November 9-11, 2021

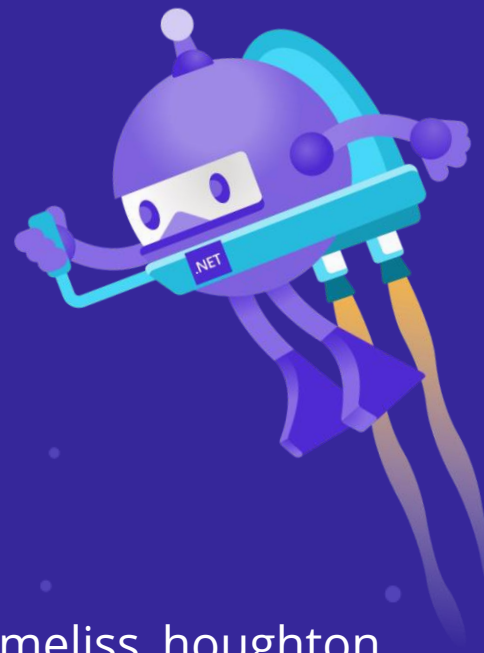
www.dotnetconf.net

.NET Conf

Discover the world of .NET

.NET Internet of Things

Melissa Houghton



melissahoughton.dev melissahoughton melissahoughton meliss_houghton

About Me

azenix

Lead Software Engineer

Microsoft® Most Valuable Professional

Developer Technologies

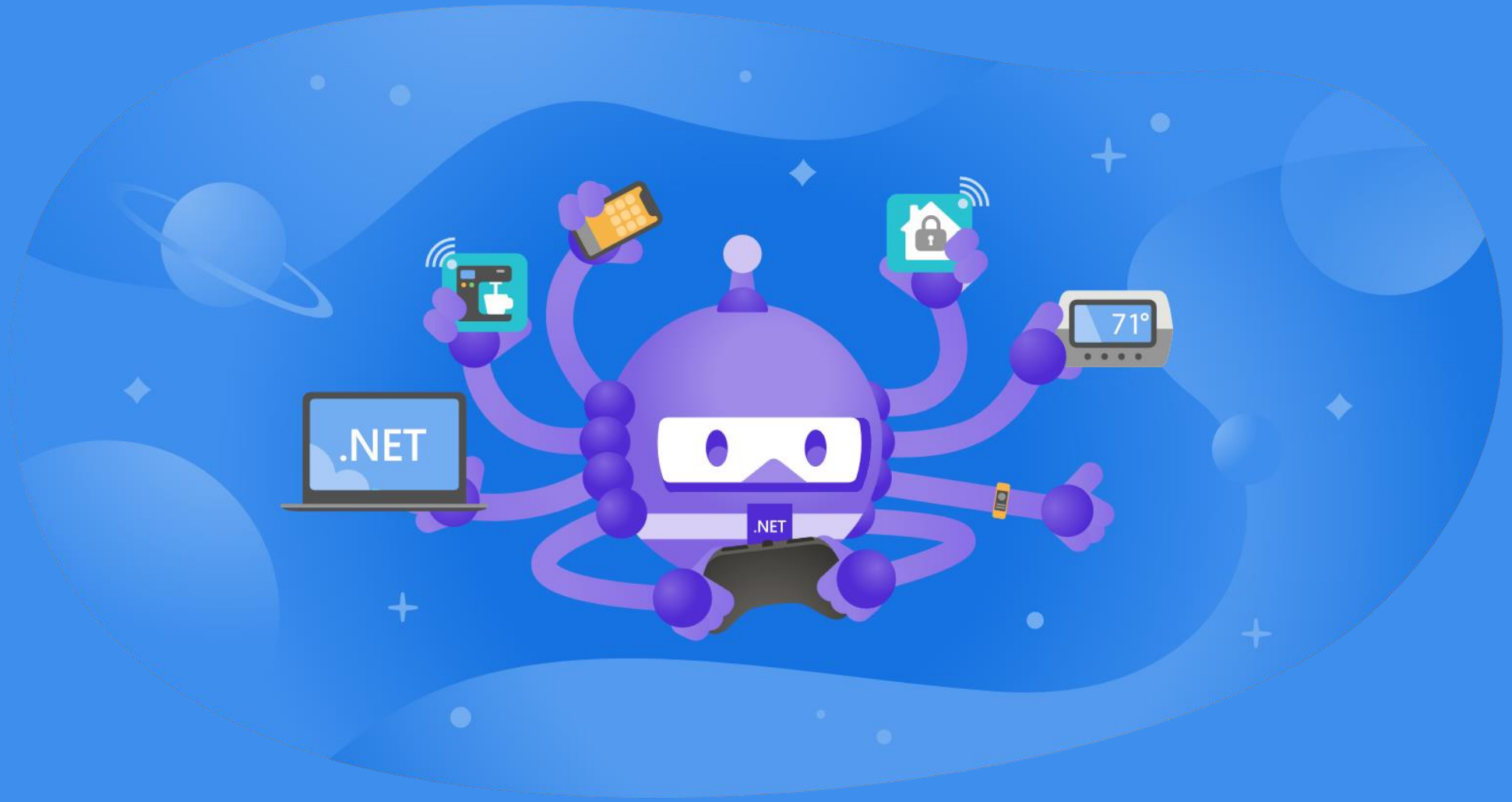
melissahoughton.dev

melissahoughton

melissahoughton

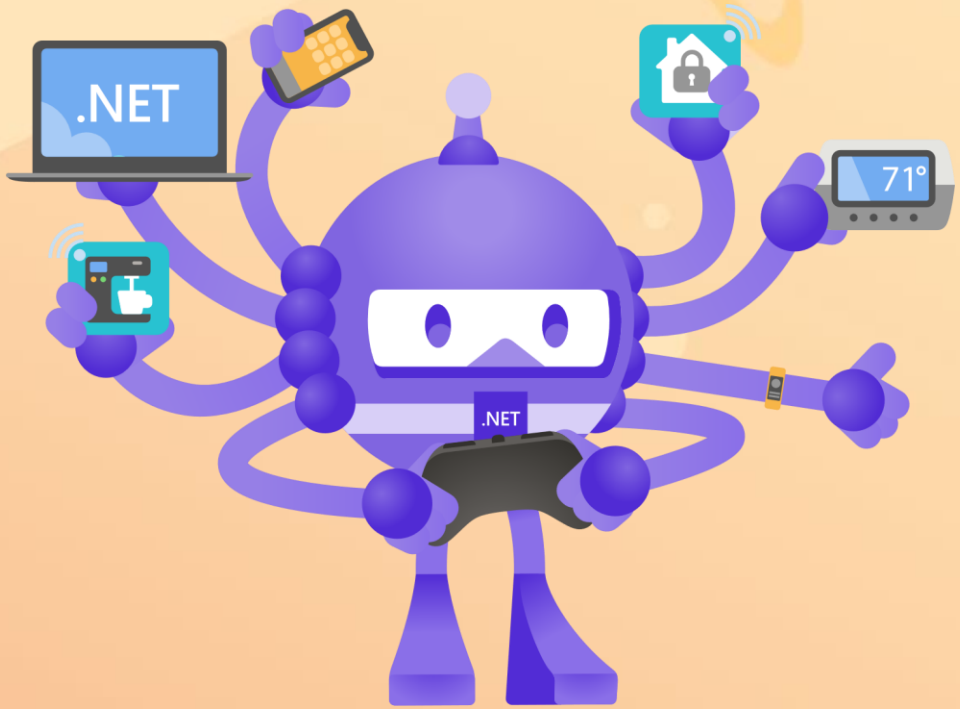
meliss_houghton

What is IoT?



How can you use .NET for IoT

.NET



.NET IoT Libraries

Libraries

Device Bindings

- Analog Converters
- Digital Logic
- Display Controller
- I/O Expanders
- Sensors
- LED Drivers
- Memory
- Motor Drivers
- Real Time Clocks

Tooling

- CLI
- Docker
- Templates
- Testing

Core APIs

System.Device.Gpio

- ADC
- CAN
- GPIO
- I2C
- PWM
- SPI

Futures

- System.Device.*

Platform

Windows 10 IoT / Linux

- X86
- X64
- ARM32
- ARM64

Hardware

Maker Boards

- Raspberry Pi
- HummingBoard
- BeagleBone Black
- Custom Hardware

System.Device.Gpio

Protocols Including:

- General-purpose I/O (GPIO)
- Inter-Integrated Circuit (I2C)
- Serial Peripheral Interface (SPI)
- Pulse Width Modulation (PWM)
- Serial port

Iot.Device.Bindings

https://github.com/dotnet/iot/tree/main/src/devices

Demo

Tools

Deployment

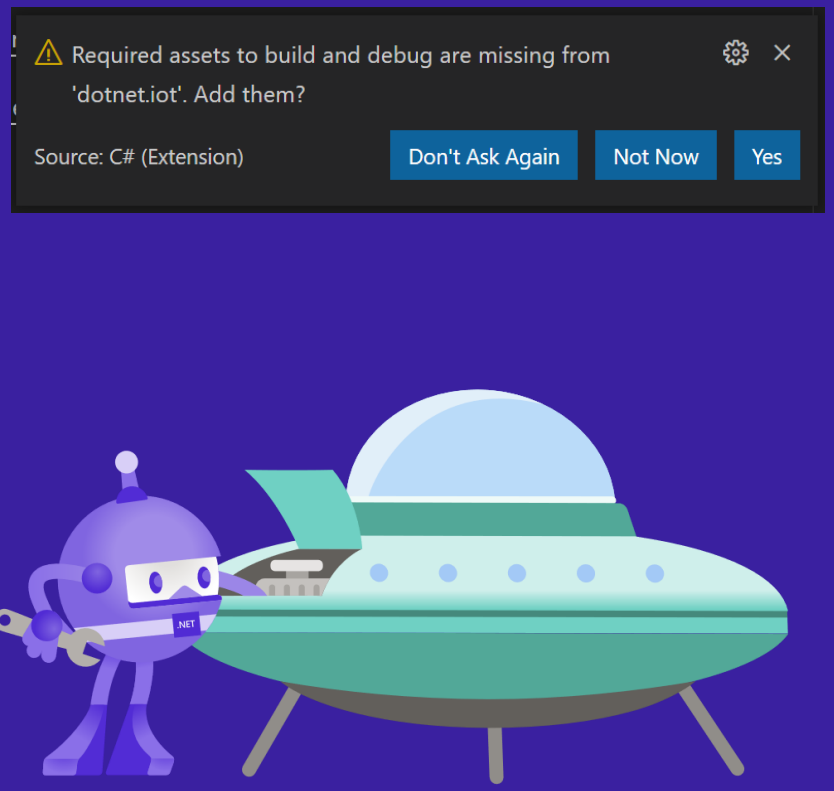
Framework-dependent

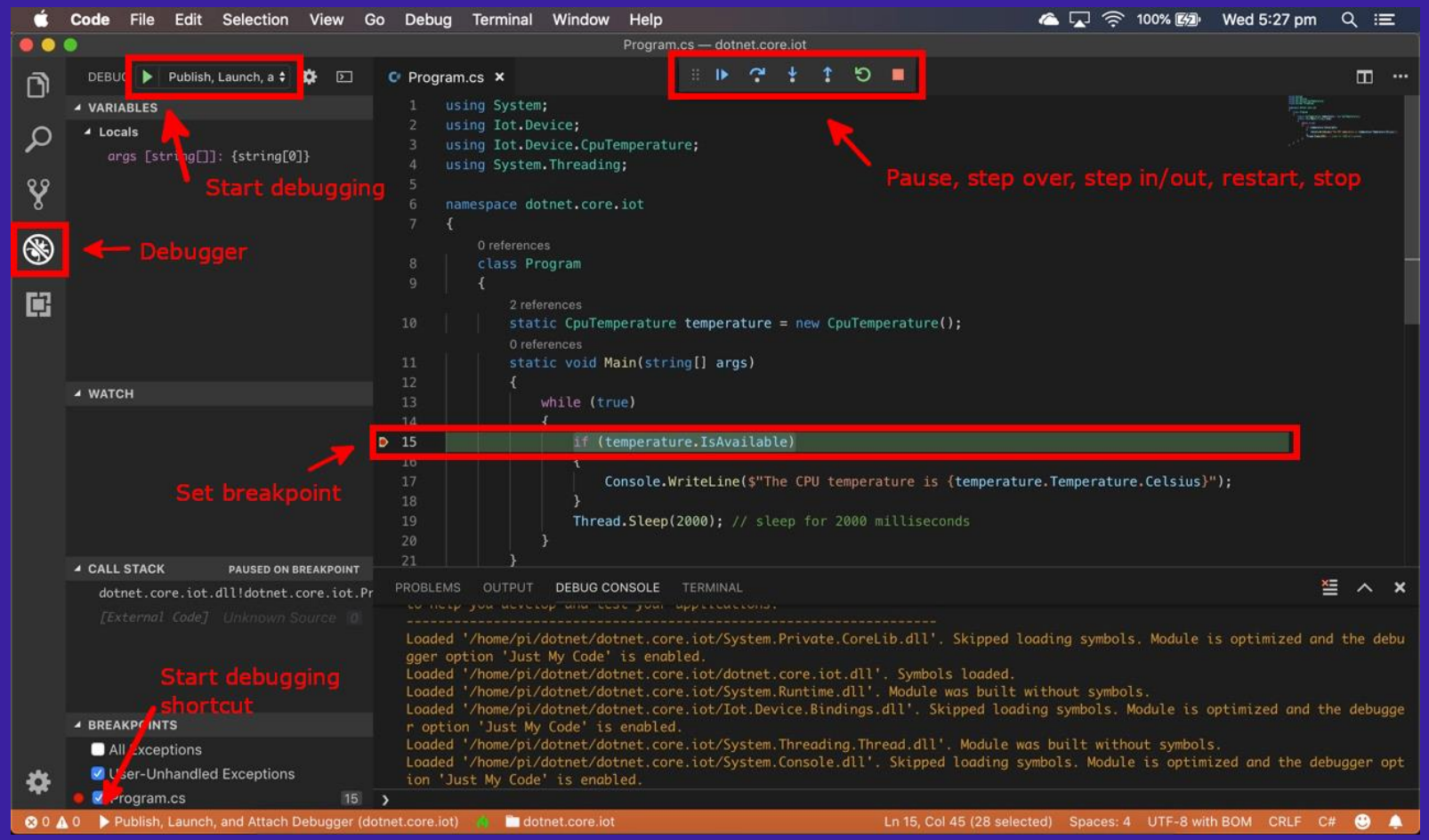
```
# Install .NET on the device
curl -sSL https://dot.net/v1/dotnet-install.sh | bash /dev/stdin --channel Current

# Publish the app with Deployment mode = Framework-dependent and Target runtime = Portable
dotnet publish

# Copy the files from the computer to the device
scp -r /publish-location/* pi@raspberrypi:/home/pi/deployment-location/

# Run the app on the device
dotnet HelloWorld.dll
```

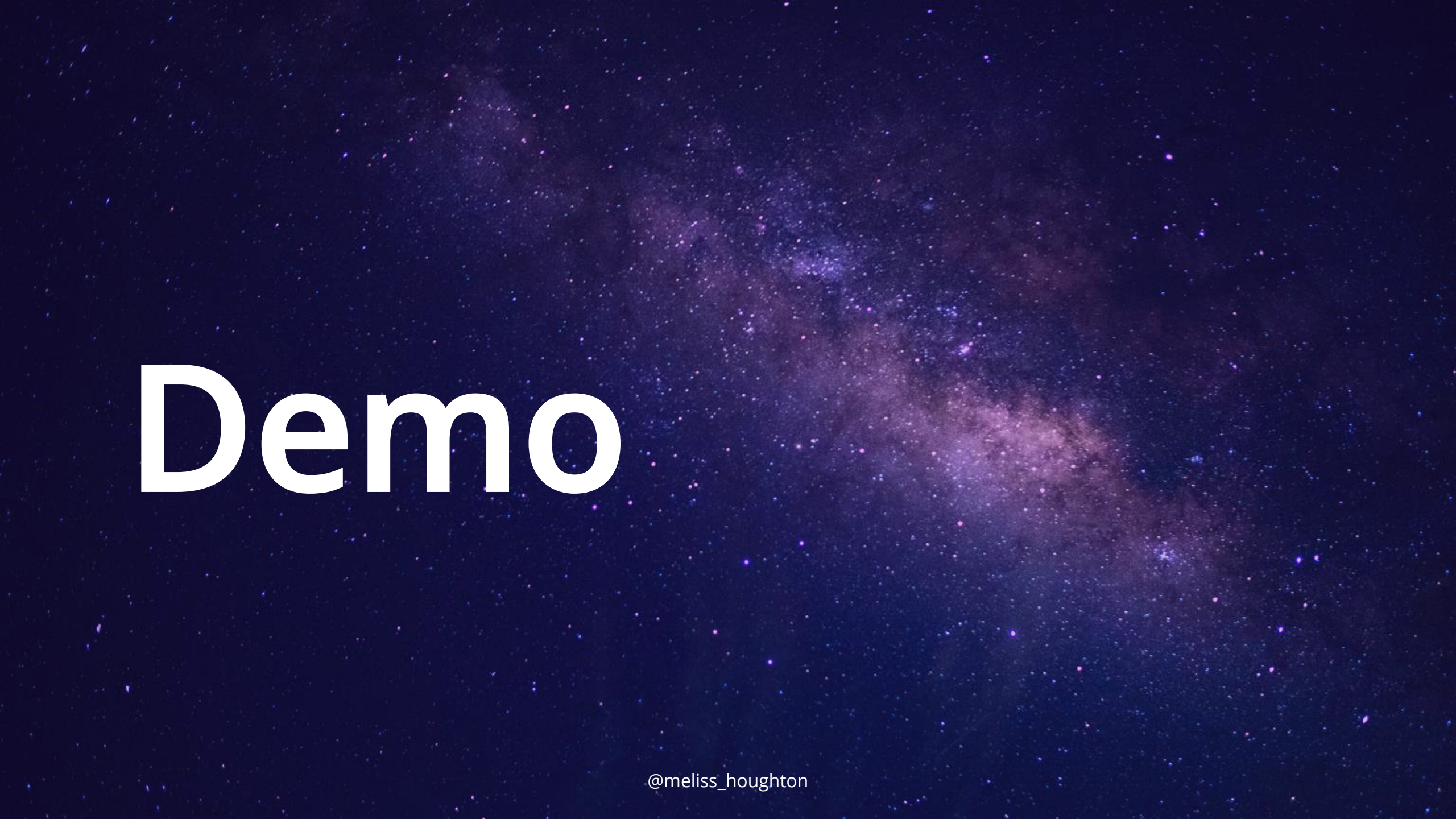
Self-contained

```
# Publish the app with Deployment mode = Self-contained and Target runtime = linux-arm
dotnet publish -r linux-arm

# Copy the files from the computer to the device
scp -r /publish-location/* pi@raspberrypi:/home/pi/deployment-location/

# Run the app on the device
chmod +x HelloWorld
./HelloWorld
```

Debugging


Required assets to build and debug are missing from 'dotnet.iot'. Add them?
Source: C# (Extension)
Don't Ask Again
Not Now
Yes


Start debugging
Pause, step over, step in/out, restart, stop
Debugger
Set breakpoint
Start debugging shortcut


Demo
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.NET nanoFramework

Demo

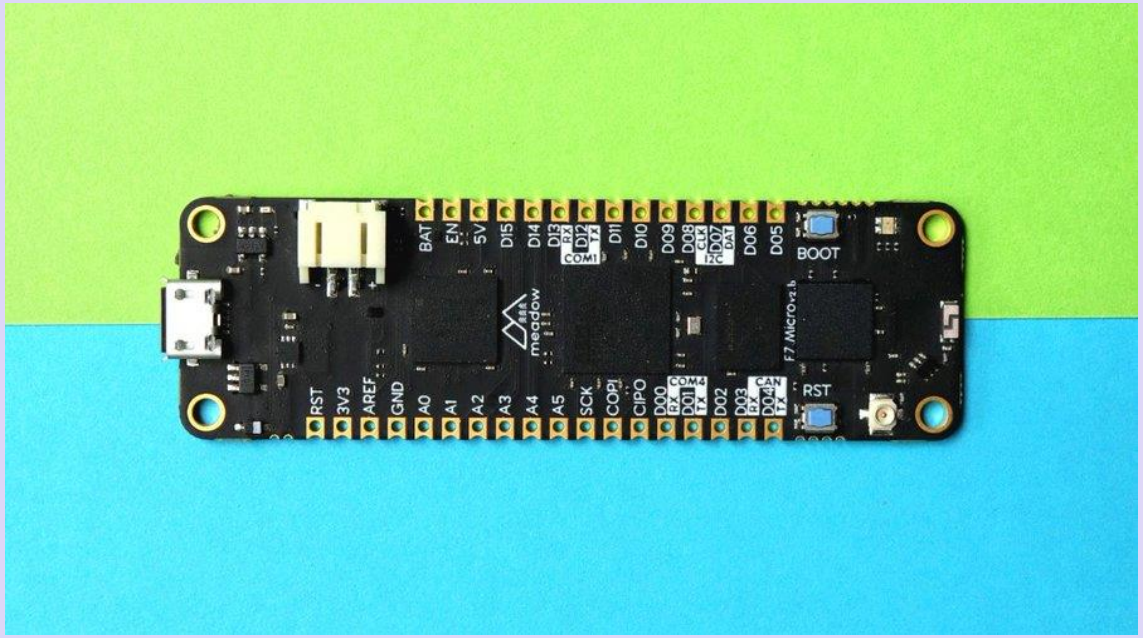
.NET IoT

- Powerful boards
- All .NET core libraries
- Iot.Device.Bindings and System.Device.Gpio
- Manual deployment setup
- Manual remote debugging
- Deploy the code via SSH connection

nanoFramework

- Low-level microcontrollers
- Specific .NET libraries
- Specific packages per sensor
- Built-in deployment
- Remote debugging experience
- Deploy via wired connection

Meadow



meadow

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Why use Meadow

- Enterprise IoT
- Full .NET on embeddable microcontrollers
- Plug and Play IoT Library
- Focused on Security
- Cloud agnostic

Program.cs

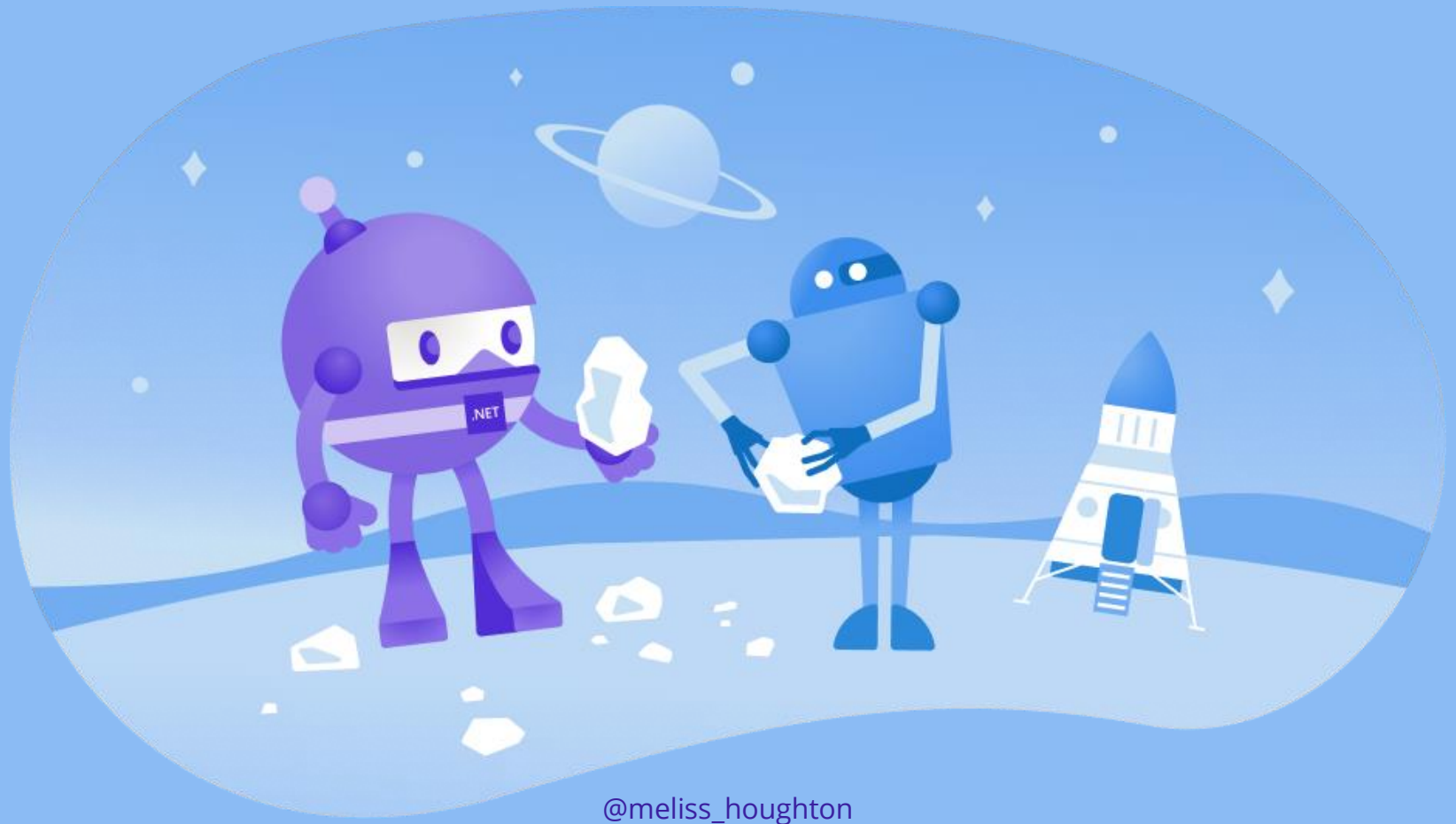
```
using Meadow;
using System.Threading;

namespace HelloMeadow
{
    class Program
    {
        static IApp app;
        public static void Main(string[] args)
        {
            // instantiate & run new meadow app
            app = new MeadowApp();
            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

MeadowApp.cs

```
using Meadow;
using Meadow.Devices;
using Meadow.Foundation.Leds;

namespace HelloMeadow
{
    public class MeadowApp : App<F7Micro, MeadowApp>
    {
        public MeadowApp()
        {
            var pwmLed = new PwmLed(
                    Device, Device.Pins.D13,
                    TypicalForwardVoltage.Blue);
            // pulse the LED
            pwmLed.StartPulse();
        }
    }
}
```

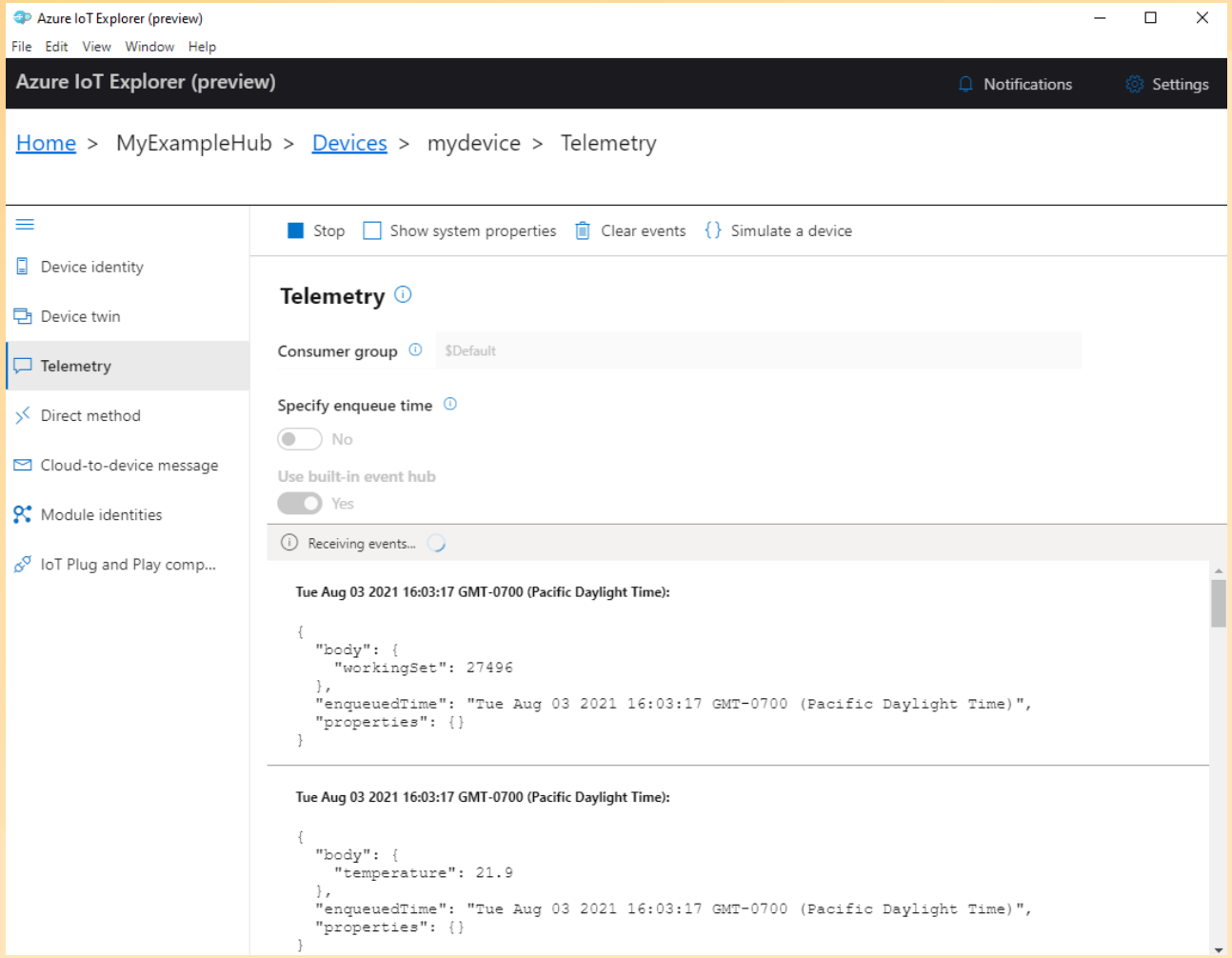
Azure IoT SDK for .NET

https://github.com/Azure/azure-iot-sdk-csharp

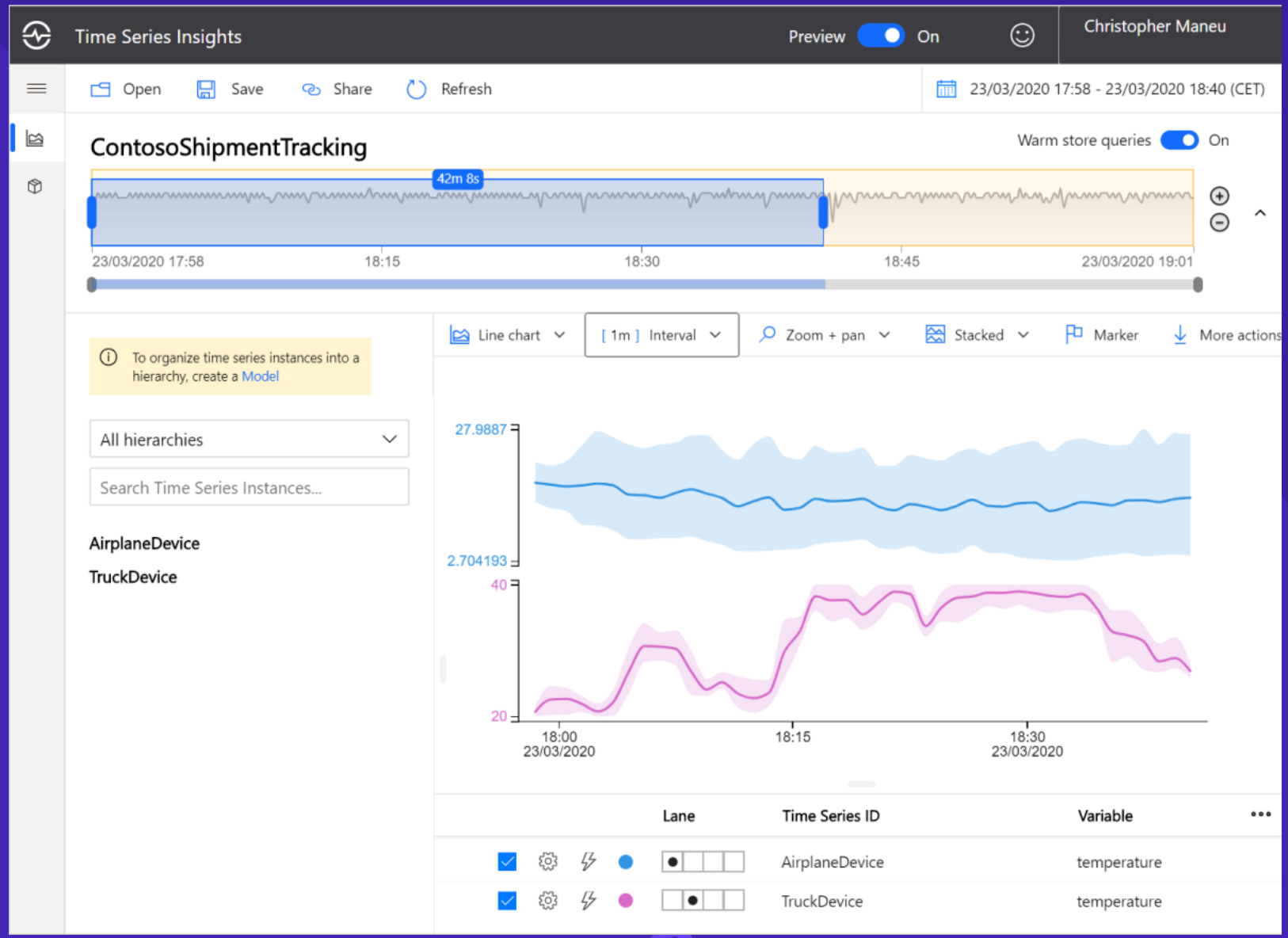


Azure IoT Hub

```
// Create device client

// And connect to IoT Hub using MQTT protocol
DeviceClient deviceClient =
        DeviceClient.Create(
                iotHubHostName,
                deviceAuthentication,
                TransportType.Mqtt);
...

// Send the telemetry message.

await deviceClient.SendEventAsync(message);
```



Time Series Insights



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Digital Twins

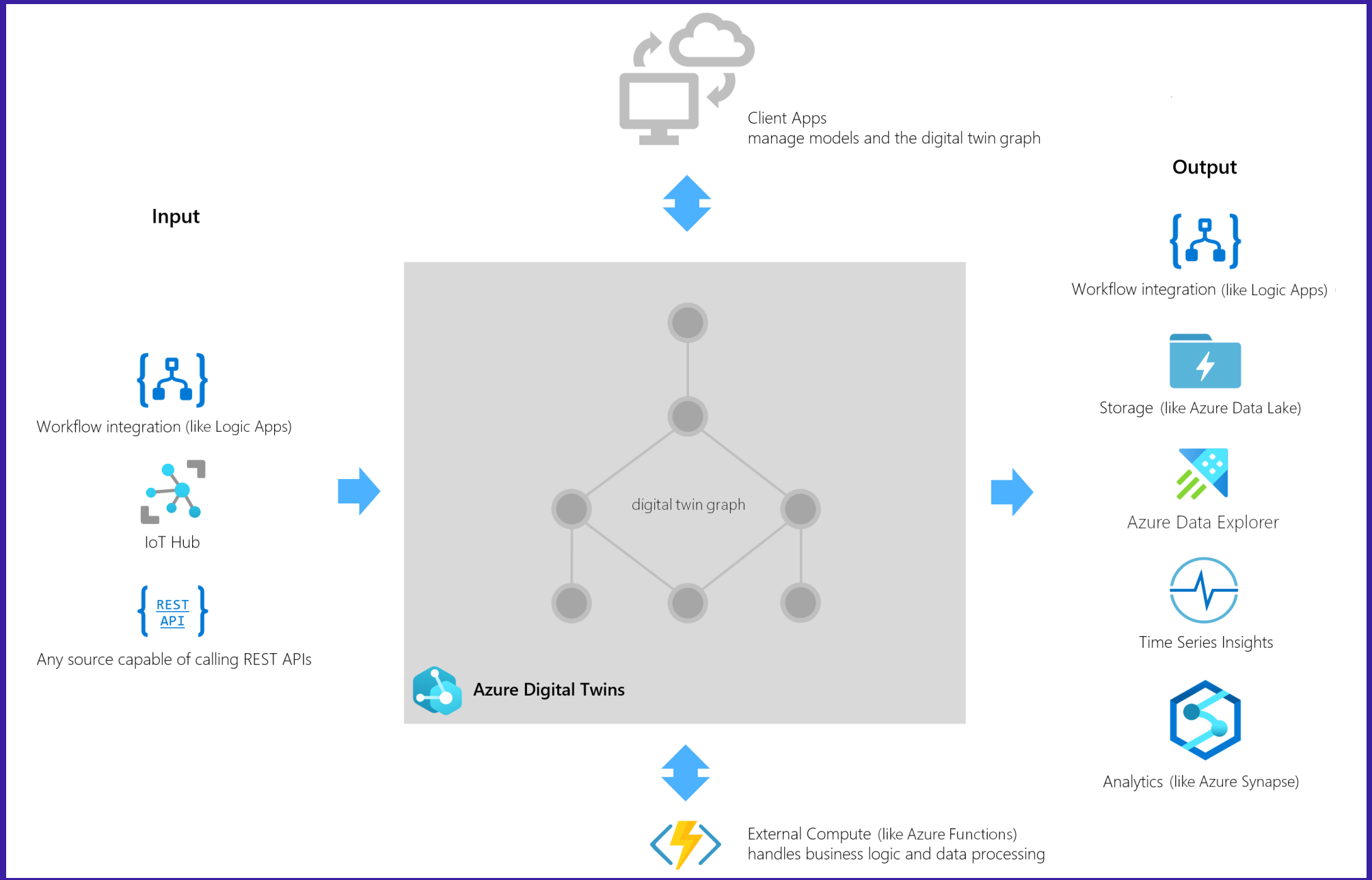
```
dotnet add package Azure.DigitalTwins.Core
dotnet add package Azure.Identity
```

```
string adtInstanceUrl = "https://<your-Azure-Digital-Twins-instance-hostName>";

var credential = new DefaultAzureCredential();
var client = new DigitalTwinsClient(new Uri(adtInstanceUrl), credential);
Console.WriteLine($"Service client created – ready to go");
```

```
var twinData = new BasicDigitalTwin();
twinData.Metadata.ModelId = "dtmi:example:SampleModel;1";
twinData.Contents.Add("data", $"Hello World!");

string prefix = "sampleTwin-";
for (int i = 0; i < 3; i++)
{
    try
    {
        twinData.Id = $"{prefix}{i}";
        await client.CreateOrReplaceDigitalTwinAsync<BasicDigitalTwin>(twinData.Id, twinData);
        Console.WriteLine($"Created twin: {twinData.Id}");
    }
    catch(RequestFailedException e)
    {
        Console.WriteLine($"Create twin error: {e.Status}: {e.Message}");
    }
}
```


Client Apps
manage models and the digital twin graph
Input
Workflow integration (like Logic Apps)
IoT Hub
REST API
Any source capable of calling REST APIs
digital twin graph
Azure Digital Twins
External Compute (like Azure Functions)
handles business logic and data processing
Output
Workflow integration (like Logic Apps)
Storage (like Azure Data Lake)
Azure Data Explorer
Time Series Insights
Analytics (like Azure Synapse)

AI/ML for IoT with .NET

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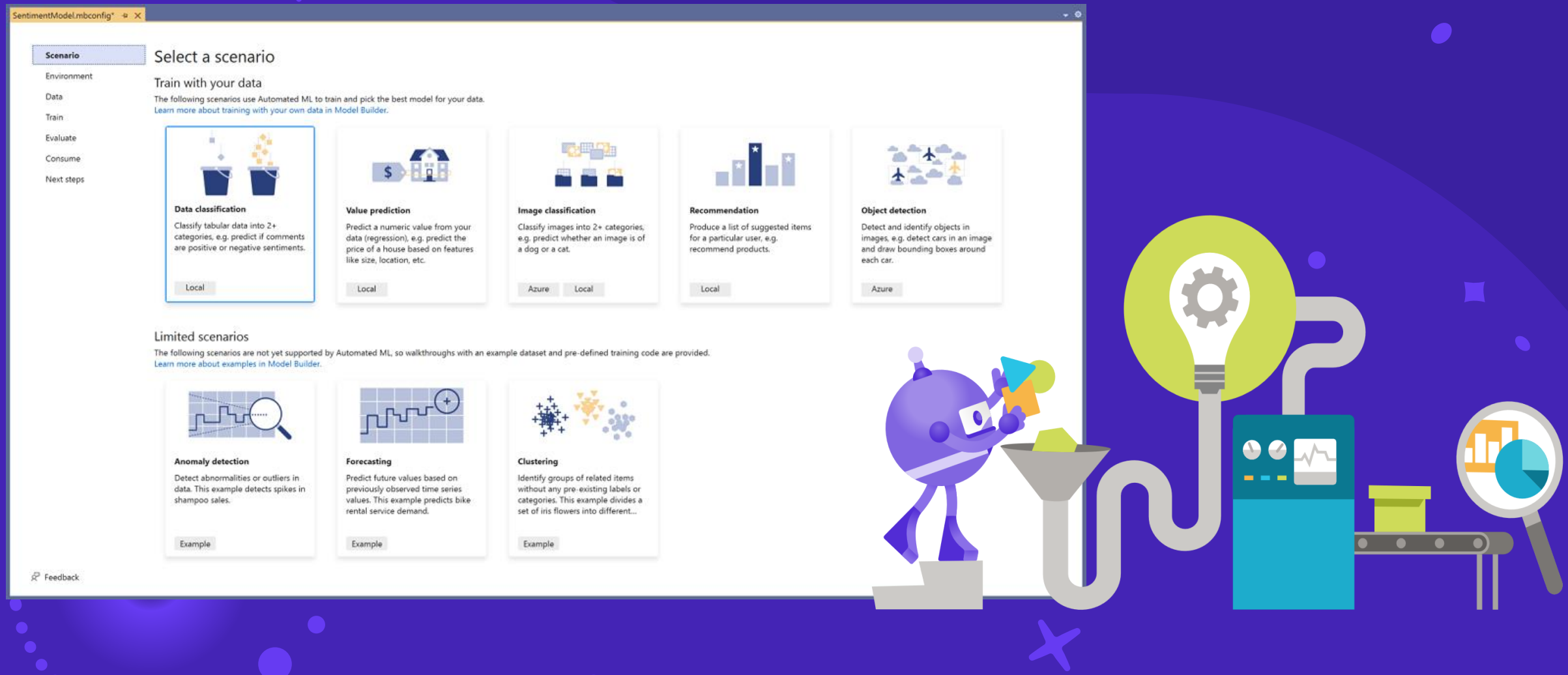
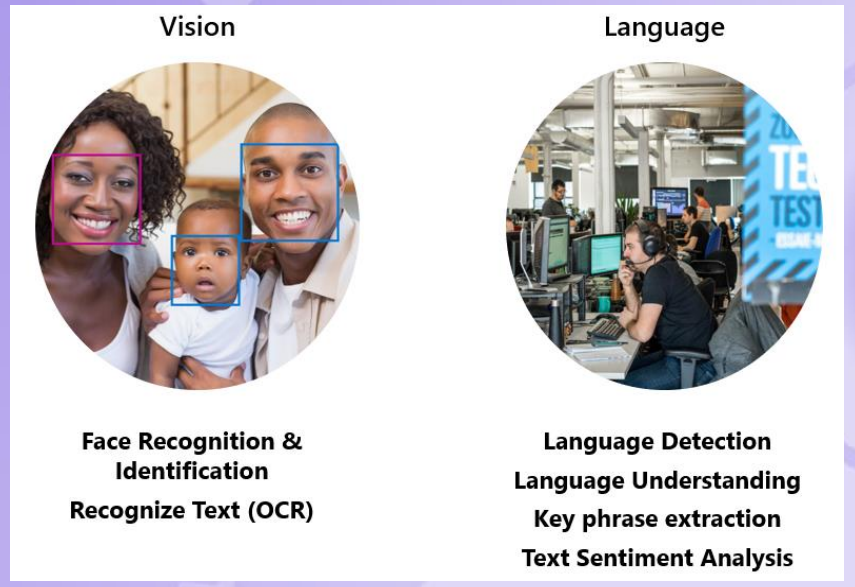
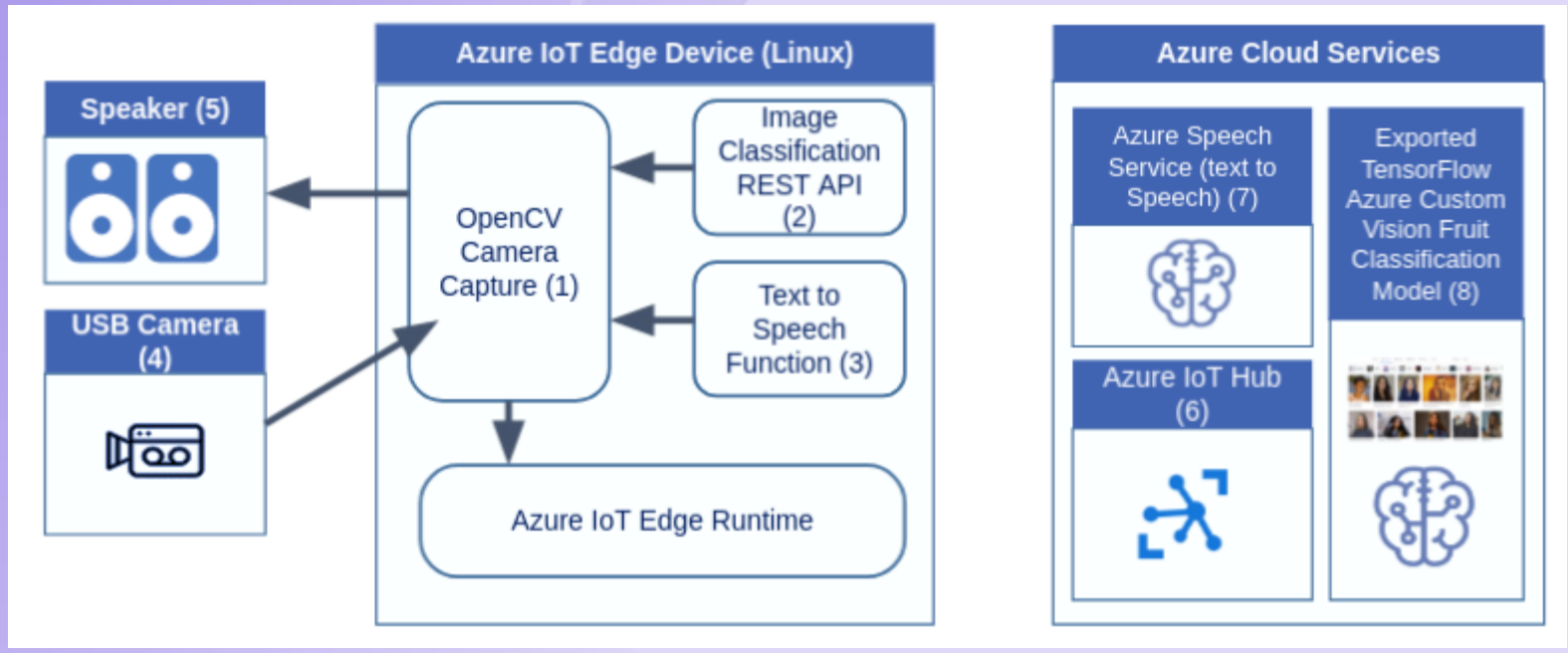
ML.NET

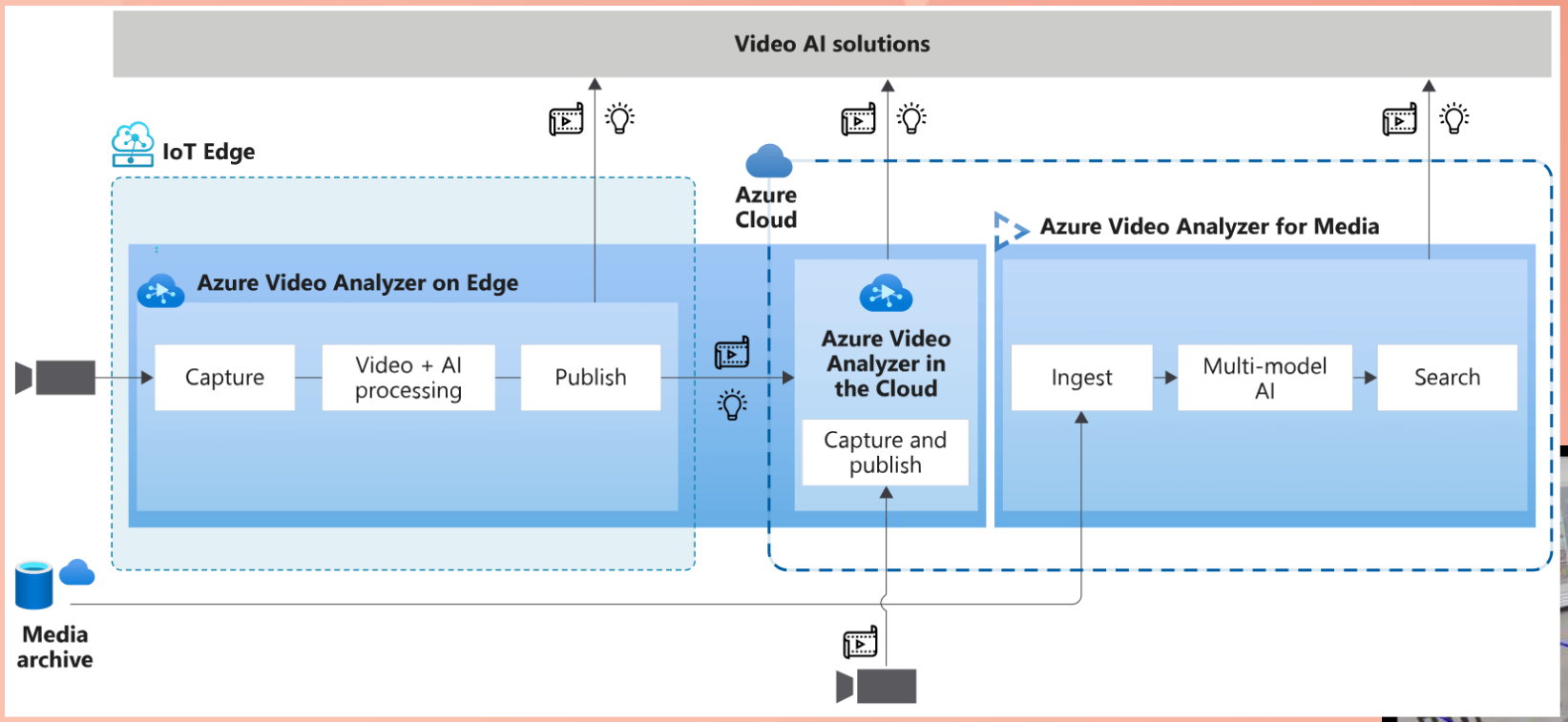

SentimentModel.mbconfig*
Scenario
Environment
Data
Train
Evaluate
Consume
Next steps
Select a scenario
Train with your data
The following scenarios use Automated ML to train and pick the best model for your data.
Learn more about training with your own data in Model Builder.
Data classification
Classify tabular data into 2+ categories, e.g. predict if comments are positive or negative sentiments.
Local
Value prediction
Predict a numeric value from your data (regression), e.g. predict the price of a house based on features like size, location, etc.
Local
Image classification
Classify images into 2+ categories, e.g. predict whether an image is of a dog or a cat.
Azure
Local
Recommendation
Produce a list of suggested items for a particular user, e.g. recommend products.
Local
Object detection
Detect and identify objects in images, e.g. detect cars in an image and draw bounding boxes around each car.
Azure
Limited scenarios
The following scenarios are not yet supported by Automated ML, so walkthroughs with an example dataset and pre-defined training code are provided.
Learn more about examples in Model Builder.
Anomaly detection
Detect abnormalities or outliers in data. This example detects spikes in shampoo sales.
Example
Forecasting
Predict future values based on previously observed time series values. This example predicts bike rental service demand.
Example
Clustering
Identify groups of related items without any pre-existing labels or categories. This example divides a set of iris flowers into different...
Example
Feedback

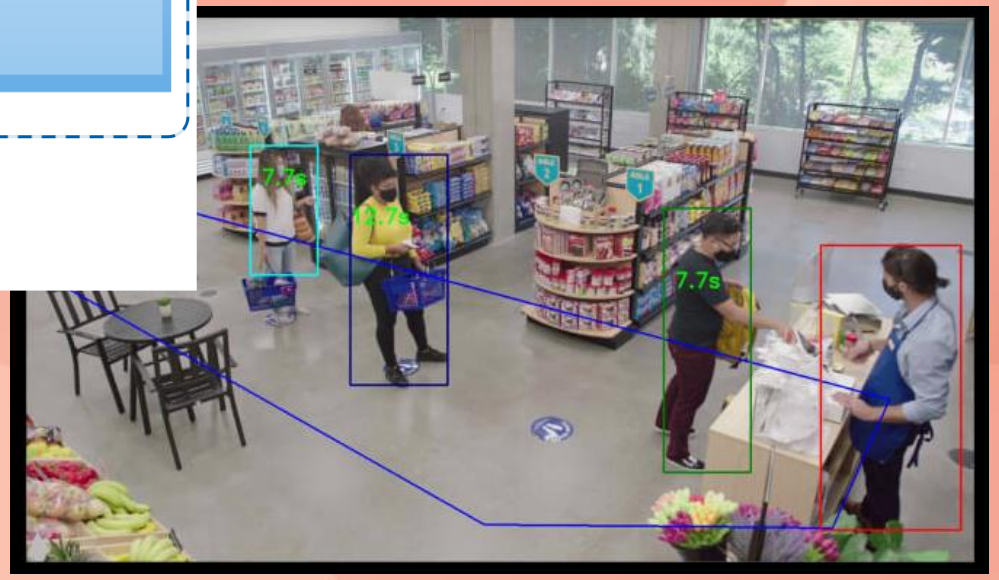
Azure Cognitive Services



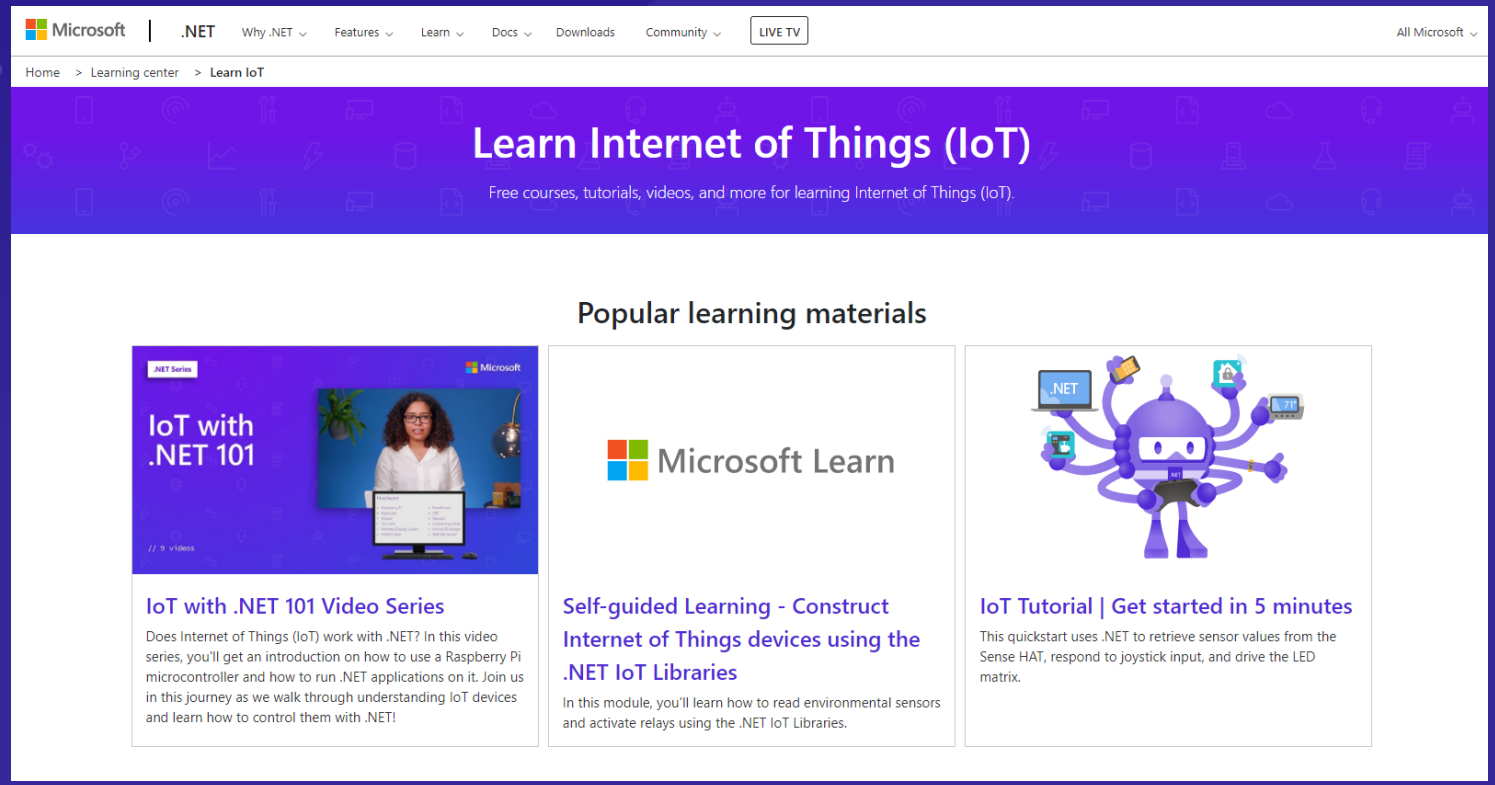


Azure Video Analyser





How to get started



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Summary

Thanks for joining!

https://bit.ly/dotnetconf-iot

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