

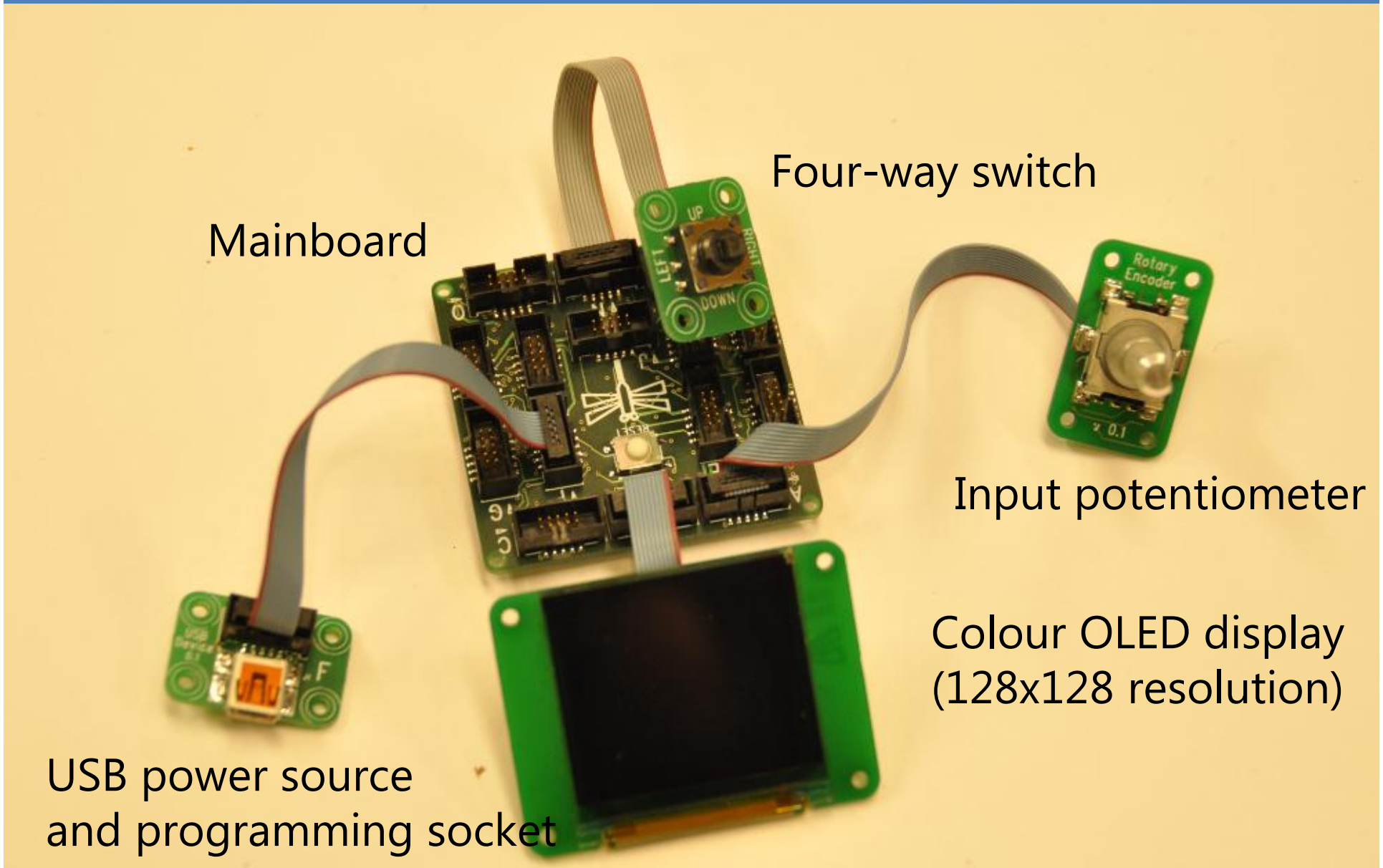
- developed quickly by a small team
- fully functional and usable
- self-contained
- usable in the wild
- able to be produced in quantity

Existing tools have *some* of the qualities we look for



Making a custom hand-held videogame device in 24 hours

Connect hardware modules (5 minutes)



Game development in C# (5 hours)

```
    public Point[] positions;
    public Point displacement;
    public Color color;

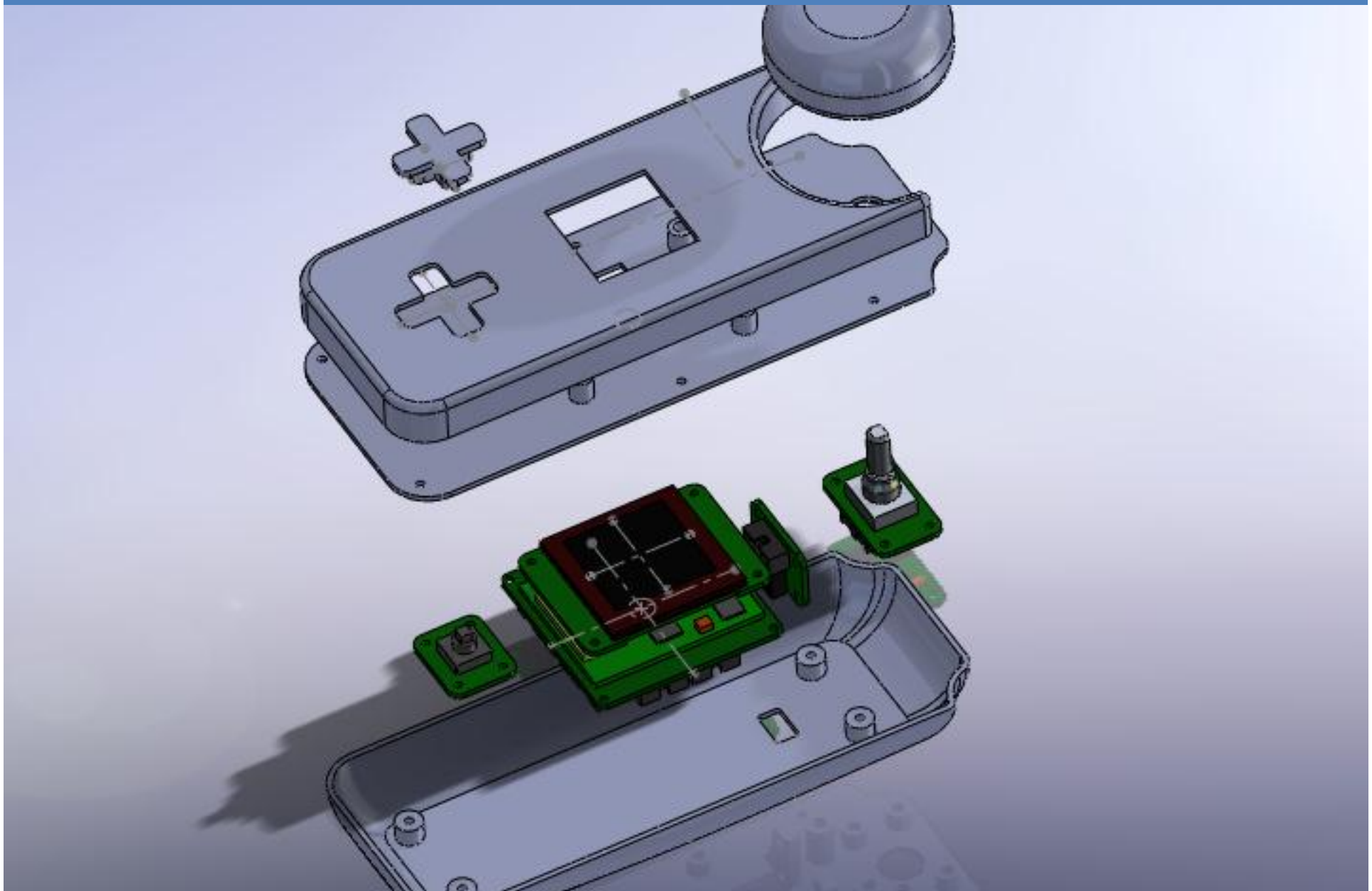
    public Piece(Point[] positions, Point displacement, Color color)
    {
        this.positions = positions;
        this.displacement = displacement;
        this.color = color;
    }

    public void Rotate(bool clockwise)
    {
        for (int i = 0; i < positions.Length; i++)
        {
            Point oldpos = positions[i];
            positions[i].x = clockwise ? -oldpos.y : oldpos.y;
            positions[i].y = clockwise ? oldpos.x : -oldpos.x;
        }
    }

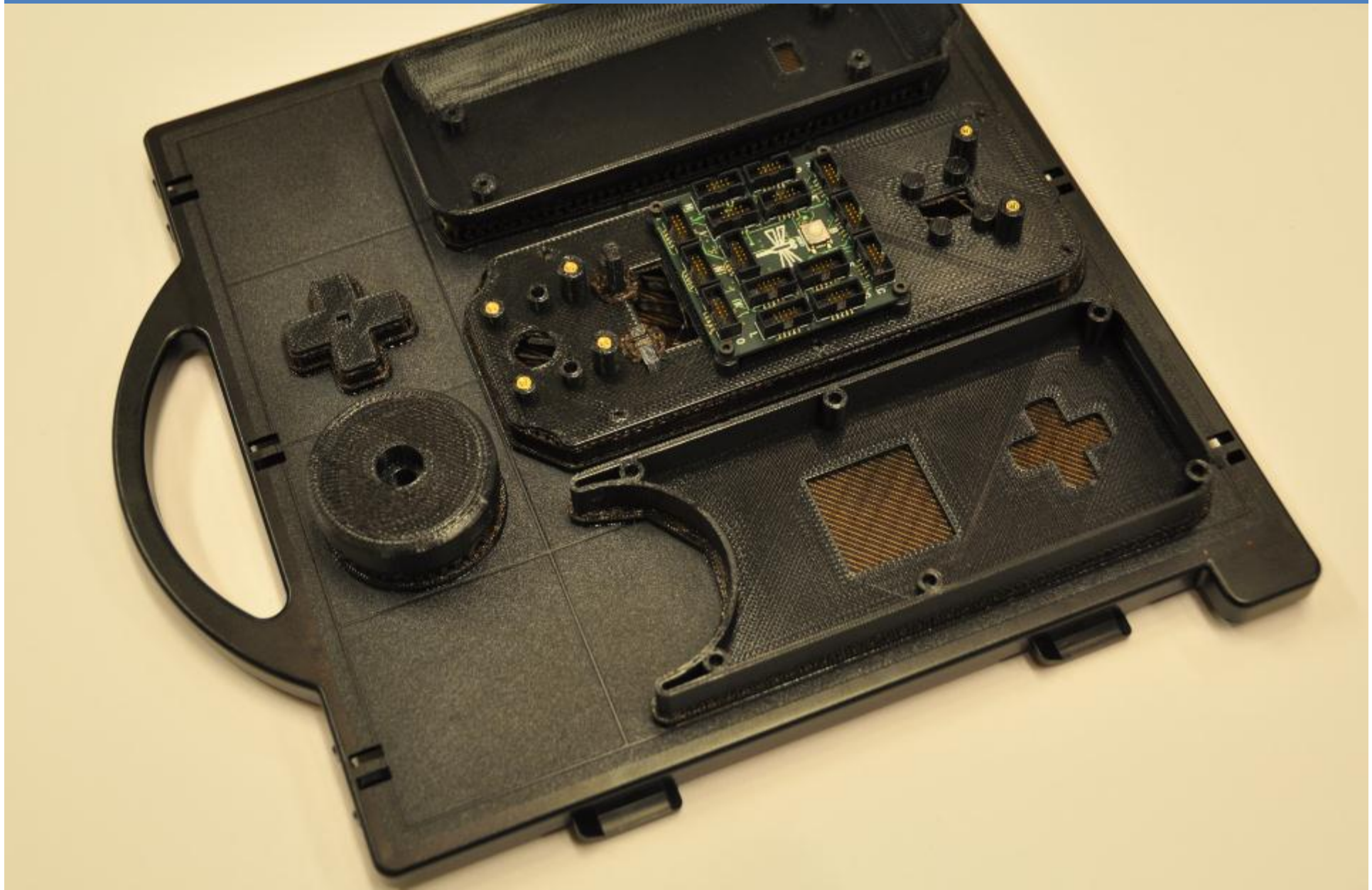
    public Piece Clone()
    {
        Piece clone = new Piece((Point[])positions.Clone(), new Point(displacement.
        return clone;
    }

}
```

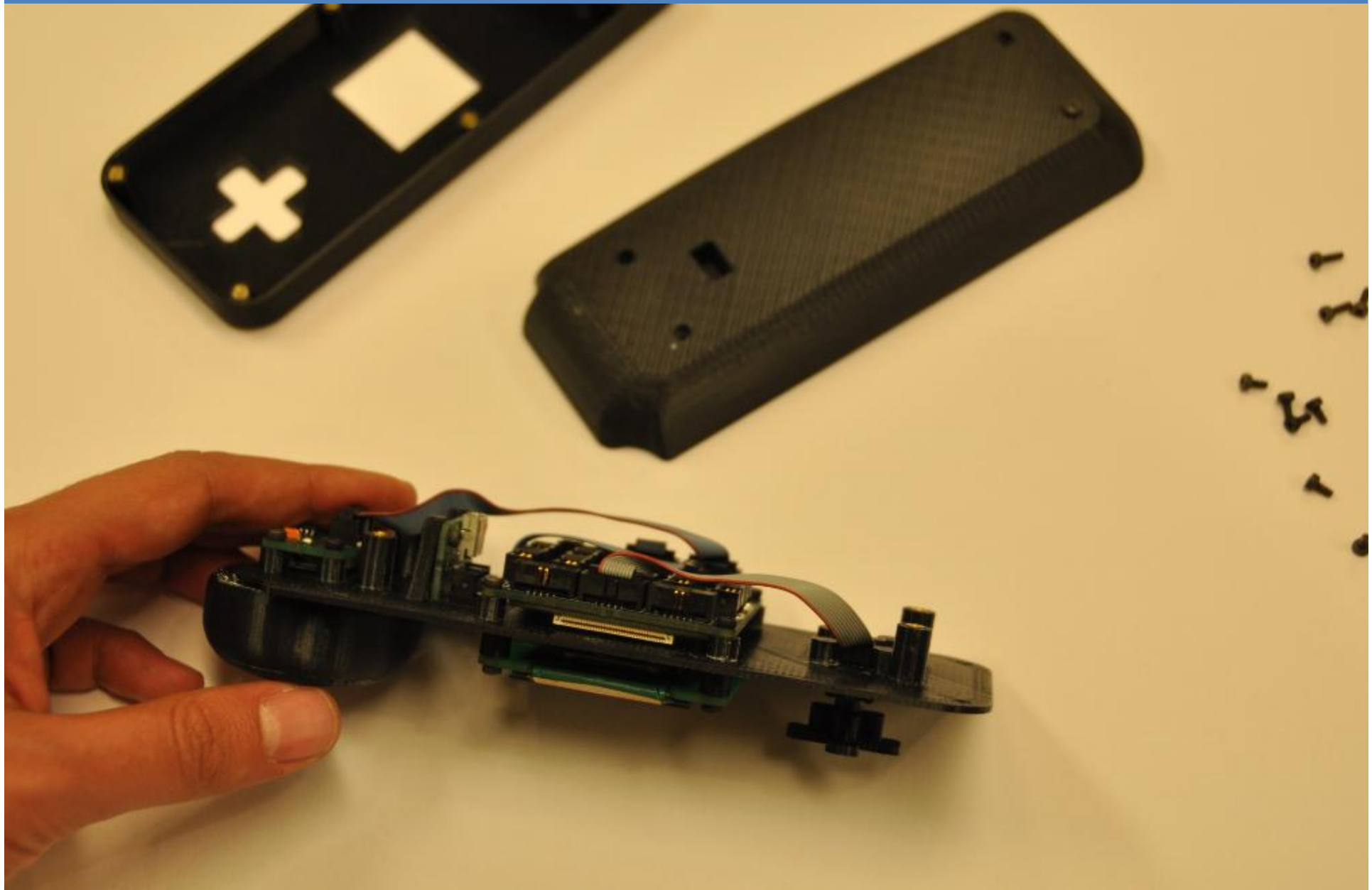
Enclosure design (3 hours)



3D printing (6 hours)



Assembly (20 minutes)



The .NET Gadgeteer Platform

Modular Hardware

Software Tools

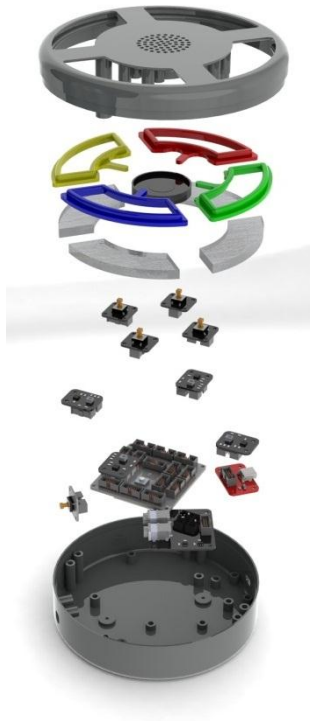
```
void ProgramStarted()
{
    // Initialize GTM.Modules an
    myButton = new GTM.Button(GT
    myLed = new GTM.MulticolorLE

    myButton.

    // Do one
    Debug.Pri
}
```

- ButtonPressed
- ButtonReleased
- DebugPrintEnabled
- Equals
- GetHashCode
- GetType
- IsPressed
- ToString

Physical Design



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ButtonPressed
ButtonReleased
DebugPrintEnabled
Equals
GetHashCode
GetType
IsPressed
ToString

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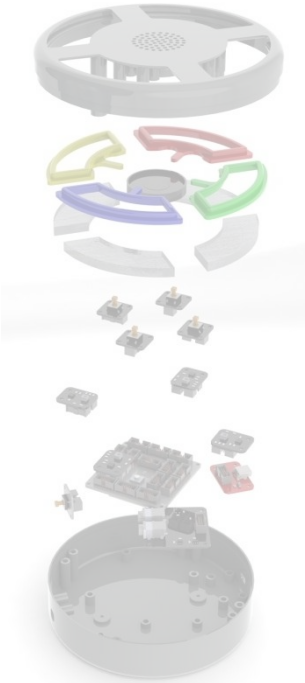
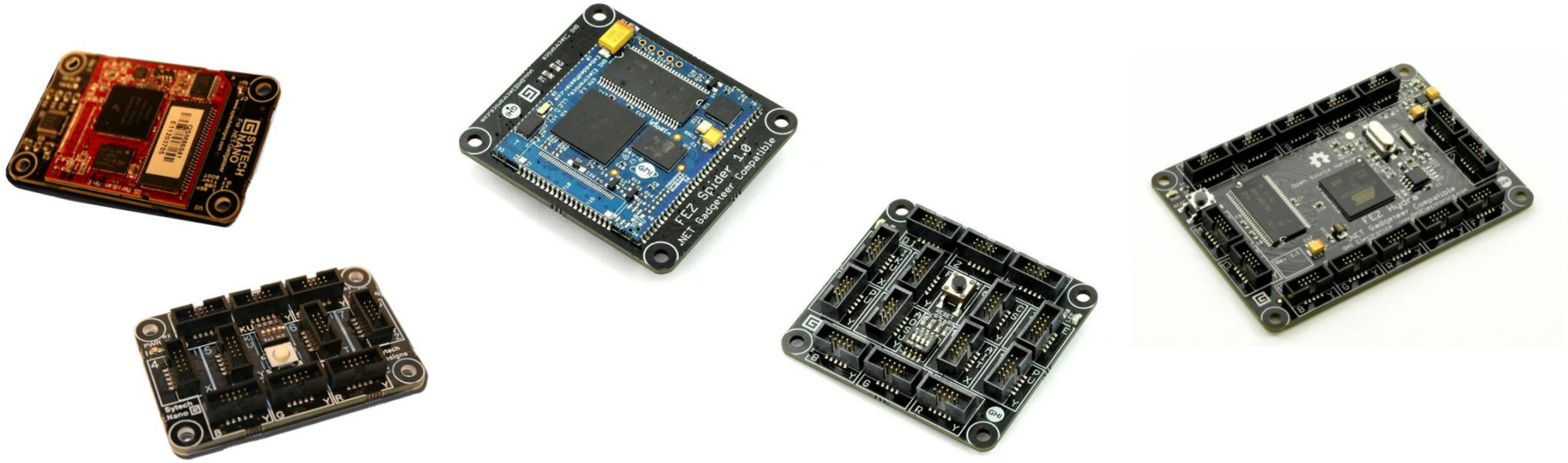


Modular hardware: mainboards

At the heart of every Gadgeteer project is a **mainboard**.

A mainboard is made up of a programmable processor (ARM7 / ARM9 / Cortex M4), memory, and a number of sockets that Gadgeteer **modules** can plug into.



Modules: sensors

Seeed Studio Compass

Seeed Accelerometer

Seeed Studio Soil Moisture Sensor

Seeed GPS

Seeed Temperature and Humidity Sensor

Seeed Studio Gyroscope

Seeed Studio Barometer

Sytech 3-Axis Accelerometer

Seeed Pulse Oxymeter

GHI PIR Sensor

Seeed Current Sensor

GHI Light Sensor

Modules: communication

GHI RS232

Seeed Cellular Radio

GHI Serial-USB

Sytech Ethernet and SD

GHI CAN (Dual-Wire)

GHI XBee Adapter

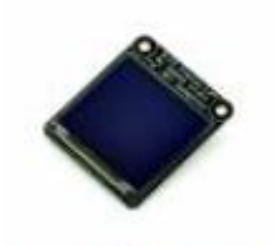
GHI Bluetooth

GHI Ethernet J11D

GHI Ethernet ERC28

GHI WiFi RS21

Modules: display and user input



Seeed OLED Display

GHI Display T35

GHI LED7R

GHI Video Out

GHI Multicolor LED (DaisyLink)

Sytech LCD Touch Panel 4.3

GHI Camera

Sytech Serial Camera

GHI Potentiometer

GHI Button

Sytech Button LED

GHI Joystick

Modules: power and actuation

Sytech USB Device

GHI USB Client SP

GHI USB Client DP (Dual-Power)

SolderMonkey LittleStep

Seeed Relays

GHI Motor Driver L298

Modules: storage and audio

GHI Micro SD Card

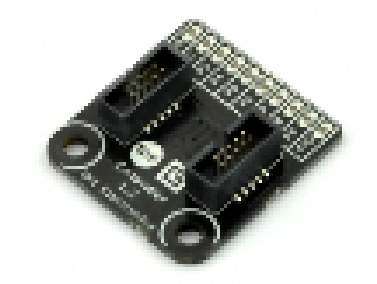
GHI USB Host

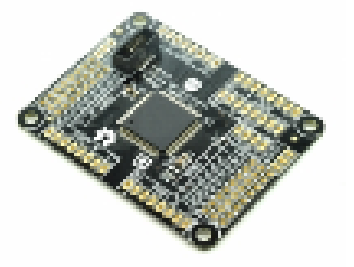
GHI SD Card

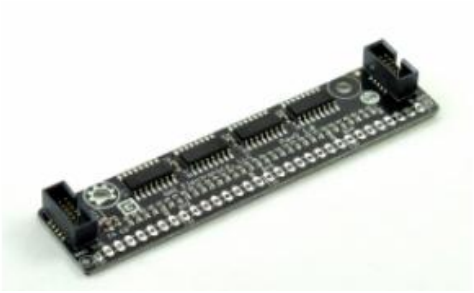
Sytech Ethernet and SD

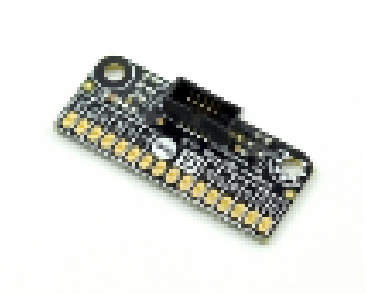
GHI Music

Modules: extensibility

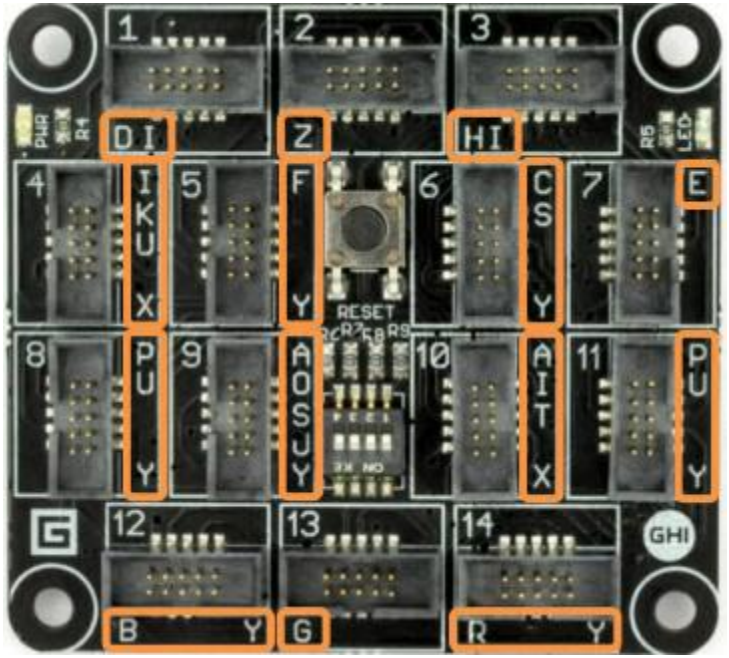








Sockets have types, which specify their electronic interface capabilities

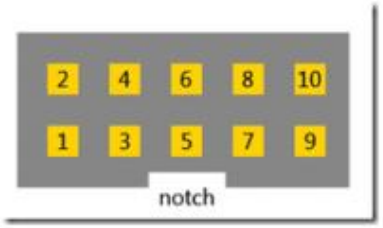


Socket Type A

Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9	Pin 10
+3.3V	+5V	AIN (G!)	AIN (G)	AIN	GPIO	[UN]	[UN]	[UN]	GND

Pinout specified by the socket type A definition.

AIN	Analog input pin.
GPIO	A general-purpose digital input/output pin, operating at 3.3 Volts.
(G)	In addition to another functionality, a pin that is also usable as a GPIO.
[UN]	Modules must not connect to this pin if using this socket type. Mainboards can support multiple socket types on one socket, as long as individual pin functionalities overlap in a compatible manner, so that a pin from one socket type can overlap with a [UN] pin of another.
!	Interrupt-capable and software pull-up capable GPIO (the pull-up is switchable and in the range of 10,000 to 100,000 ohms).
+3.3V	Connection to the +3.3V power net.
+5V	Connection to the +5V power net.
GND	Connection the power ground net.



Socket types definition table

TYPE	LETTER	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8	PIN 9	PIN 10
3 GPIO	X	+3.3V	+5V	GPIO!	GPIO	GPIO	[UN]	[UN]	[UN]	[UN]	GND
7 GPIO	Y	+3.3V	+5V	GPIO!	GPIO	GPIO	GPIO	GPIO	GPIO	GPIO	GND
Analog In	A	+3.3V	+5V	AIN (G!)	AIN (G)	AIN	GPIO	[UN]	[UN]	[UN]	GND
CAN	C	+3.3V	+5V	GPIO!	TD (G)	RD (G)	GPIO	[UN]	[UN]	[UN]	GND
USB Device	D	+3.3V	+5V	GPIO!	D-	D+	GPIO	GPIO	[UN]	[UN]	GND
Ethernet	E	+3.3V	+5V	[UN]	LED1 (OPT)	LED2 (OPT)	TX D-	TX D+	RX D-	RX D+	GND
SD Card	F	+3.3V	+5V	GPIO!	DAT0	DAT1	CMD	DAT2	DAT3	CLK	GND
USB Host	H	+3.3V	+5V	GPIO!	D-	D+	[UN]	[UN]	[UN]	[UN]	GND
I2C	I	+3.3V	+5V	GPIO!	[UN]	[UN]	GPIO	[UN]	SDA	SCL	GND
UART+Handshaking	K	+3.3V	+5V	GPIO!	TX (G)	RX (G)	RTS	CTS	[UN]	[UN]	GND
Analog Out	O	+3.3V	+5V	GPIO!	GPIO	AOUT	[UN]	[UN]	[UN]	[UN]	GND
PWM	P	+3.3V	+5V	GPIO!	[UN]	[UN]	GPIO	PWM (G)	PWM (G)	PWM	GND
SPI	S	+3.3V	+5V	GPIO!	GPIO	GPIO	CS	MOSI	MISO	SCK	GND
Touch	T	+3.3V	+5V	[UN]	YU	XL	YD	XR	[UN]	[UN]	GND
UART	U	+3.3V	+5V	GPIO!	TX (G)	RX (G)	GPIO	[UN]	[UN]	[UN]	GND
LCD 1	R	+3.3V	+5V	LCD R0	LCD R1	LCD R2	LCD R3	LCD R4	LCD VSYNC	LCD HSYNC	GND
LCD 2	G	+3.3V	+5V	LCD G0	LCD G1	LCD G2	LCD G3	LCD G4	LCD G5	BACKLIGHT	GND
LCD 3	B	+3.3V	+5V	LCD B0	LCD B1	LCD B2	LCD B3	LCD B4	LCD EN	LCD CLK	GND
Manufacturer Specific	Z	+3.3V	+5V	[MS]	[MS]	[MS]	[MS]	[MS]	[MS]	[MS]	GND
DaisyLink Downstream*	*	+3.3V	+5V	GPIO!	GPIO	GPIO	[MS]	[MS]	[MS]	[MS]	GND

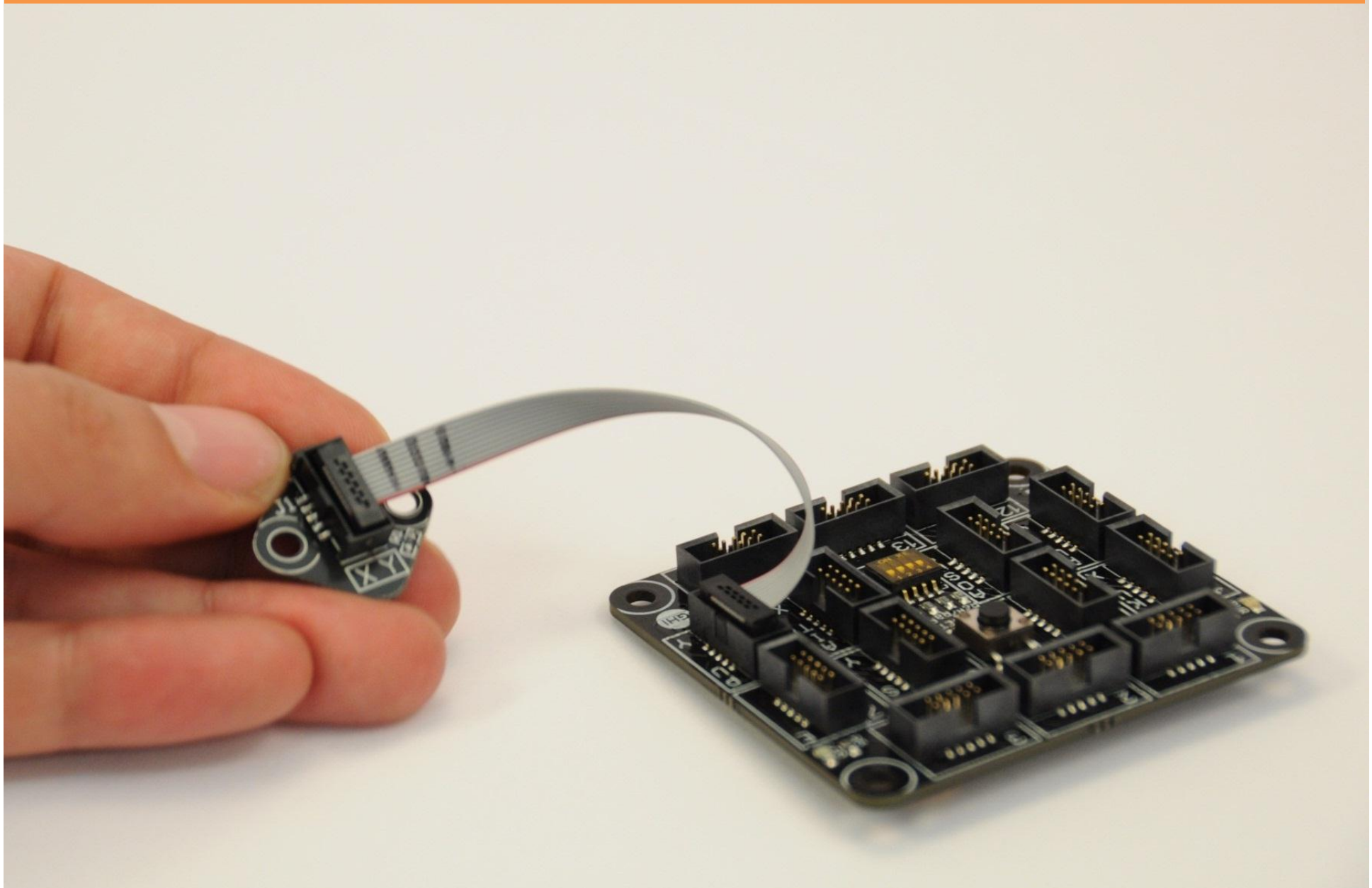
GPIO A general-purpose digital input/output pin, operating at 3.3 Volts.

[UN] Modules must not connect to this pin if using this socket type. Mainboards can support multiple socket types on one socket, as long as individual pin functionalities overlap in a compatible manner. A pin from one socket type can overlap with a [UN] pin of another.

! Interrupt-capable and software pull-up capable GPIO (the pull-up is switchable and in the range of 10,000 to 100,000 ohms).

***** Socket type * should not appear on a mainboard, only on DaisyLink modules. The [MS] pins on this socket type can optionally support reflashing the firmware on the module.

Connecting a module to a mainboard



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Software Tools

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void ProgramStarted()
{
    // Initialize GTM.Modules an
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```

- ButtonPressed
- ButtonReleased
- DebugPrintEnabled
- Equals
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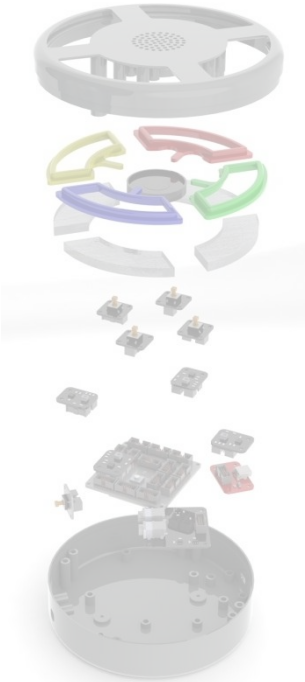
Physical Design



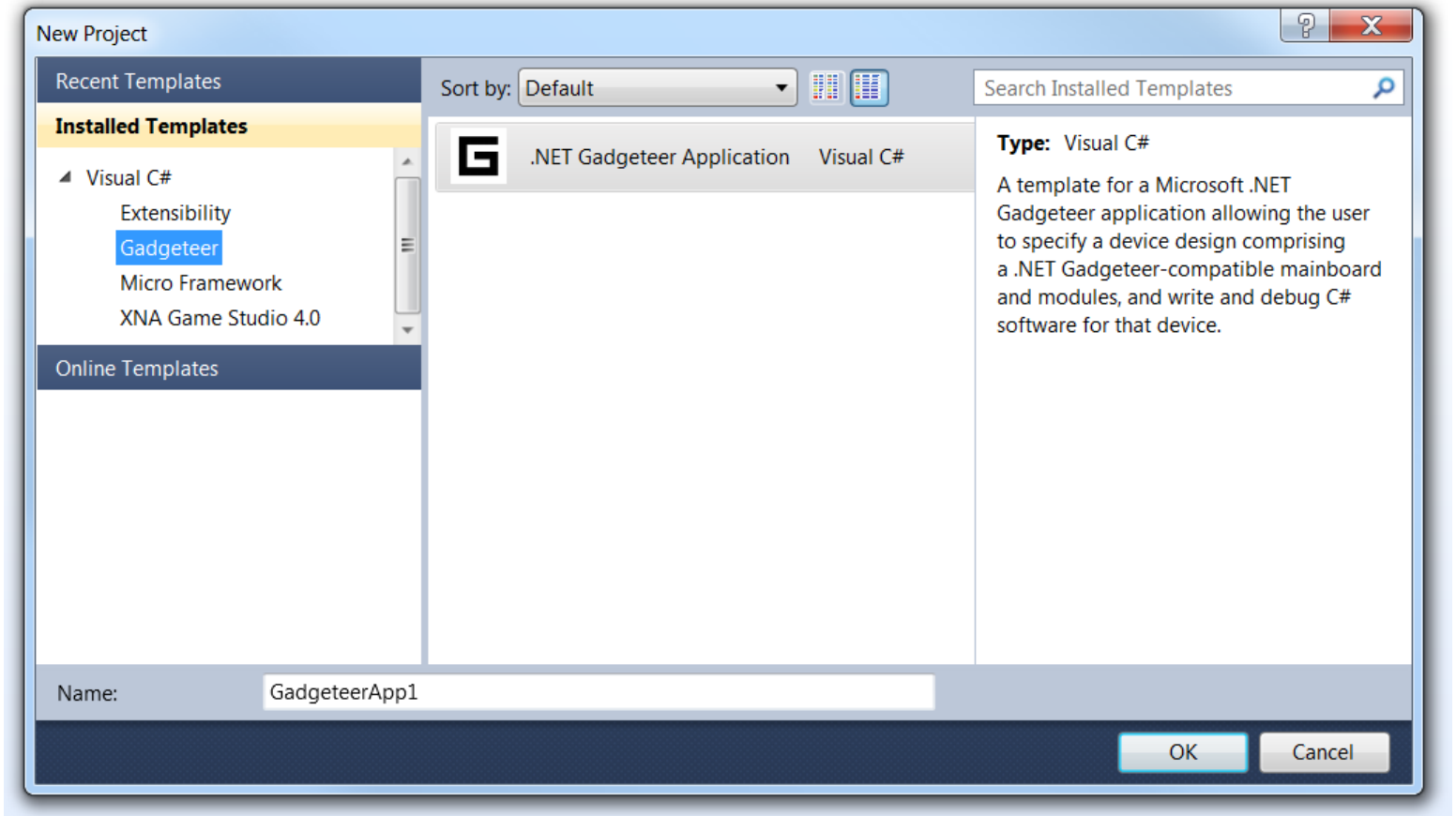
Software tools

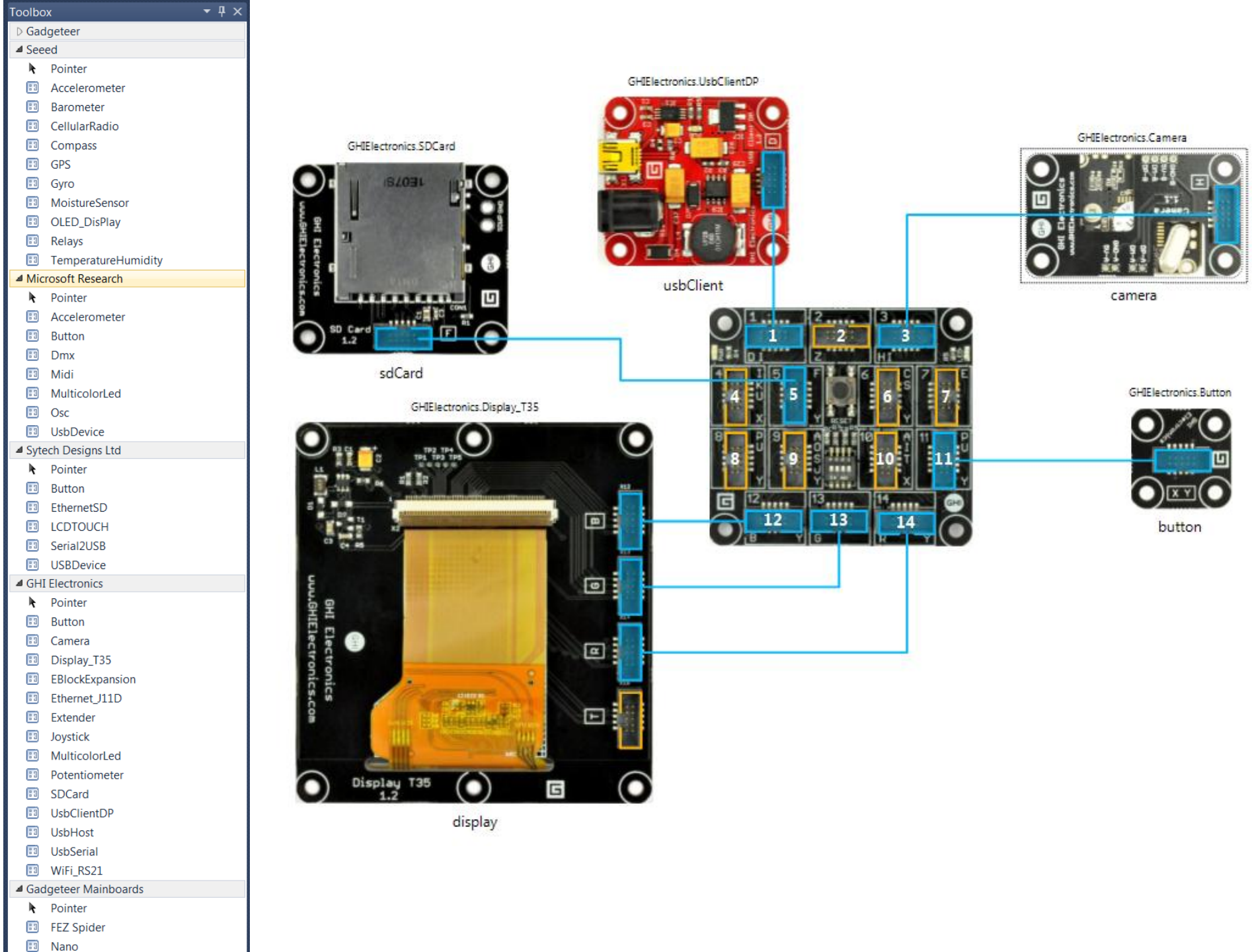
Based on the .NET **Micro** Framework:

- Subset of .NET
- Programming in C# and Visual Basic
- Interactive debugging

.NET Gadgeteer adds:

- Gadgeteer Core Libraries
- Visual Studio Graphical Designer
- Framework for mainboard and module drivers


New Project
Recent Templates
Installed Templates
Visual C#
Extensibility
Gadgeteer
Micro Framework
XNA Game Studio 4.0
Online Templates
Sort by:
Default
Search Installed Templates
.NET Gadgeteer Application
Visual C#
Type: Visual C#
A template for a Microsoft .NET Gadgeteer application allowing the user to specify a device design comprising a .NET Gadgeteer-compatible mainboard and modules, and write and debug C# software for that device.
Name:
GadgeteerApp1
OK
Cancel


Toolbox
Gadgeteer
Seeed
Pointer
Accelerometer
Barometer
CellularRadio
Compass
GPS
Gyro
MoistureSensor
OLED_DisPlay
Relays
TemperatureHumidity
Microsoft Research
Pointer
Accelerometer
Button
Dmx
Midi
MulticolorLed
Osc
UsbDevice
Sytech Designs Ltd
Pointer
Button
EthernetSD
LCDTOUCH
Serial2USB
USBDevice
GHI Electronics
Pointer
Button
Camera
Display_T35
EBlockExpansion
Ethernet_J11D
Extender
Joystick
MulticolorLed
Potentiometer
SDCard
UsbClientDP
UsbHost
UsbSerial
WiFi_RS21
Gadgeteer Mainboards
Pointer
FEZ Spider
Nano
GHIElectronics.UsbClientDP
usbClient
GHIElectronics.SDCard
sdCard
GHIElectronics.Camera
camera
GHIElectronics.Display_T35
display
GHIElectronics.Button
button

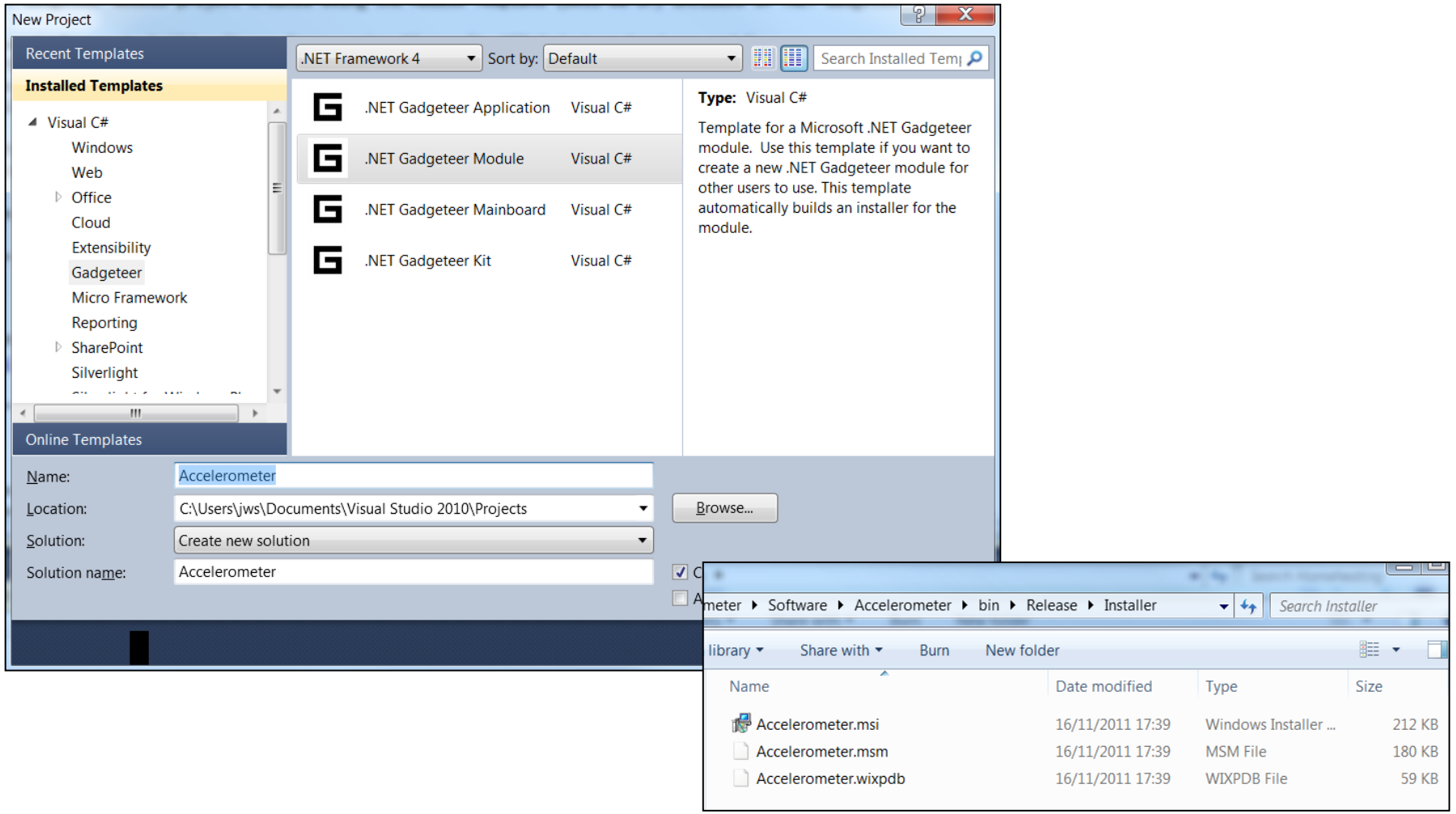
```
void ProgramStarted()
{
    // Associate events with event-handling methods
    button.ButtonPressed += new Button.ButtonEventHandler(button_ButtonPressed);
    camera.PictureCaptured += new Camera.PictureCapturedEventHandler(camera_PictureCaptured);
}

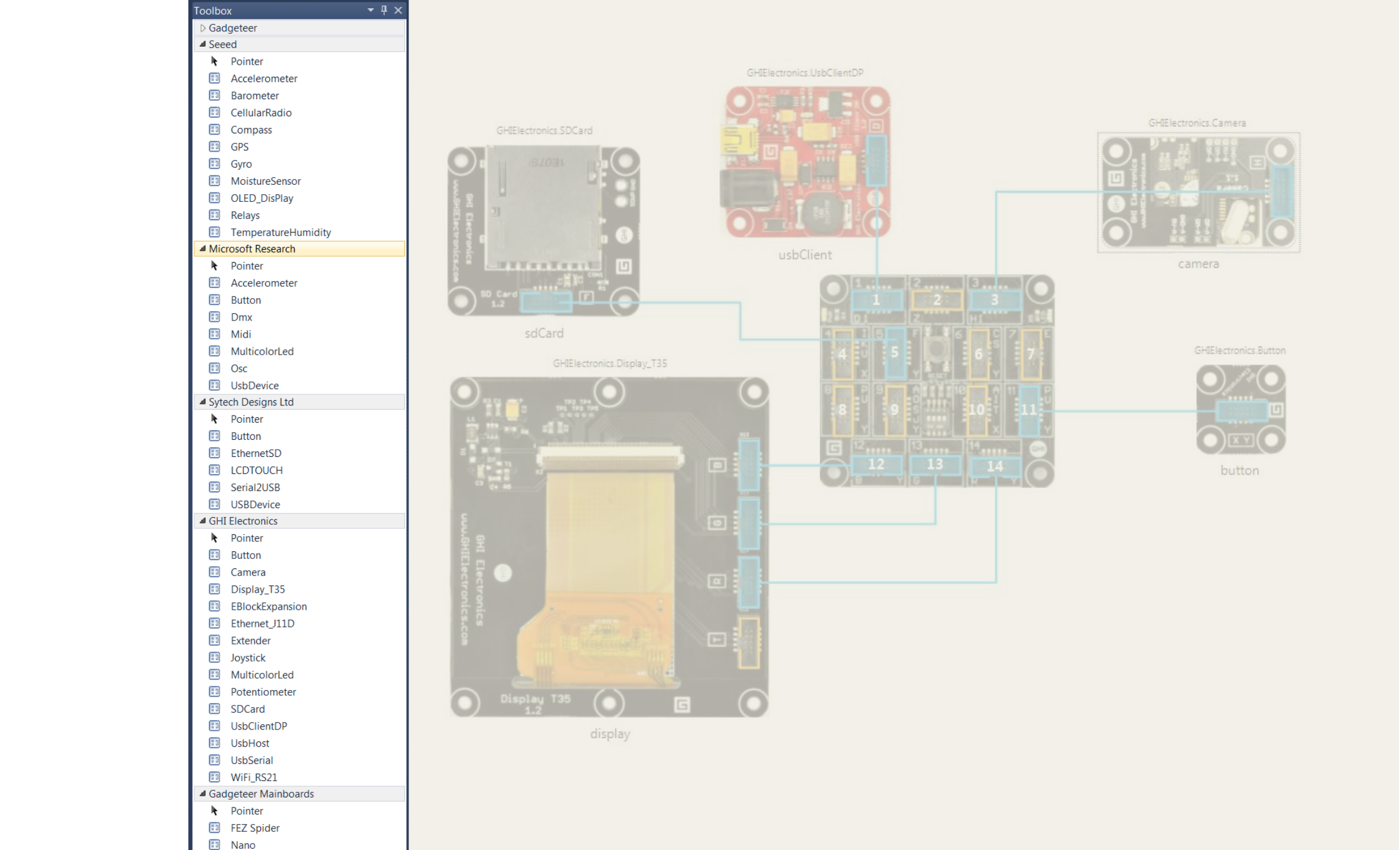
void button_ButtonPressed(Button sender, Button.ButtonState state)
{
    camera.TakePicture();
}

void camera_PictureCaptured(Camera sender, GT.Picture picture)
{
    // Show the picture on the display
    display.SimpleGraphics.DisplayImage(picture, 0, 0);

    // Save the picture to the SD card
    sdCard.GetStorageDevice().WriteFile("picture.bmp", picture.PictureData);
}
```

Hardware module driver wizard




Toolbox
Gadgeteer
Seeed
Pointer
Accelerometer
Barometer
CellularRadio
Compass
GPS
Gyro
MoistureSensor
OLED_DisPlay
Relays
TemperatureHumidity
Microsoft Research
Pointer
Accelerometer
Button
Dmx
Midi
MulticolorLed
Osc
UsbDevice
Sytech Designs Ltd
Pointer
Button
EthernetSD
LCDTOUCH
Serial2USB
USBDevice
GHI Electronics
Pointer
Button
Camera
Display_T35
EBlockExpansion
Ethernet_J11D
Extender
Joystick
MulticolorLed
Potentiometer
SDCard
UsbClientDP
UsbHost
UsbSerial
WiFi_RS21
Gadgeteer Mainboards
Pointer
FEZ Spider
Nano
GHIElectronics.SDCard
GHIElectronics.UsbClientDP
GHIElectronics.Camera
usbClient
camera
sdCard
GHIElectronics.Display_T35
GHIElectronics.Button
button
display

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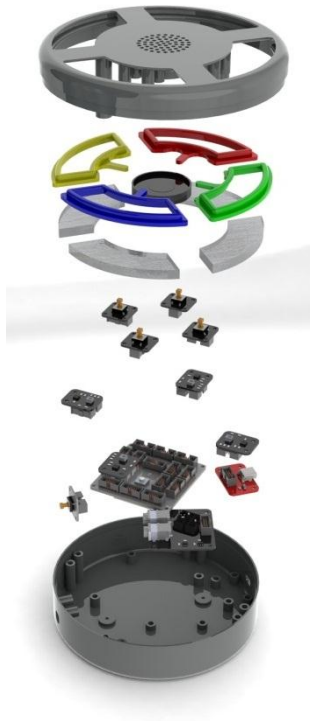
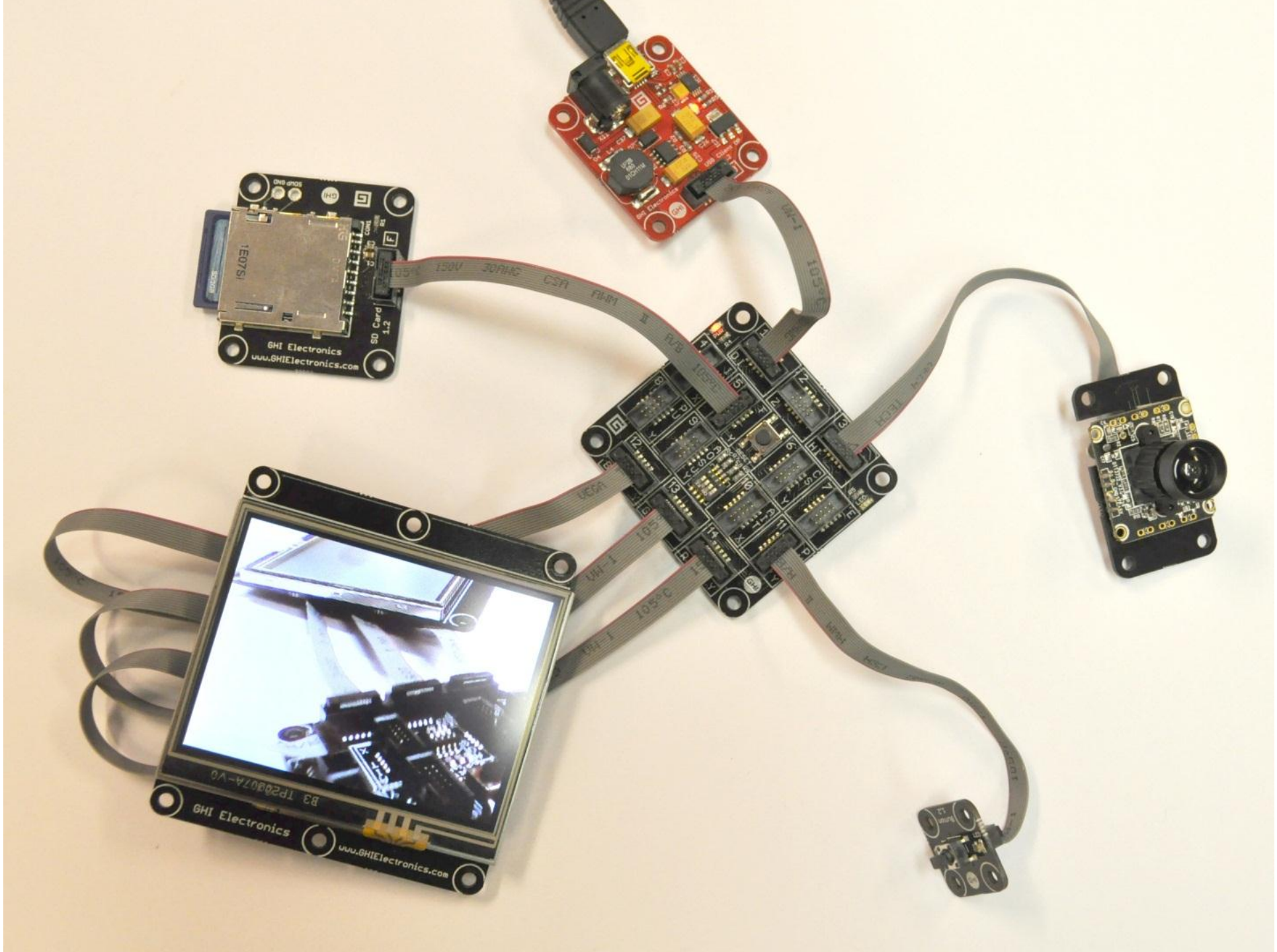
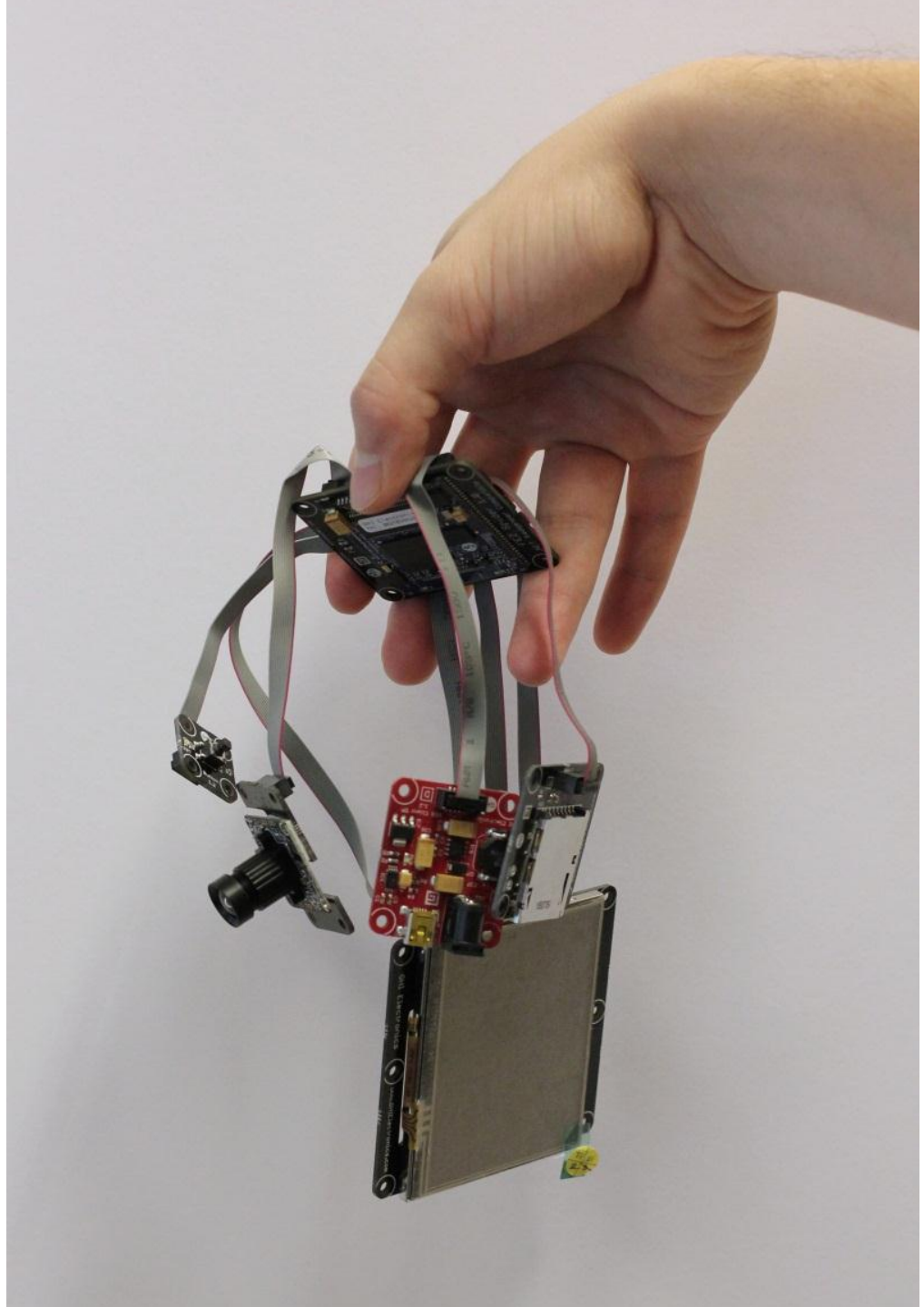
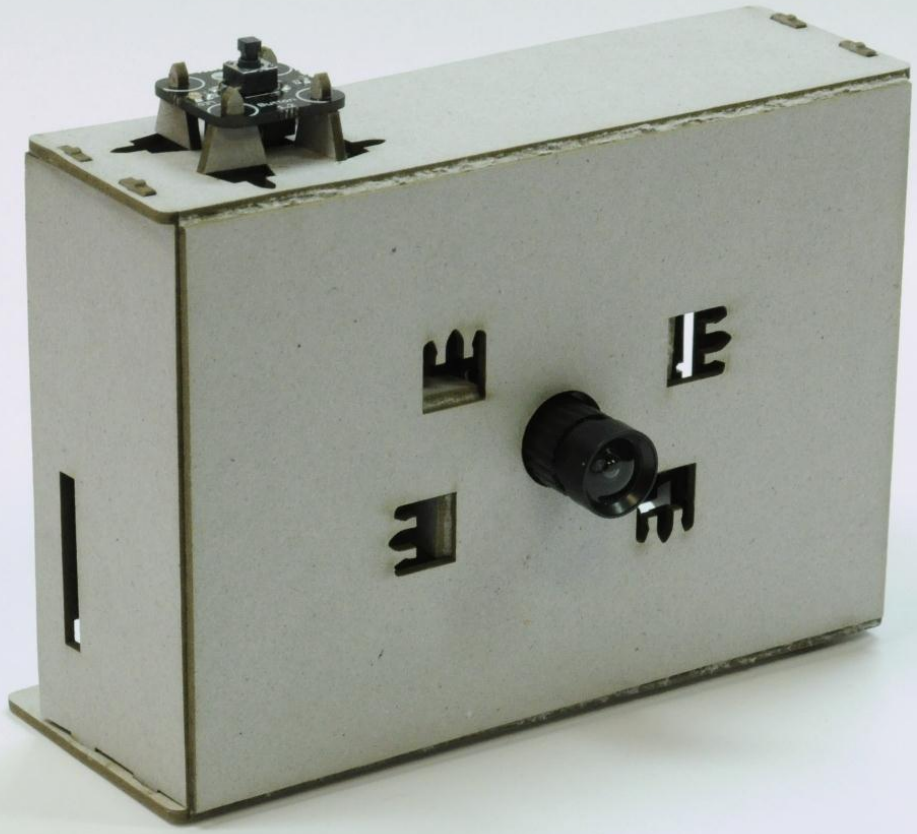



GHI Electronics
www.GHIElectronics.com
SD Card 1.2
GHI Electronics
www.GHIElectronics.com

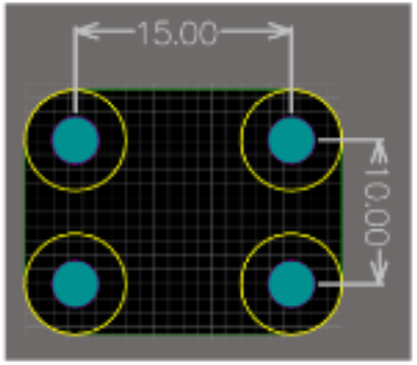




Hardware design guidelines

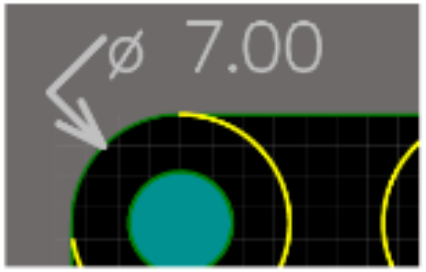
The keep-out area should be clearly delimited in the silkscreen on both sides of the PCB, as shown in the following illustration. For small modules, where space is tight, it is possible to interrupt the keep-out delimiter silkscreen to make space for other labeling or silkscreen elements. Under no circumstances should you place components inside the keep-out area.

All mounting holes should be placed on a 5-mm grid, that is, the distance between adjacent holes should be a multiple of 5 mm, as shown in the following illustration.



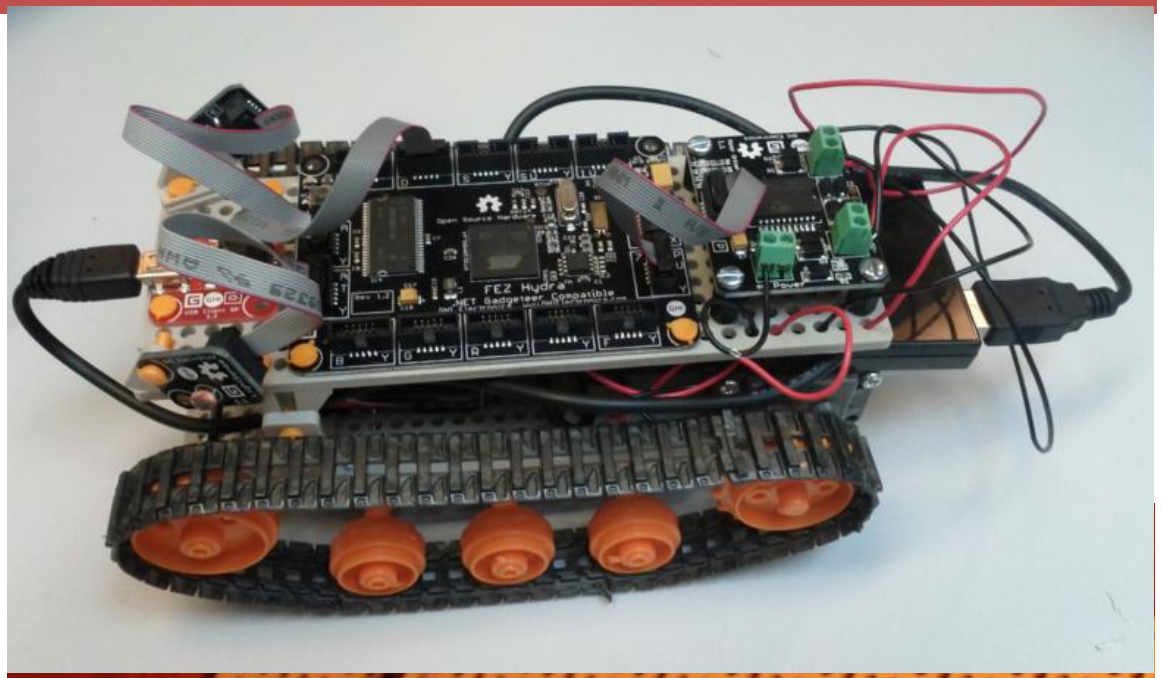
Corners

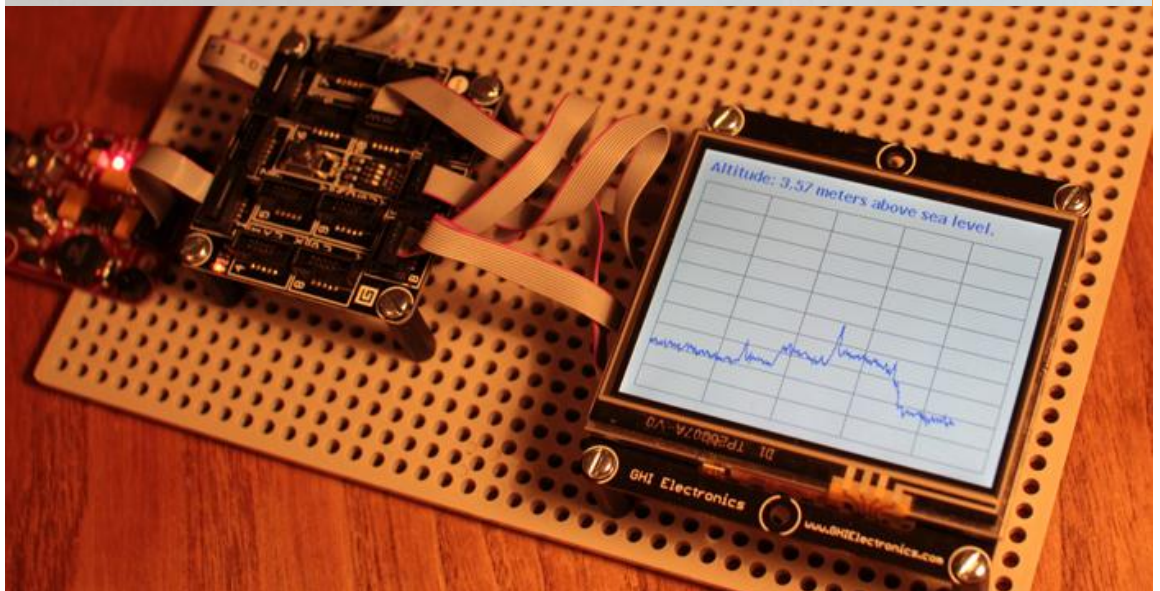
Corners should be rounded, with a 7-mm-diameter curve that is concentric with a mounting hole's keep out area, as shown in the following illustration.



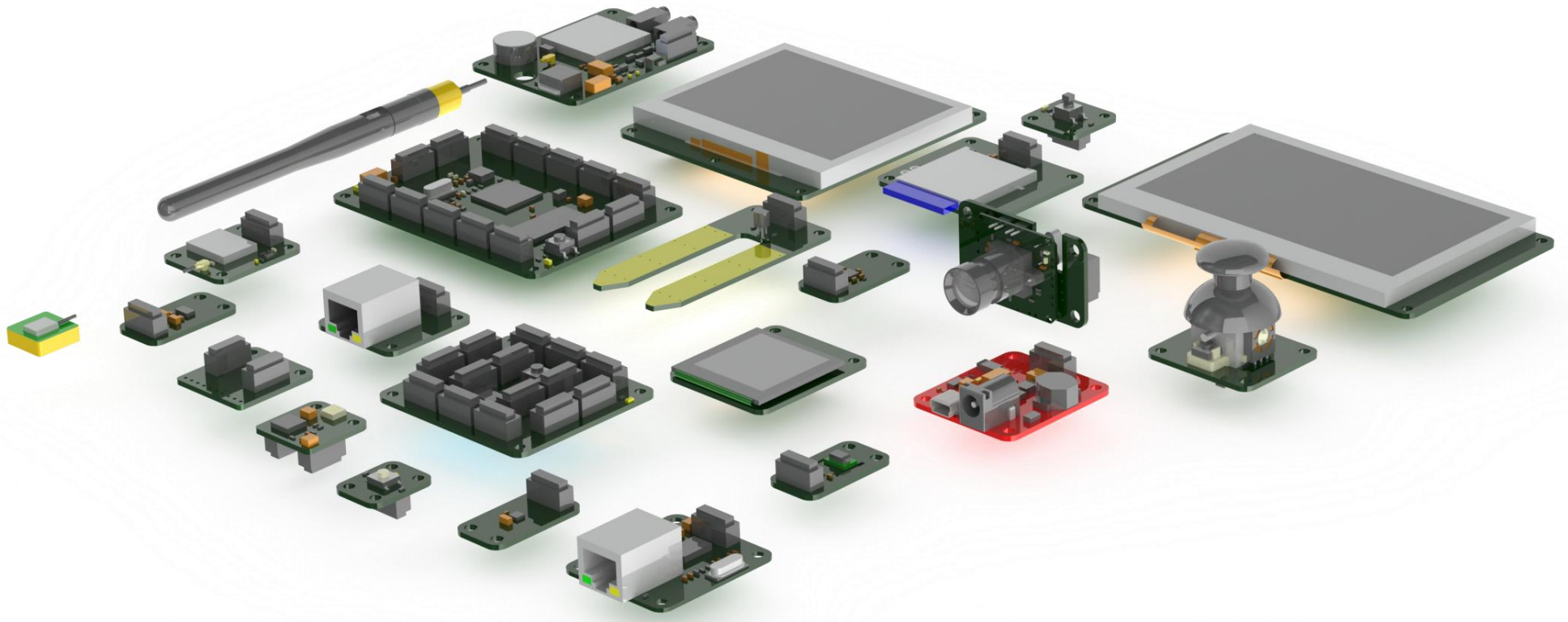
If a corner does not include a mounting hole, the corner does not need to be rounded. However, we recommend that you maintain the same 7-mm rounding diameter for consistency.

Standardized mounting holes

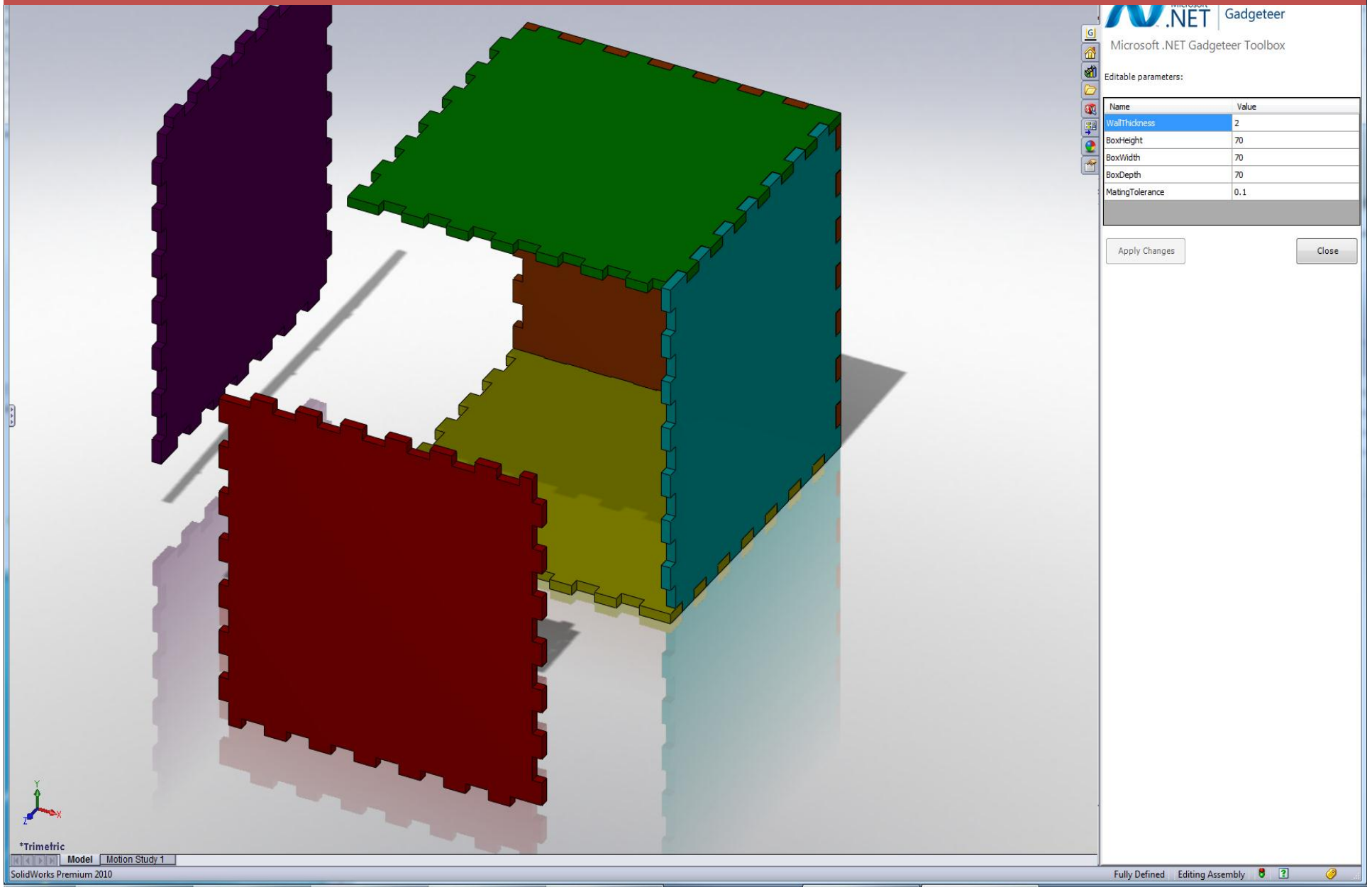




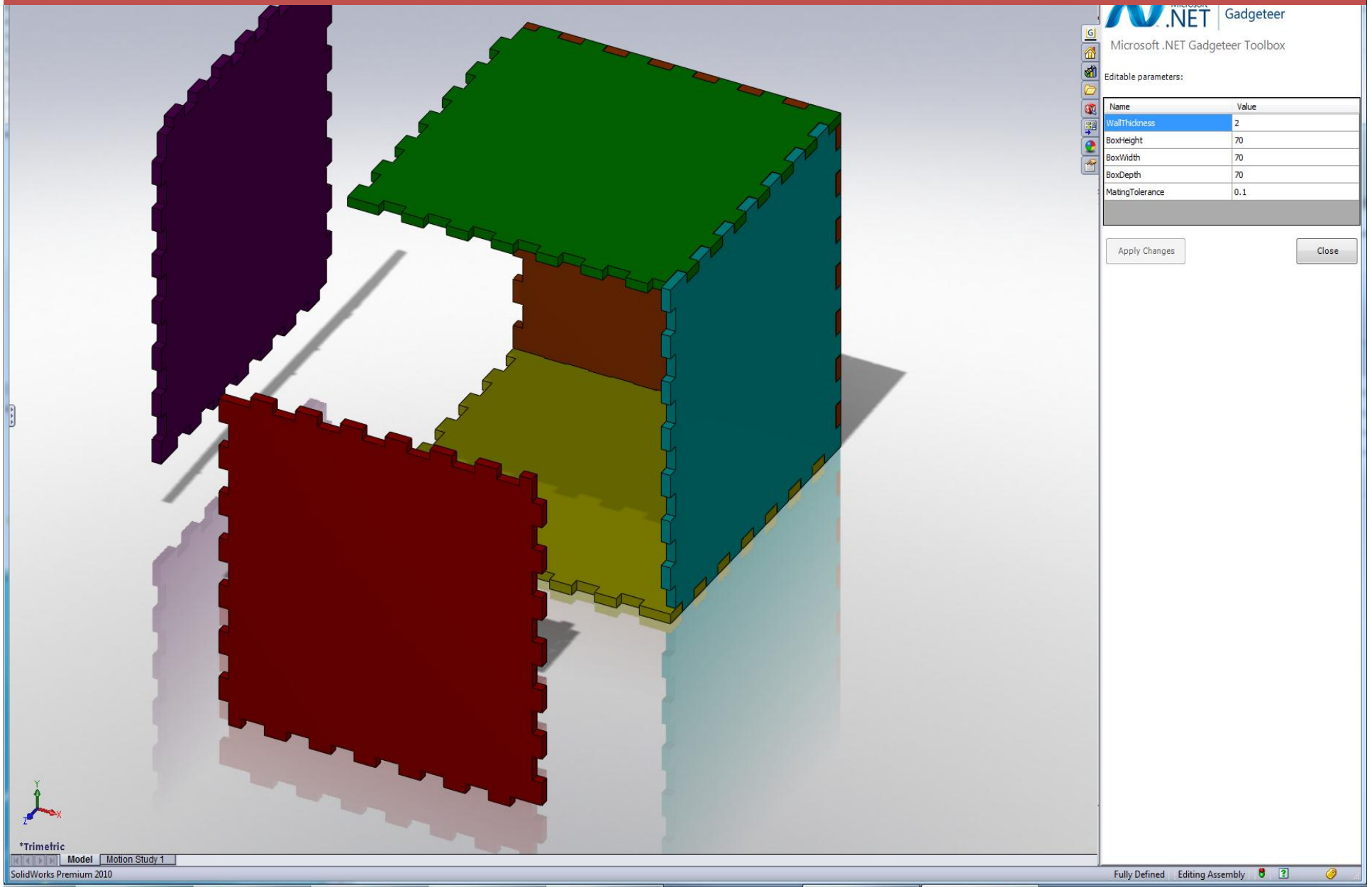
3D models of hardware modules



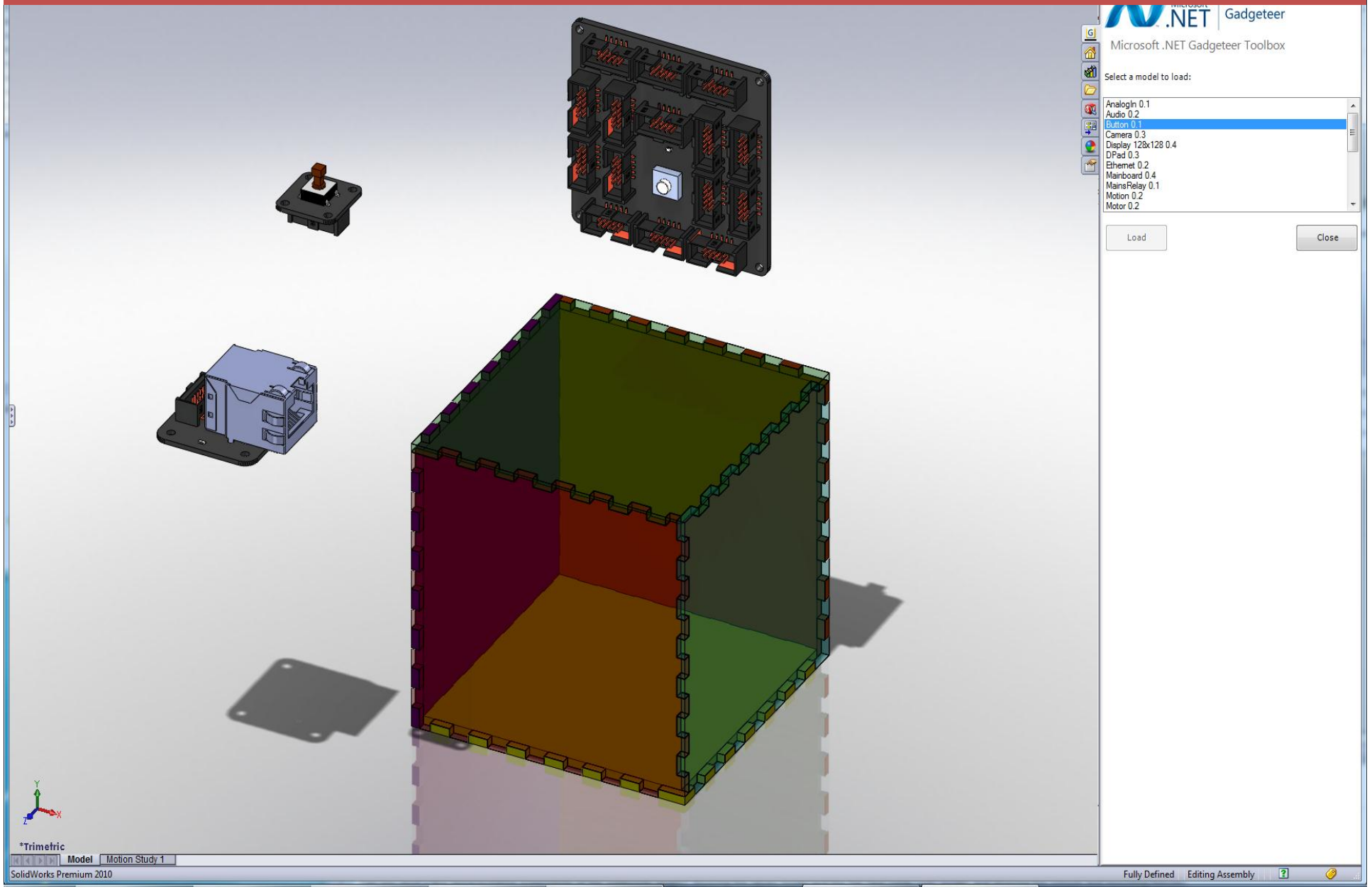
Integration with 3D CAD (SolidWorks)



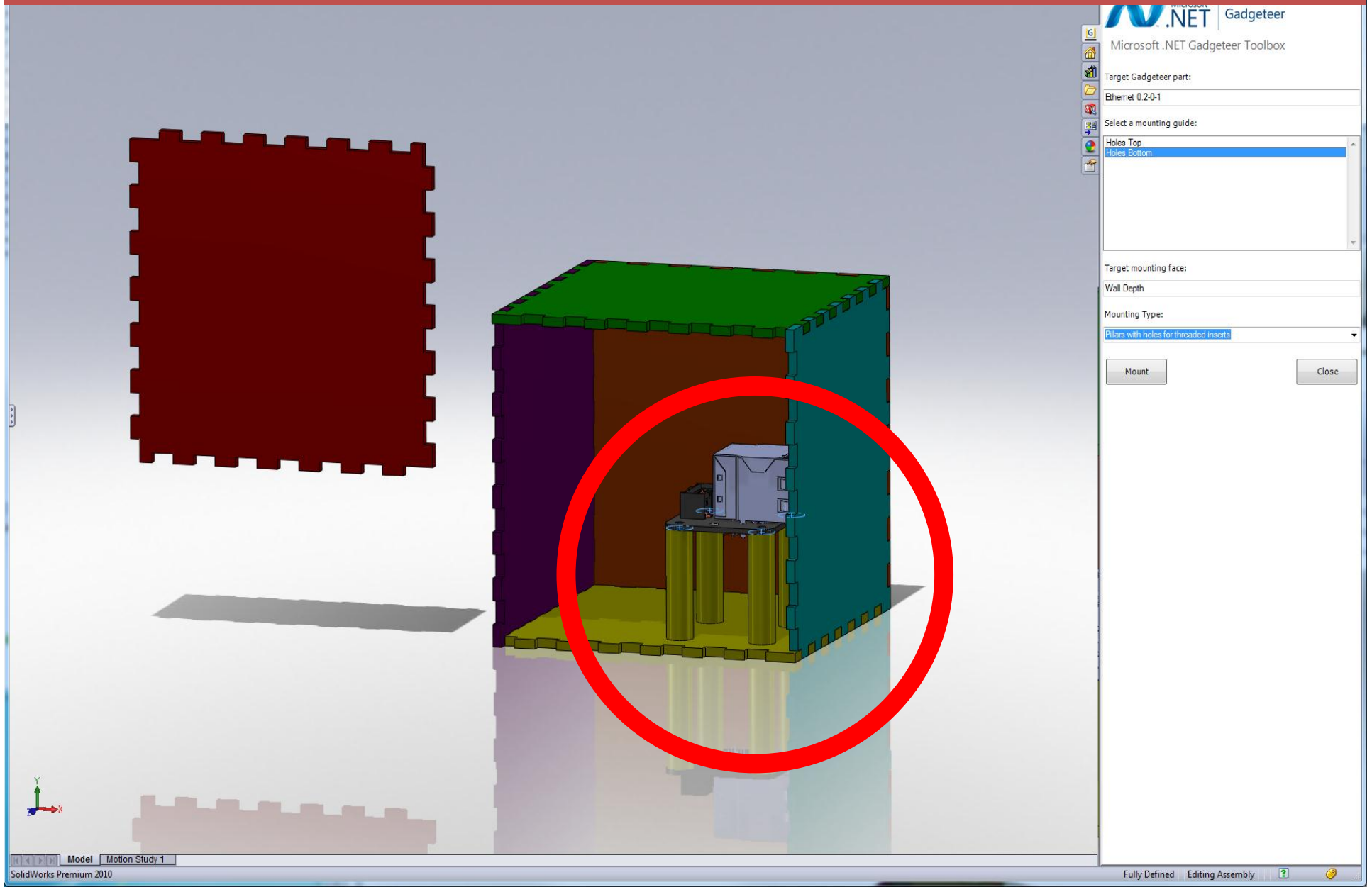
Parametric enclosure templates



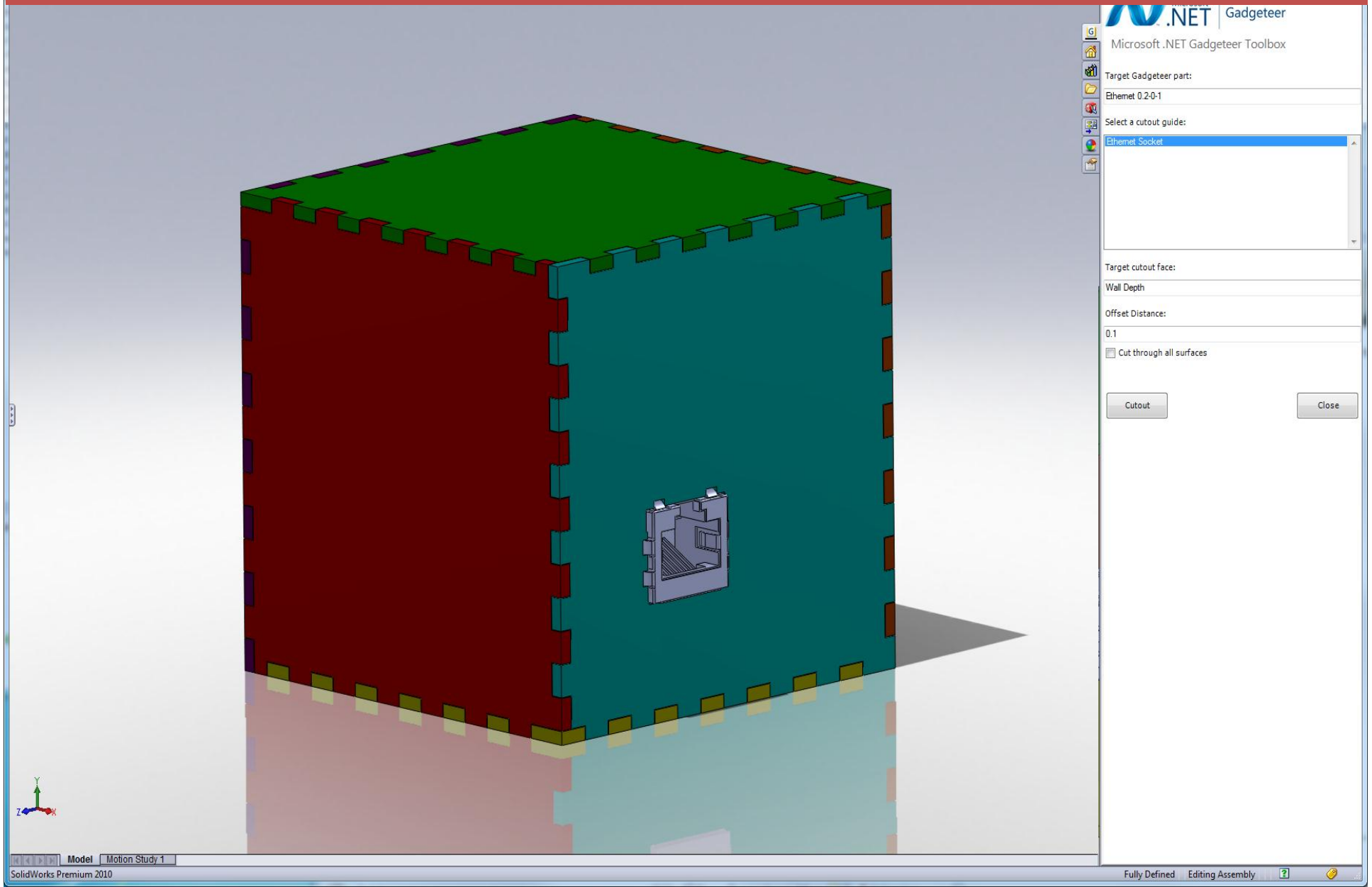
Adding and positioning 3D models



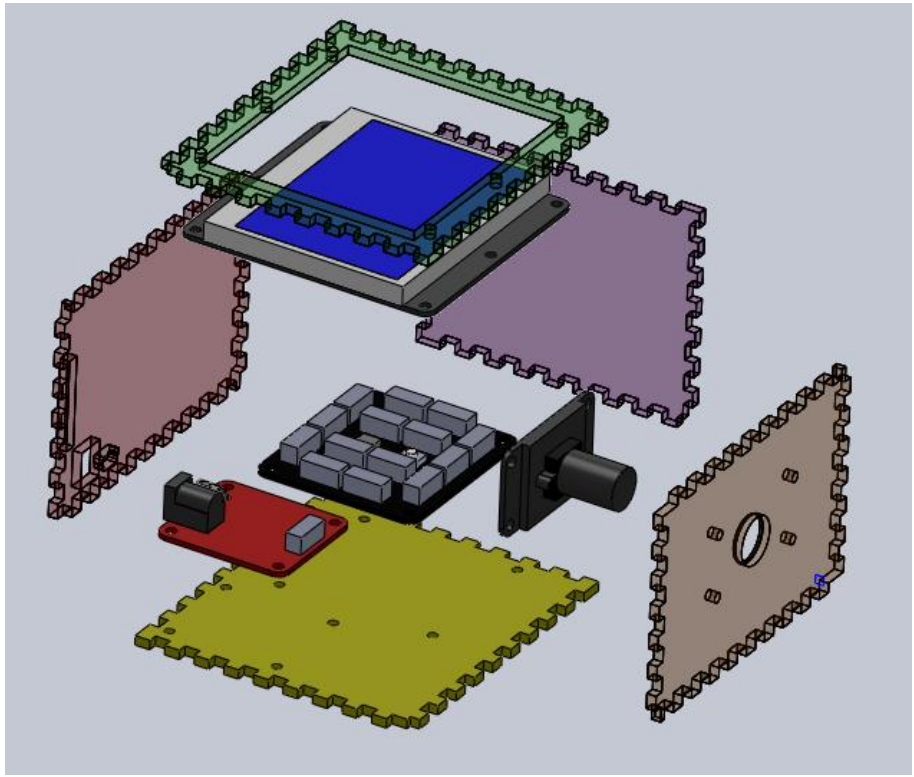
Automatic mounting feature generation

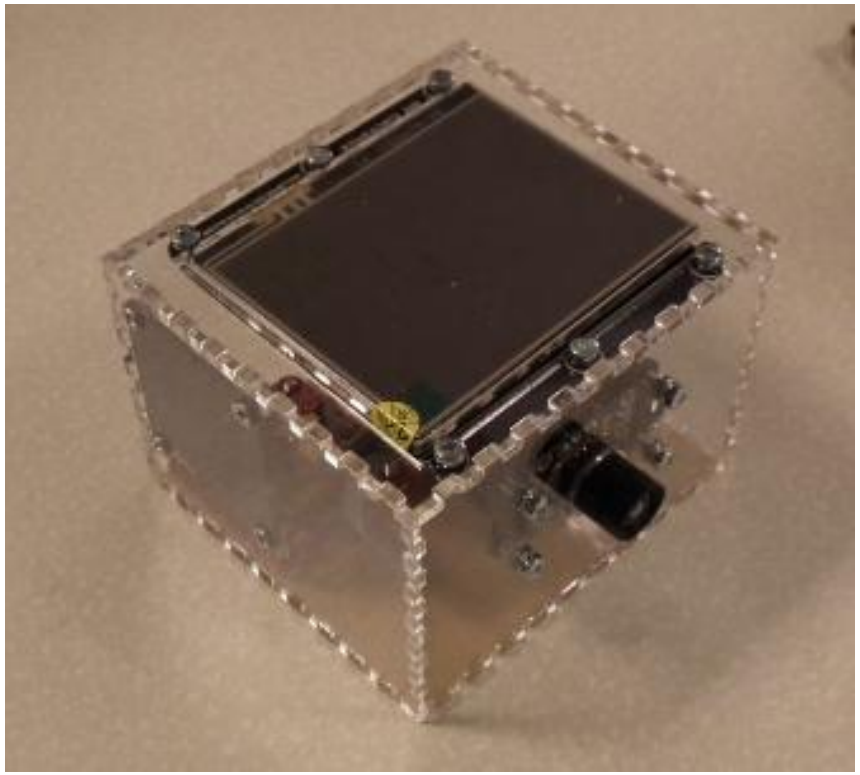


Automatic cut-out generation

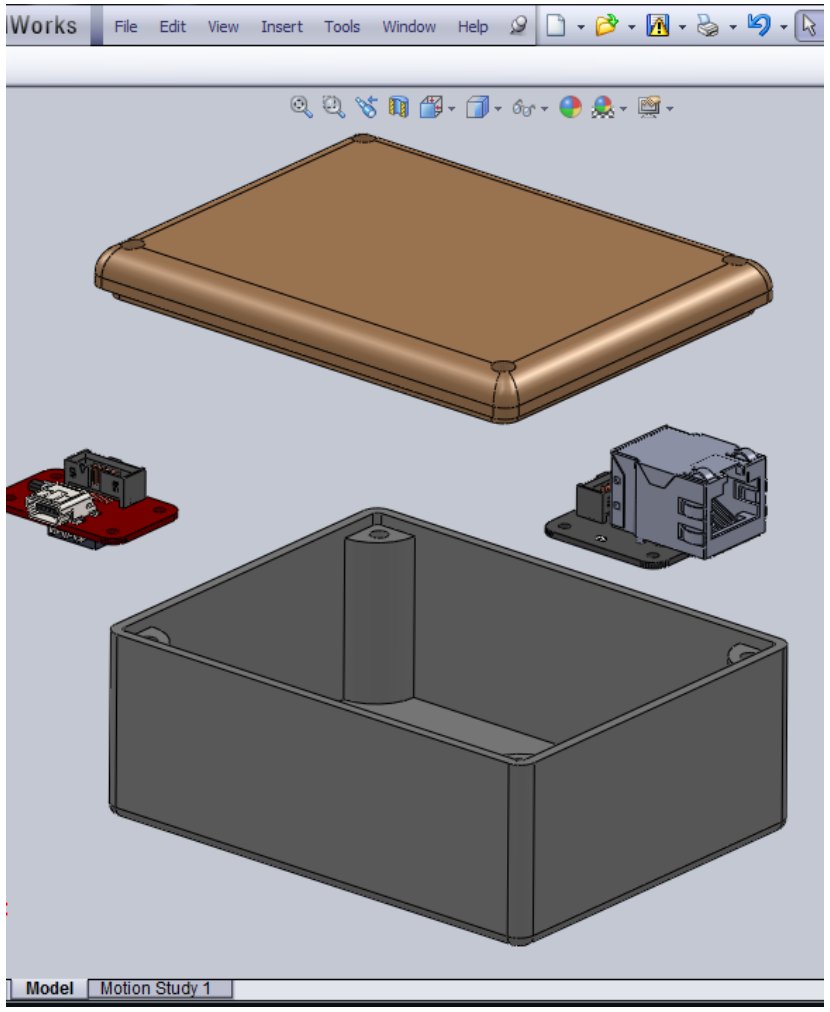


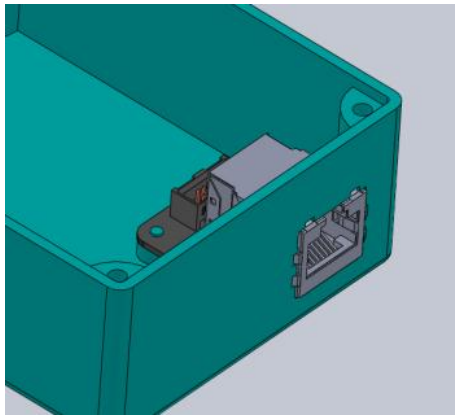
Laser-cut enclosure based on the *Jigsaw Box* template

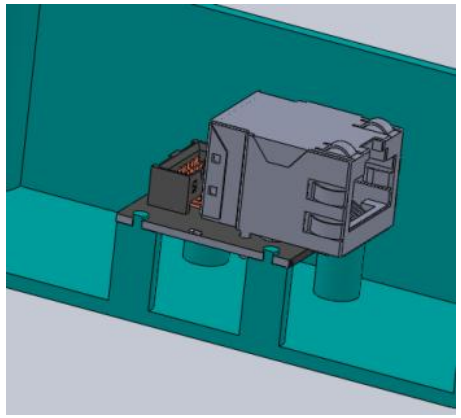


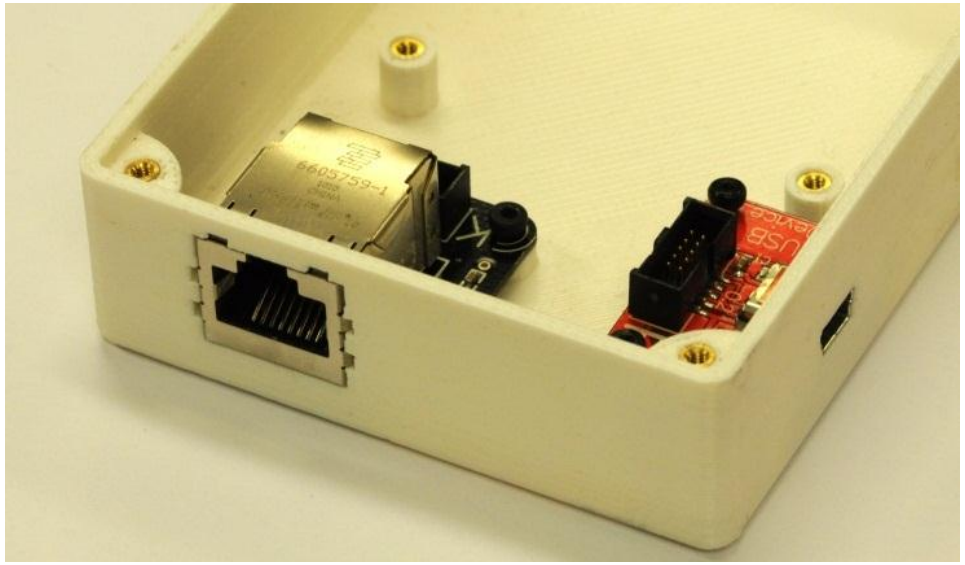


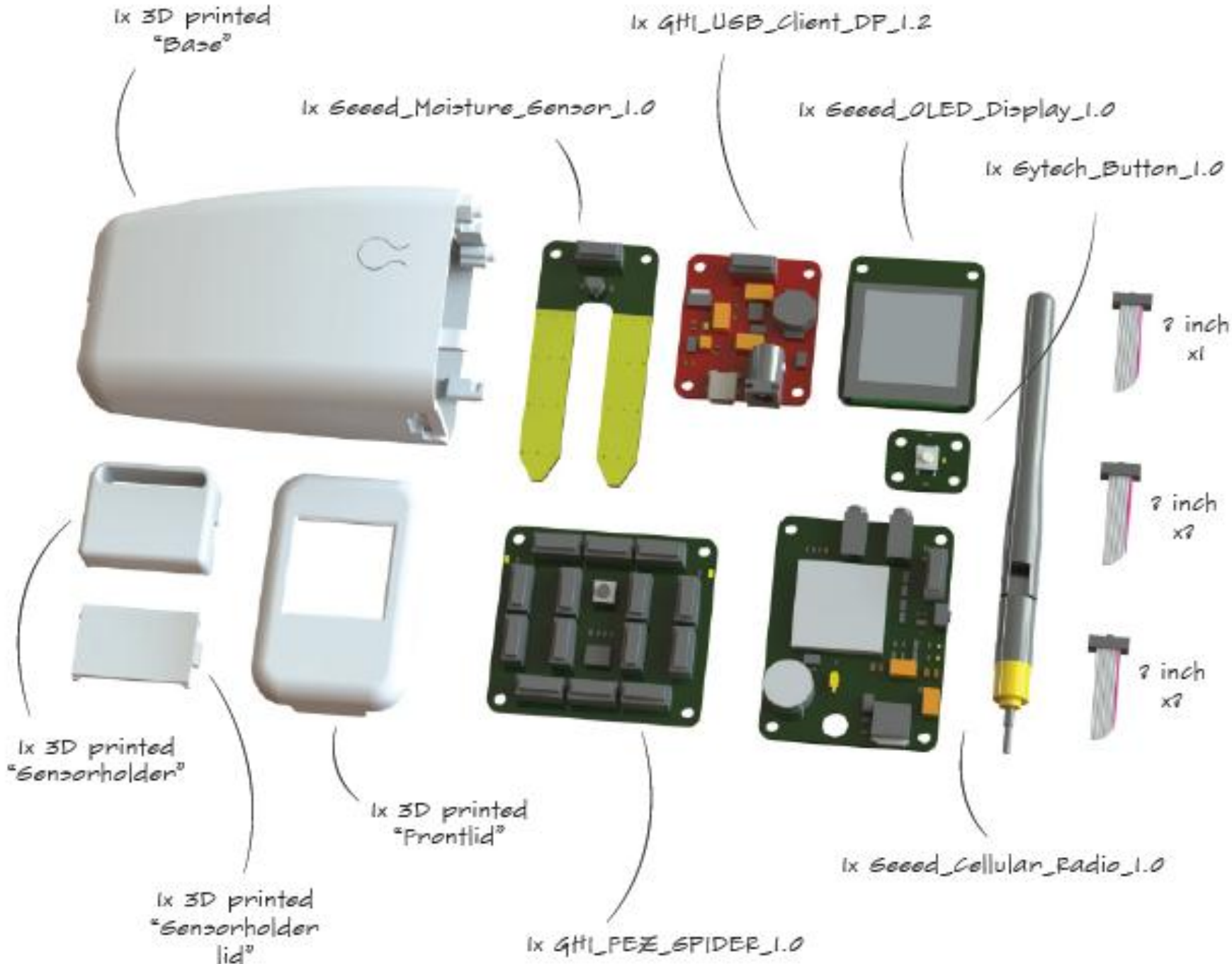
3D-printed enclosure based on the *Project Box* template

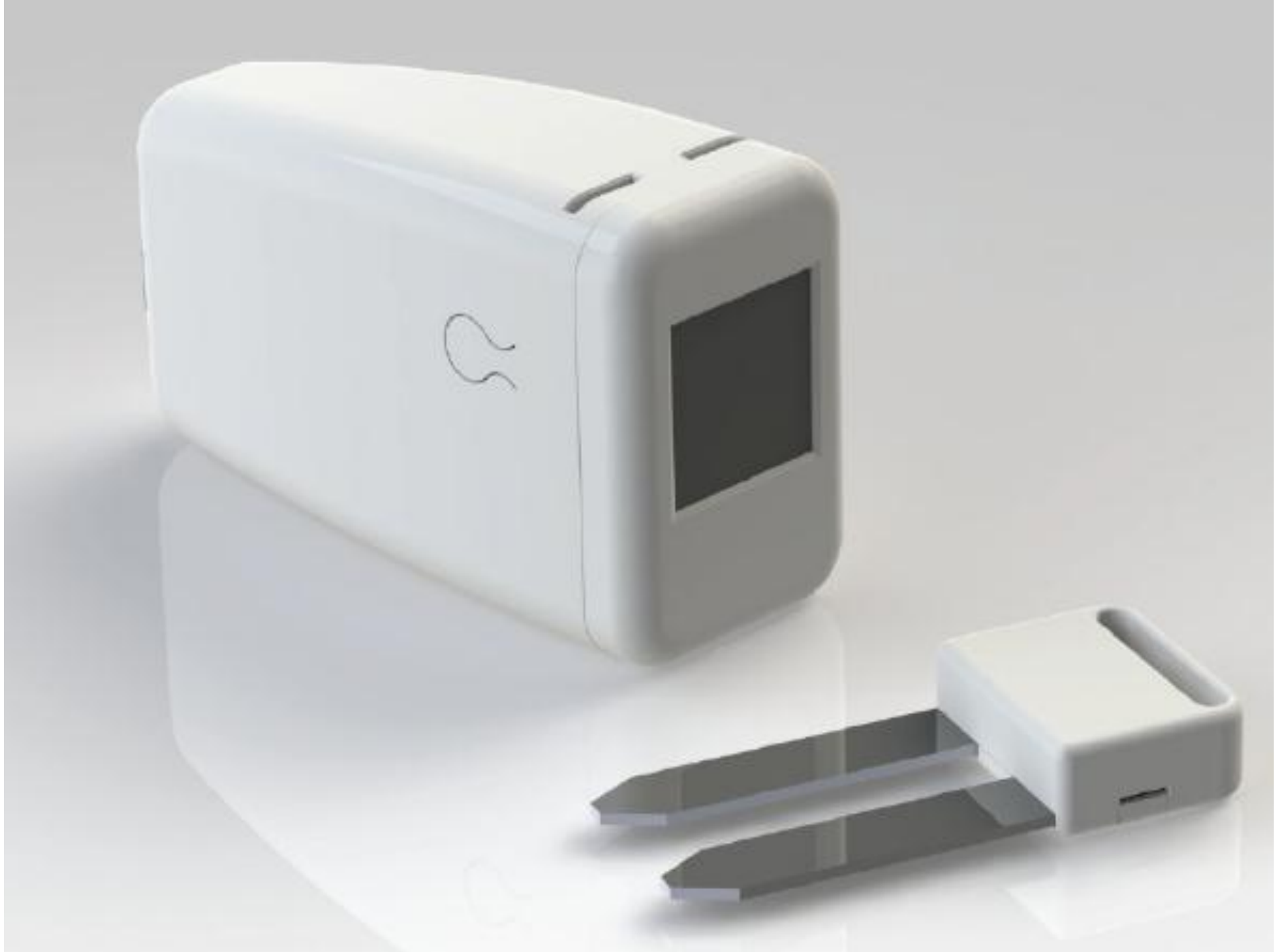




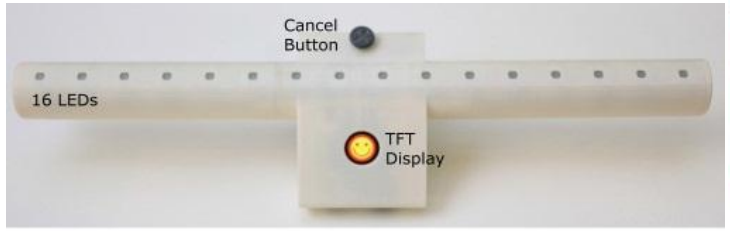


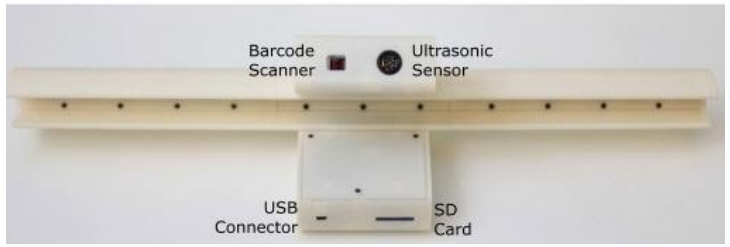


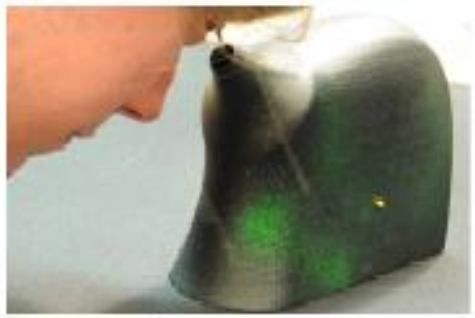

1x 3D printed "Base"
1x Grd_USB_Client_DP_1.2
1x Seeed_Moisture_Sensor_1.0
1x Seeed_OLED_Display_1.0
1x Sytech_Button_1.0
? inch x1
? inch x?
? inch x?
1x 3D printed "Sensorholder"
1x 3D printed "Frontlid"
1x 3D printed "Sensorholder lid"
1x Grd_PEZ_SPIDER_1.0
1x Seeed_Cellular_Radio_1.0



Custom devices in ubicomp research



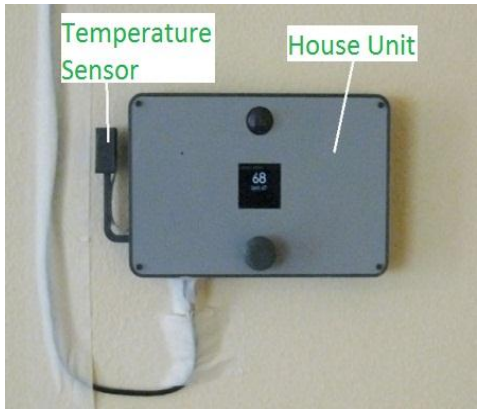


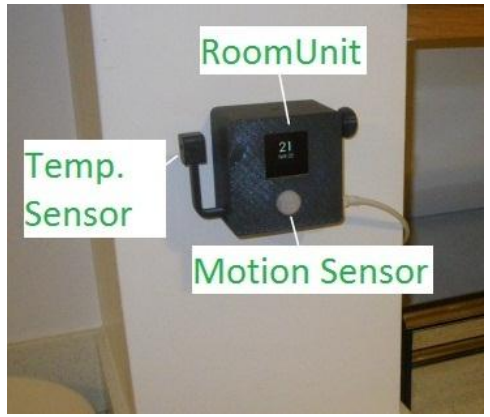


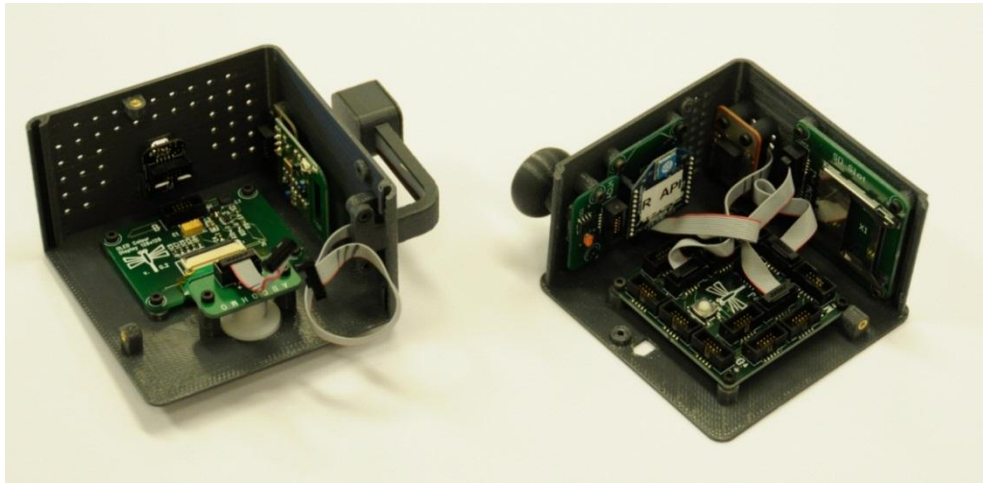
DIY Biology (Kuznetsov et al, DIS 2012), **Telematic Dinner Party** (Barden et al, DIS 2012), **How to Nudge In Situ** (Kalnikaitė et al, UbiComp 2011), **PreHeat** (Scott et al, UbiComp 2011), **Serendipitous Displays** (Helmes et al., Interact 2011), **Sonic Mementos** (Petrelli et al, CHI 2010)

PreHeat (Scott et al, UbiComp 2011)

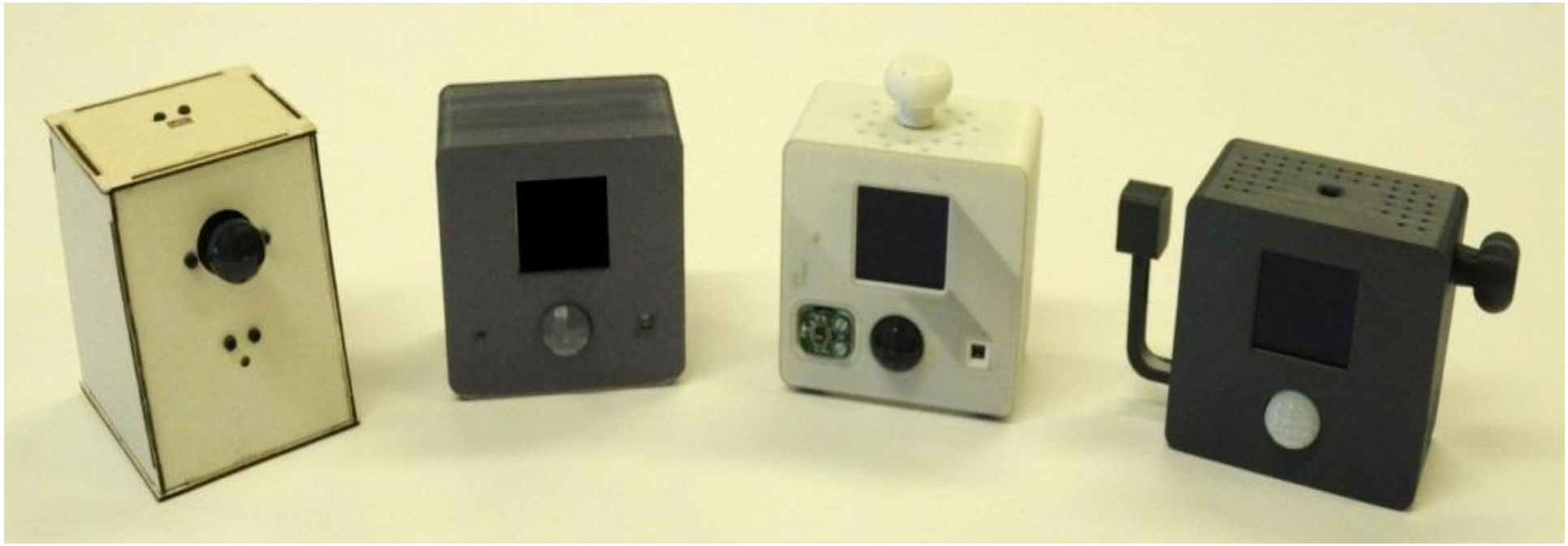
Home heating using occupancy sensing & prediction



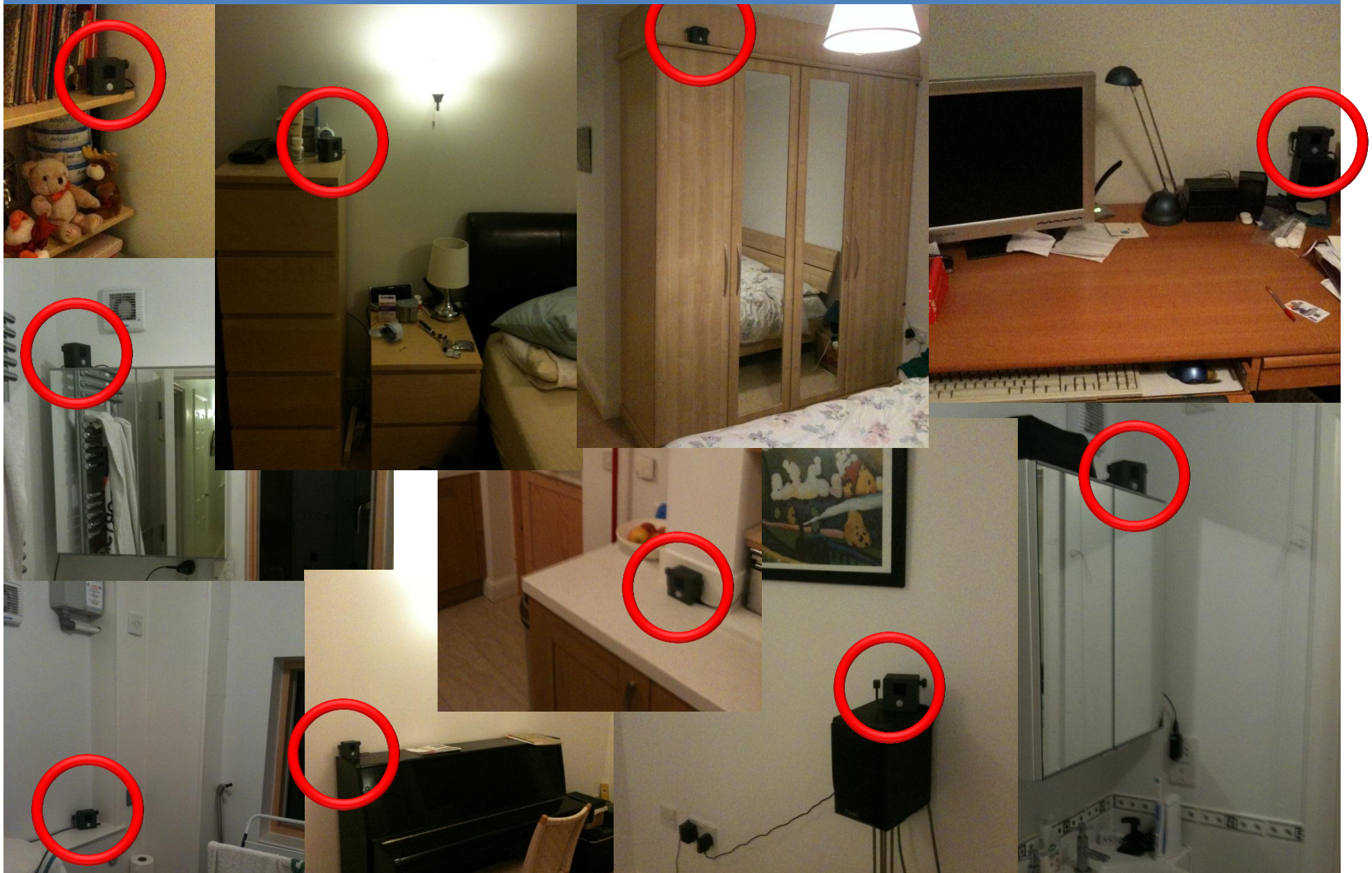




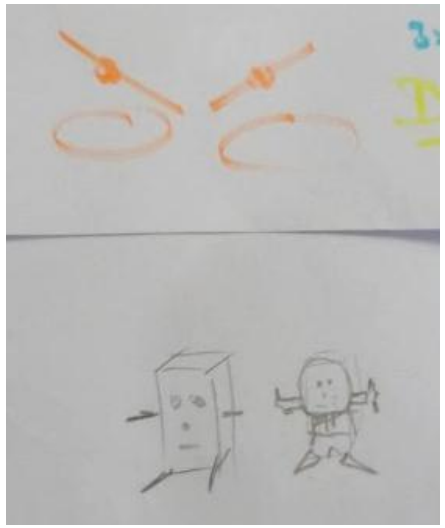
Form-factor iteration

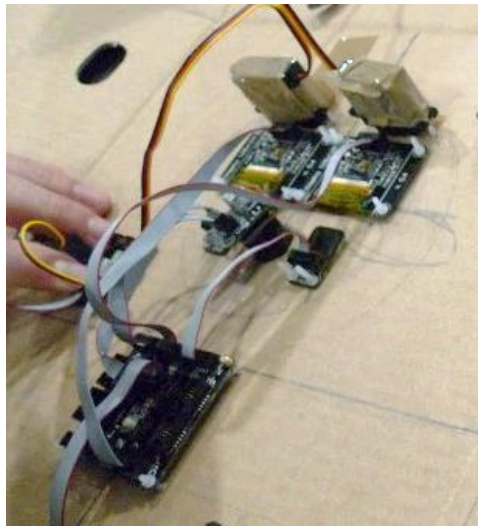


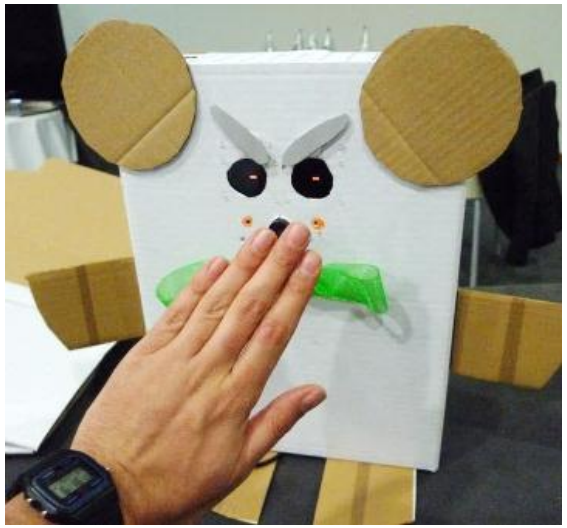
Production and deployment of 50 devices

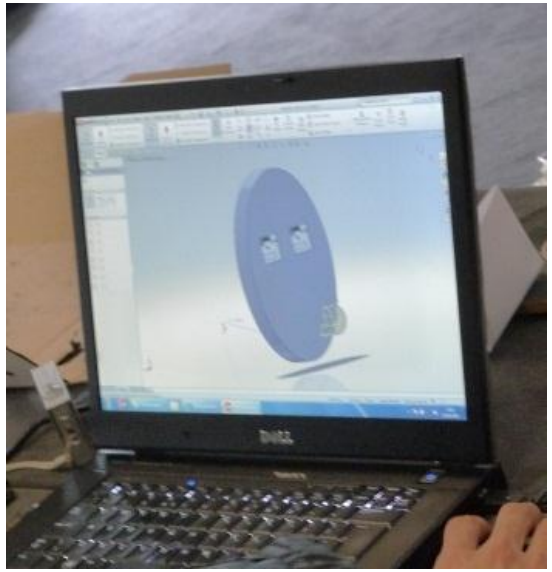


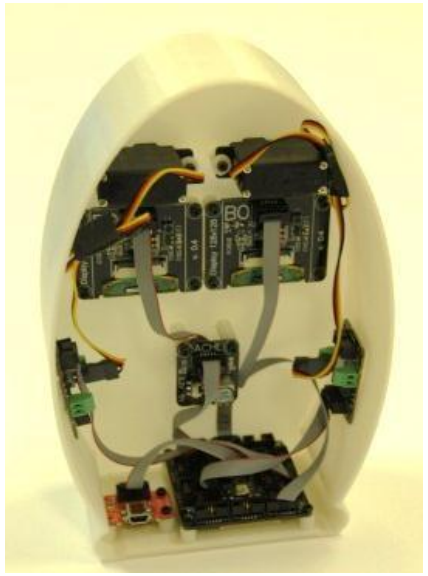
TEI'11 Studio: from sketch to 3d-printed demo

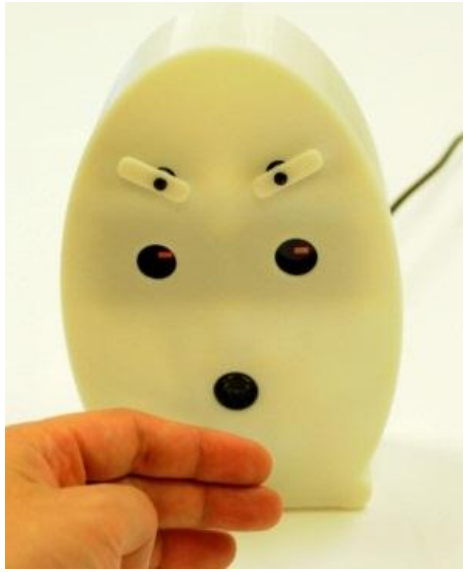








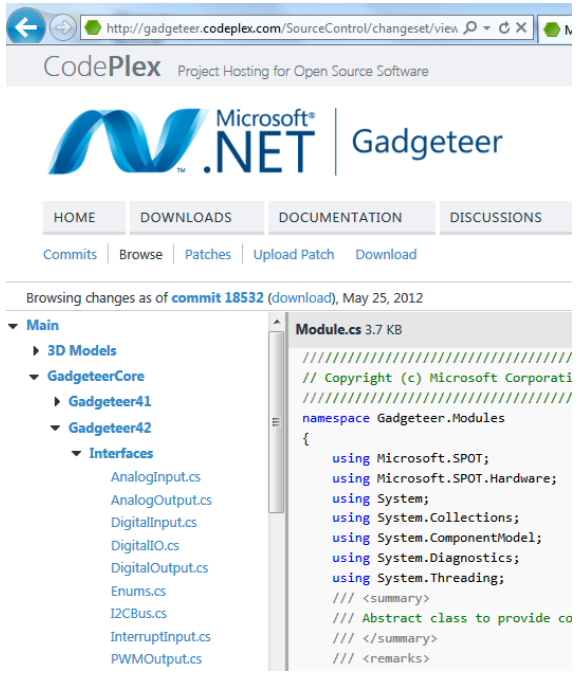




Getting .NET Gadgeteer out of the lab

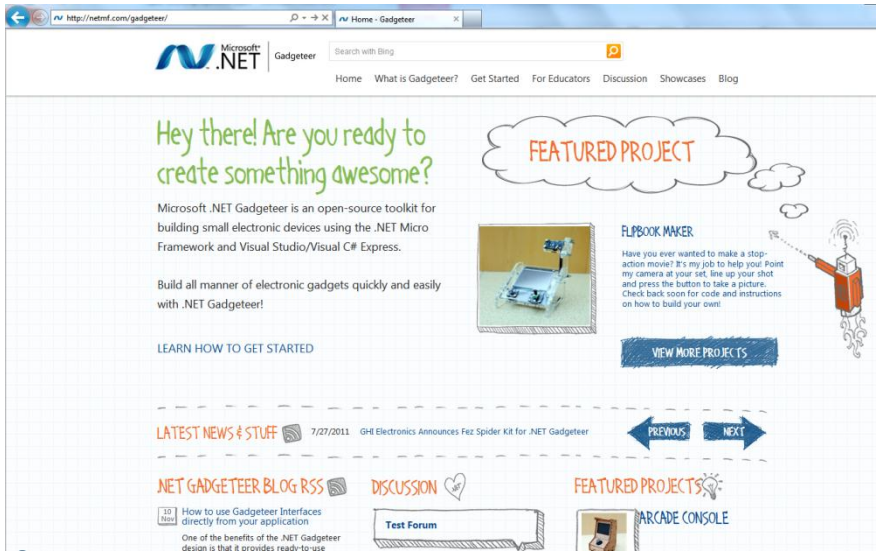
http://gadgeteer.codeplex.com/

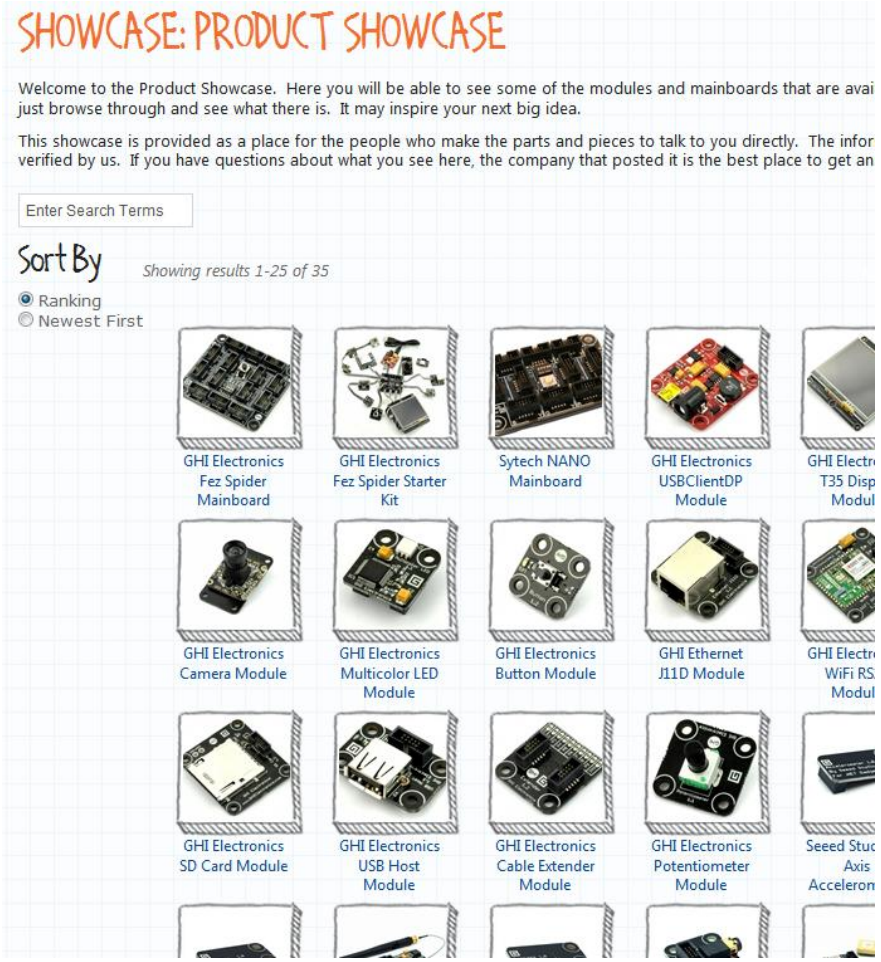
Open source repository for project documentation, software and hardware designs



http://netmf.com/gadgeteer/

Hardware index, example projects, forums





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Acknowledgements

Huge thanks to the following Microsoft teams:

- Microsoft Research Connections who are supporting Gadgeteer outreach activities
- The MSR Advanced Prototyping team who built the Visual Studio Designer
- The Microsoft Garage members who beta tested Gadgeteer

And to interns and collaborators who have used the platform in their research.

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