Agenda

- Introduction to STMicro
- Overview of STM32 Nucleo Ecosystem
- Introduction to STM32Cube solution
- STM32Cube FW package presentation
  - Exploring the package content
  - Versioning and maintenance model
  - Documentation update for the STM32Cube F4
- Hardware Abstraction Layer
  - HAL overview
  - System peripherals HAL drivers overview (RCC, GPIO ,DMA, Cortex, PWR)
  - Standard peripheral HAL driver model
  - Guidelines for writing a HAL example
- Demo of STM32CubeMX PC software too
- Presentation and Demo of mbed

STMicroelectronics

NWCPP

Ken Sullivan

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Feb 18 2015

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Who we are

- A global semiconductor leader
- The largest European semiconductor company
- 2014 revenues of **$7.40B**
- Approximately **43,600** employees worldwide
- Approximately **8,700** people working in R&D
- **11** manufacturing sites
- Listed on New York Stock Exchange, Euronext Paris and Borsa Italiana, Milano

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As of December 31, 2014

Where you find us

Our MEMS & Sensors
are augmenting
the consumer experience

Our digital consumer products
are powering the augmented
digital lifestyle

Our automotive products
are making driving safer,
greener and more
entertaining

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Our Microcontrollers
are everywhere
making everything smarter
and more secure

Our smart power products
are allowing our mobile products to operate longer
and making more of our energy resources

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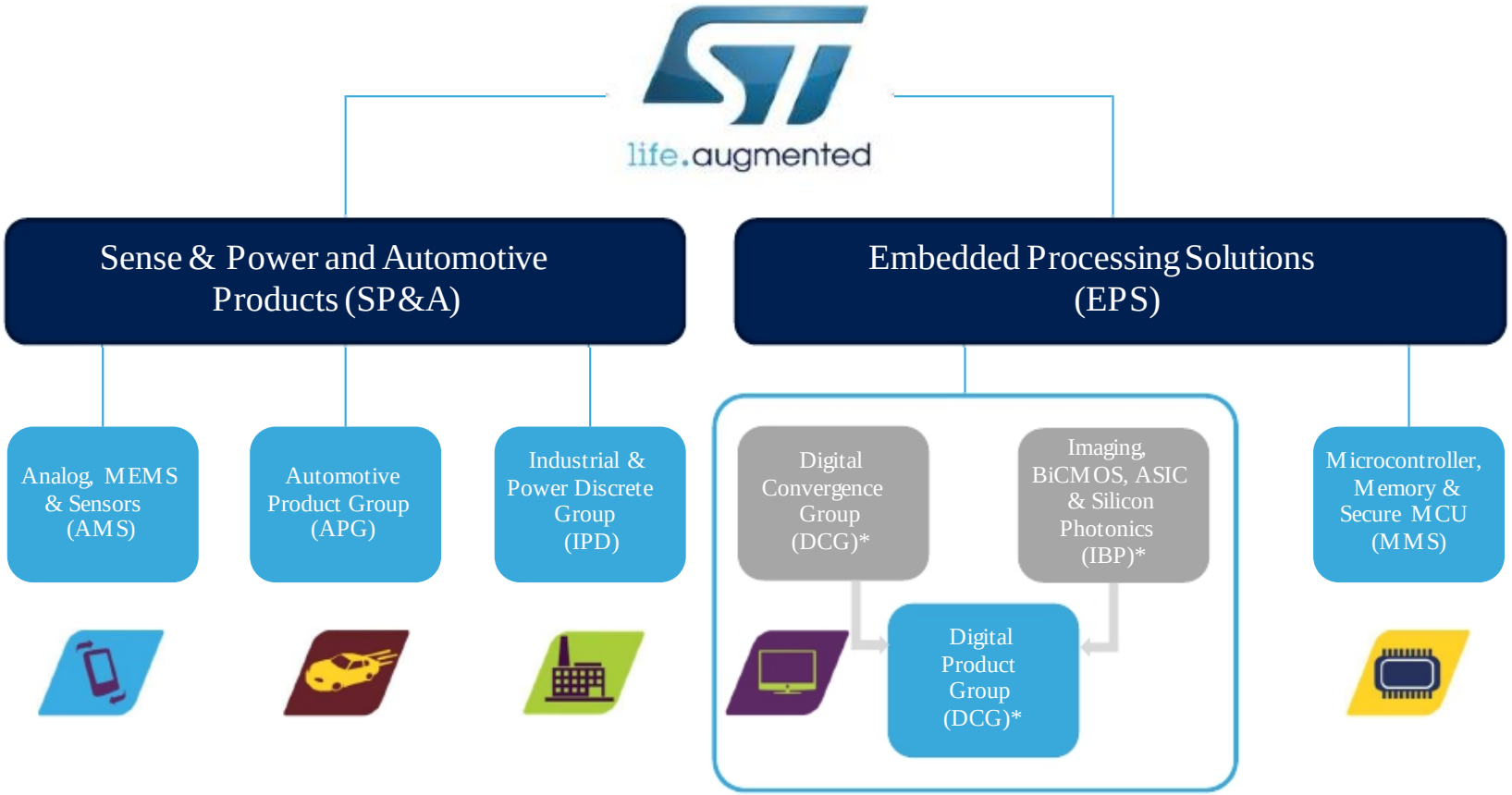
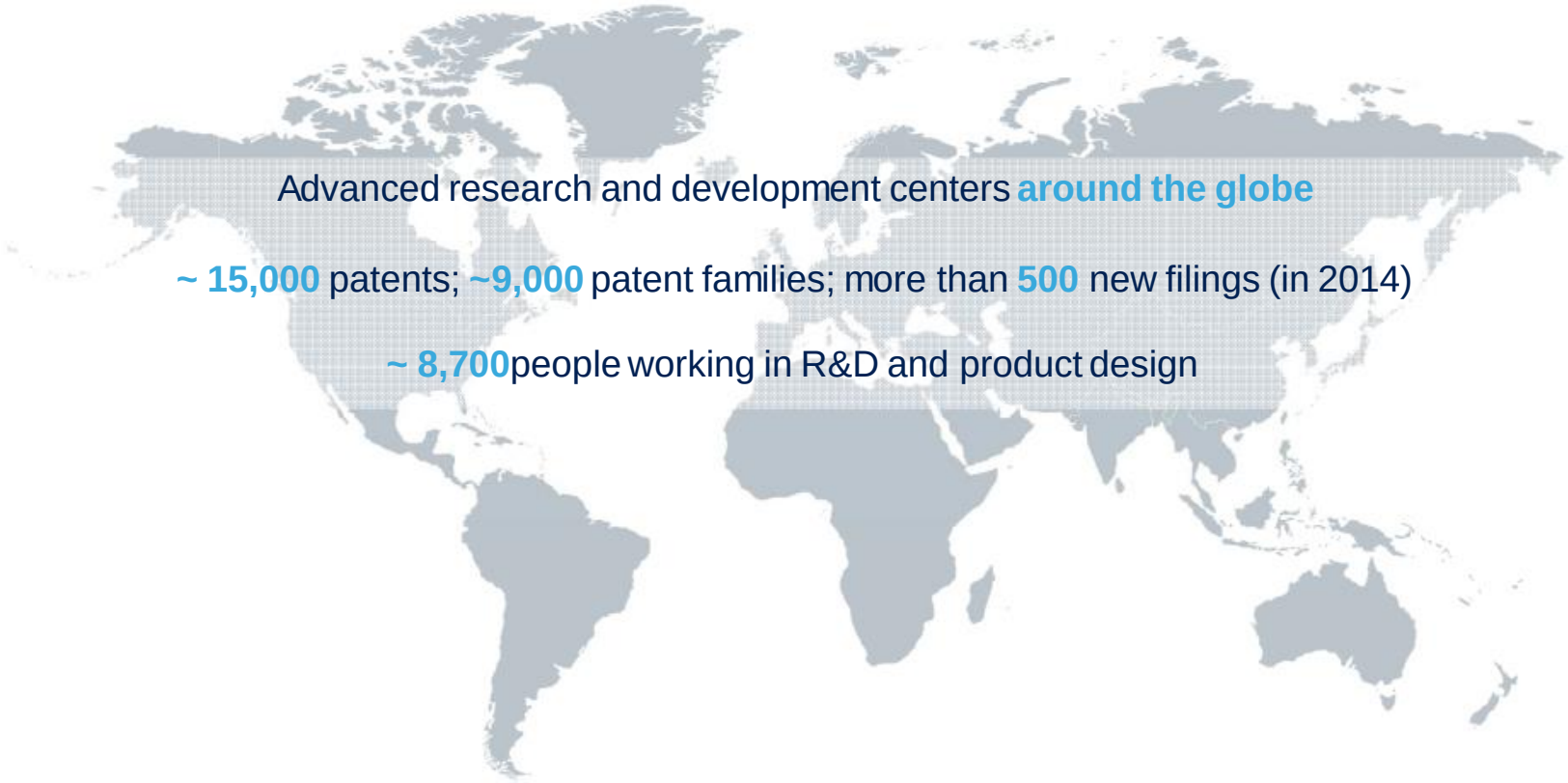
Product Segments



Effective Q4 2014, DCG and IBP product groups merged to form DPG.

Flexible and Independent Manufacturing

An unwavering Commitment to R&D



Advanced research and development centers **around the globe**

~ 15,000 patents; **~9,000** patent families; more than **500** new filings (in 2014)

~ 8,700 people working in R&D and product design

As of December 31, 2014

Partners with our Customers worldwide

ST's vision and strategy

OUR VISION

Everywhere microelectronics make a positive contribution to people's lives, ST is there

OUR STRATEGY

Leadership in Sense & Power, Automotive Products and Embedded Processing Solutions

OUR 5 GROWTH DRIVERS

Smart Power

MEMS and Sensors

Digital Consumer & ASICs

Automotive

Microcontrollers

STM32 Nucleo Ecosystem

Electronics made easy!

Edoardo Gallizio

edoardo.gallizio@st.com

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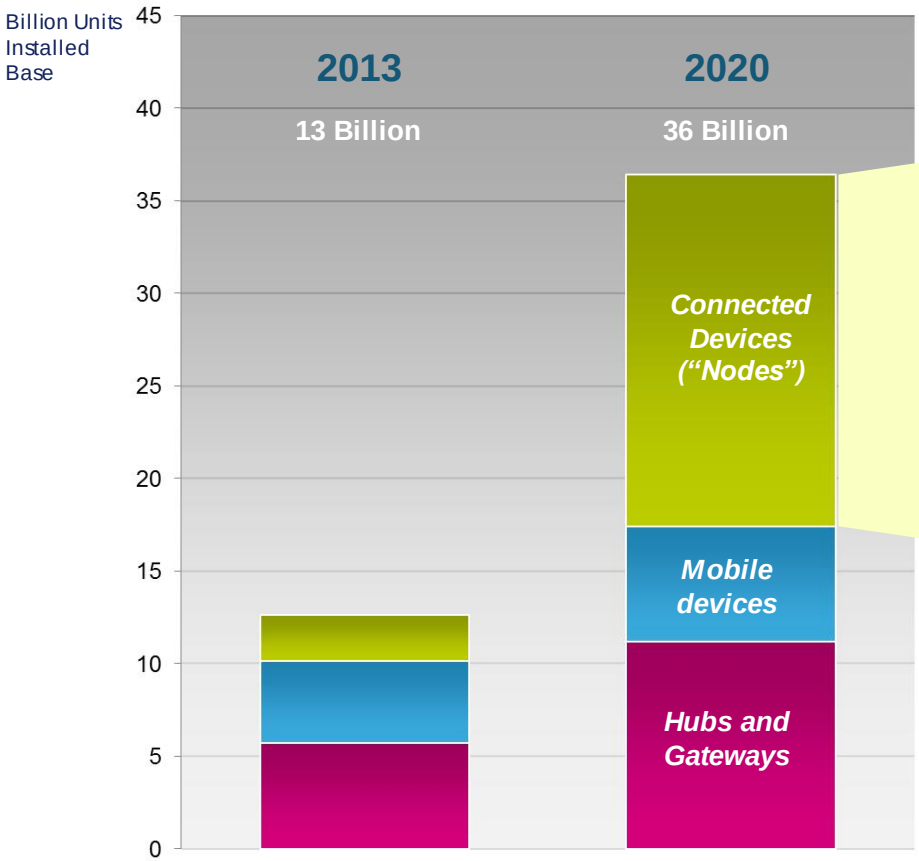
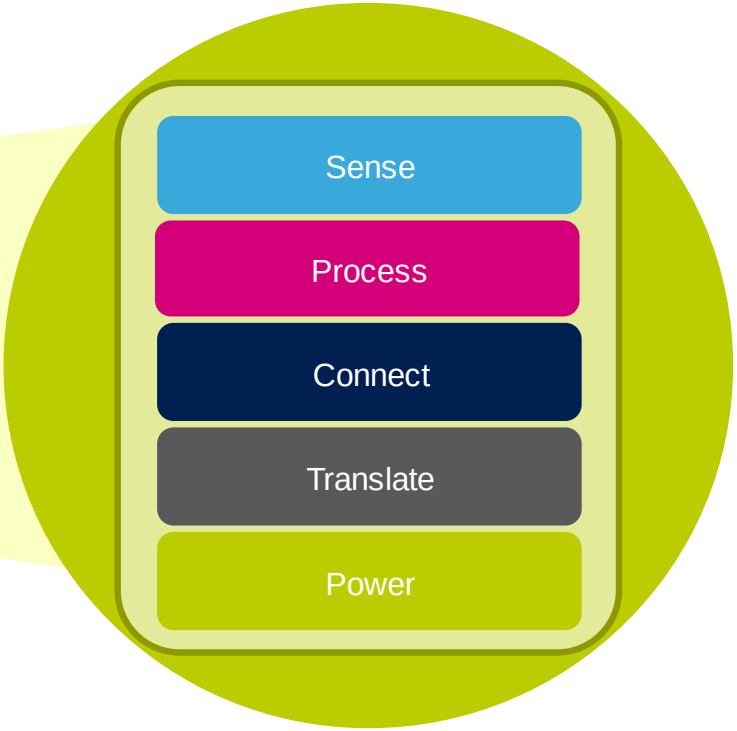
It’s a great Opportunity





Augmented Things

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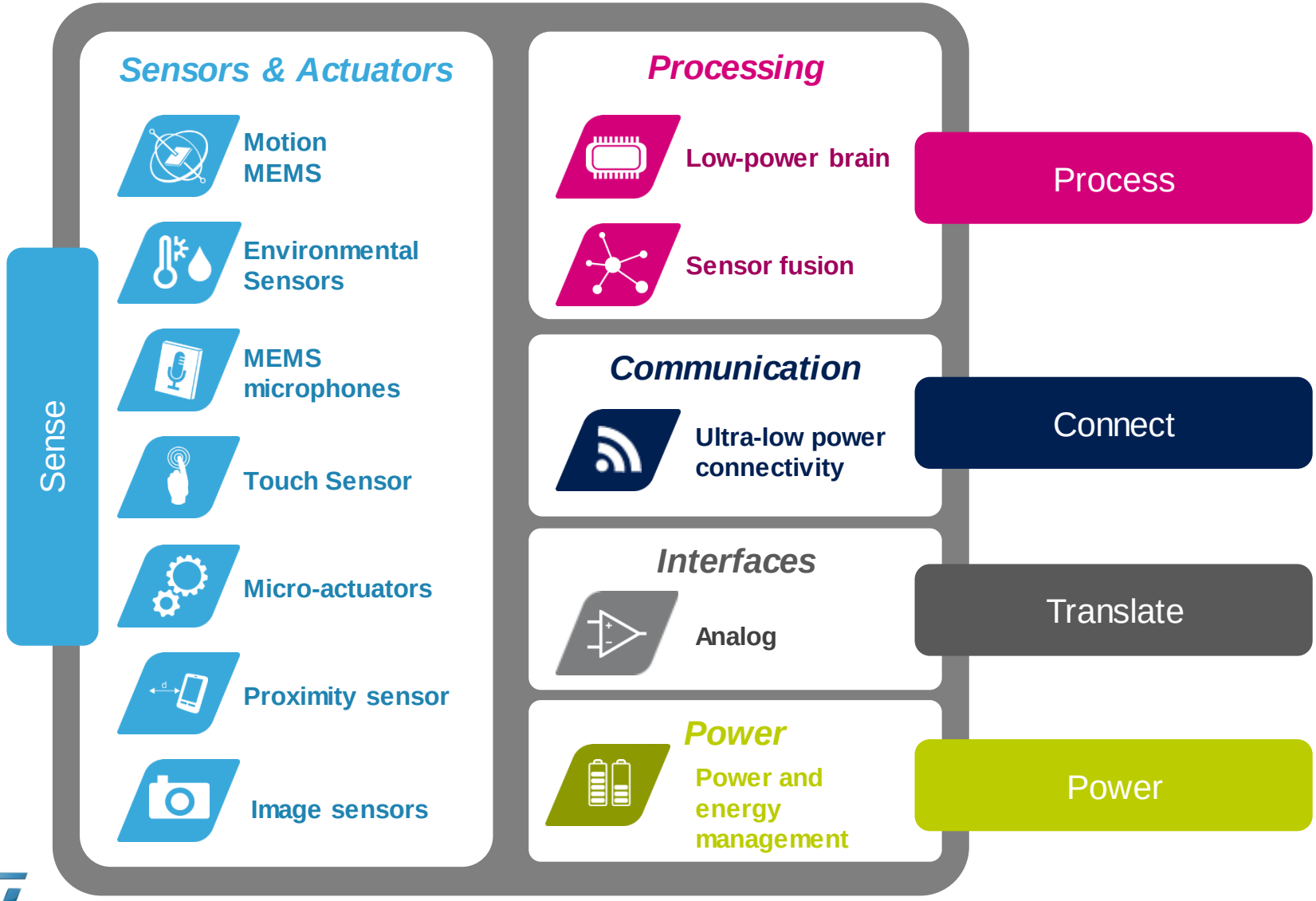
The Building Blocks are already here



IoT Products & ST offering

ST has a unique portfolio with all the key technologies and products

- Sensors
- Ultra-low power connectivity
- Ultra Low Power Microcontrollers
- Analog and mixed signal components
- Smart Energy Management
- Dev. Tools

Smart Industrial

Smart City

Smart Street Lights

Smart Meters

Environment smart node

Smart parking systems

Healthcare

Activity monitor

Heart rate and EGC monitor

Blood Pressure monitor

Smart Home

Home safety systems

Home automation & remote controls

Environment smart nodes

Fitness & Wellness

Activity Monitor

Smart watch / glass

OHRM

Smart Clothing

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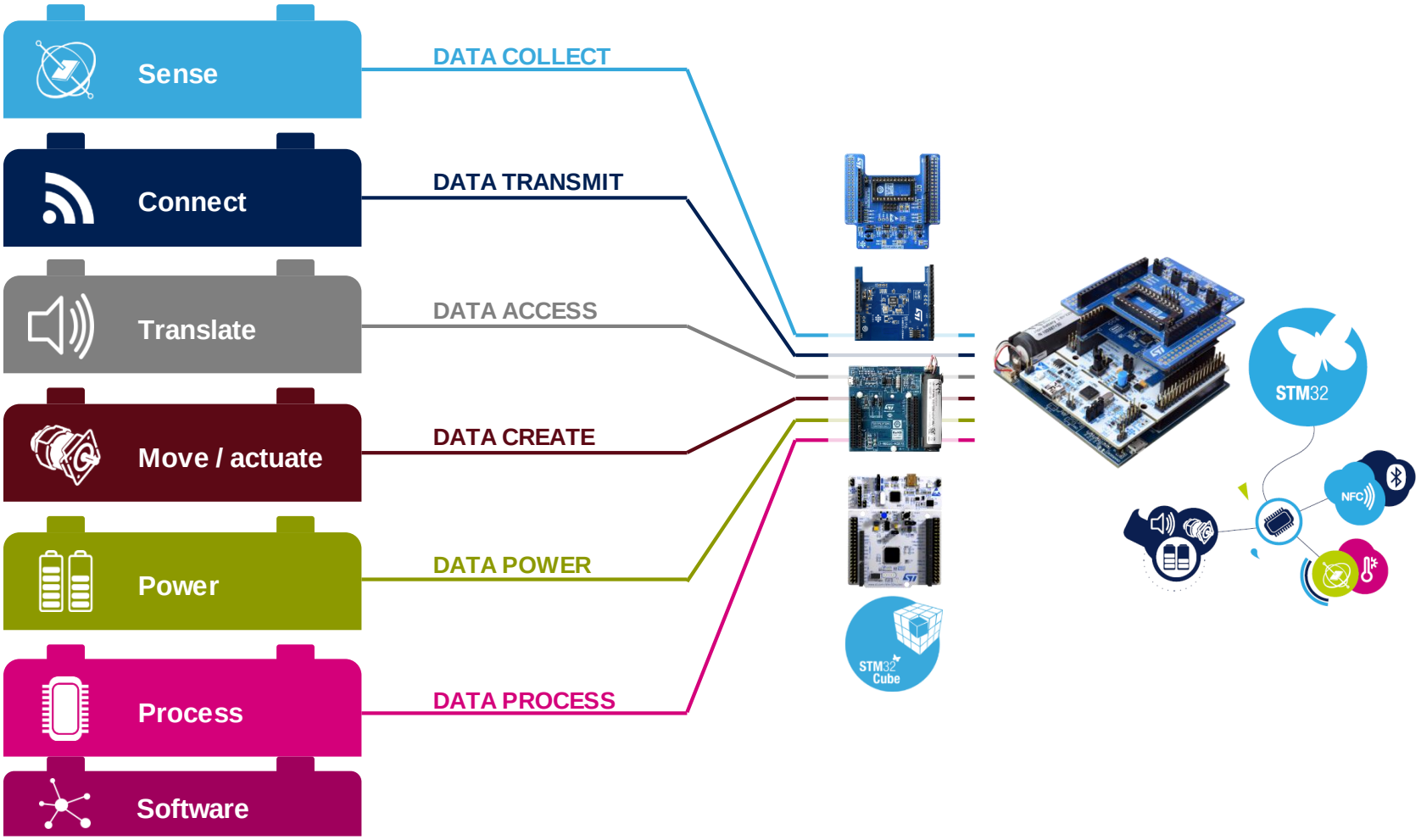
STM32 Nucleo Ecosystem

Building block approach

The building blocks | Your need | Our answer



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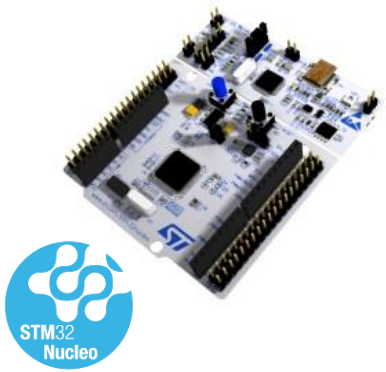
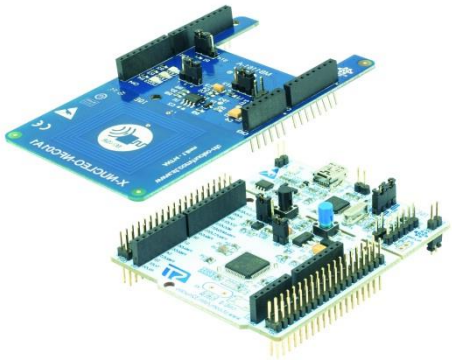
STM32 Nucleo Ecosystem
Hardware Components

STM32 Nucleo Development Boards

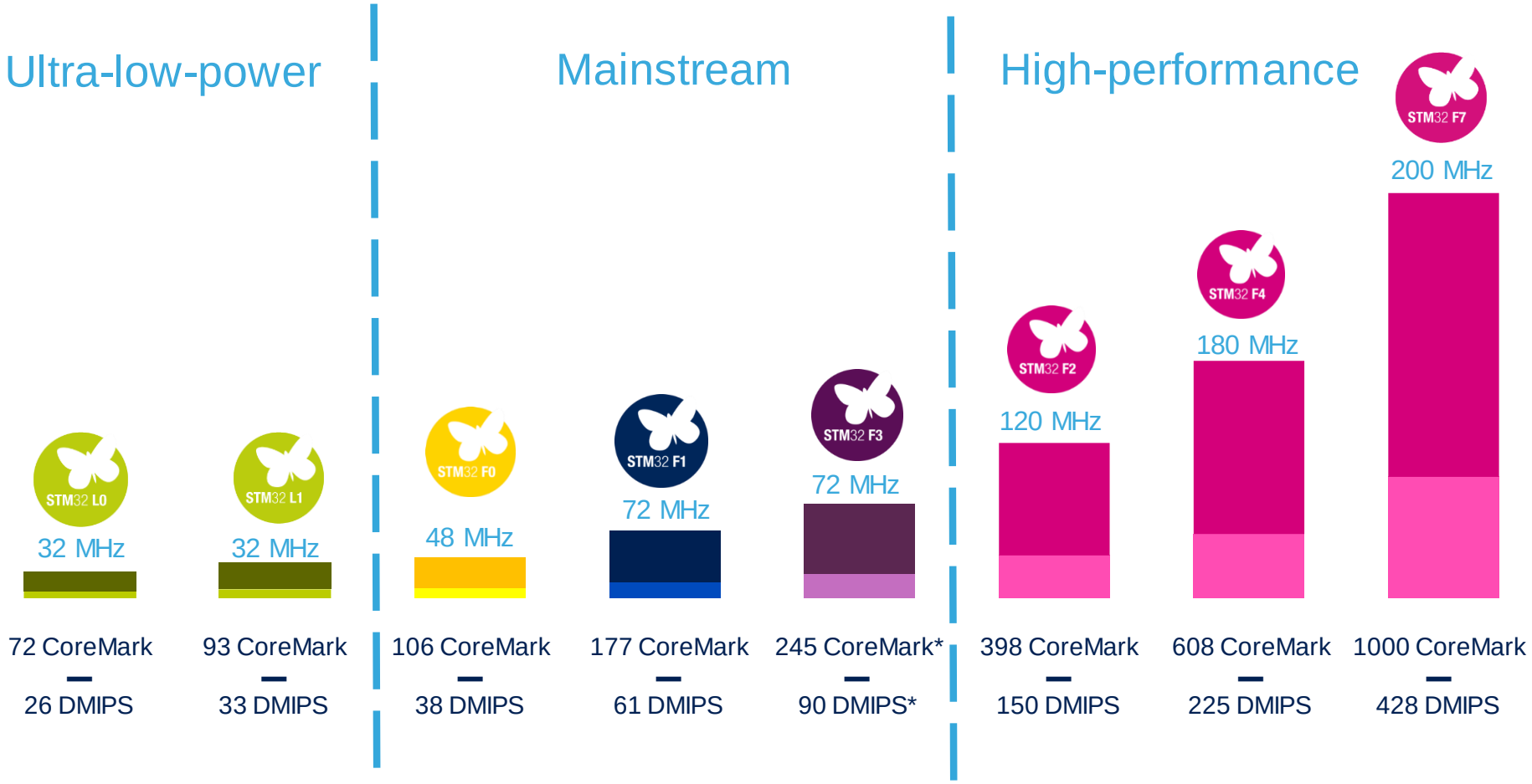
- Based on ST's 32-bit ARM Cortex-M based STM32 microprocessors
- Development boards for all STM32 families available or planned



- **STM32 Nucleo Expansion Boards**
  - Boards with additional functionality: sensing, connectivity, power, analog
  - Plugged on top or bottom of the STM32 Nucleo developer board or stacked on top of other expansion boards
  - Leveraging ST wide product portfolio



STM32 Wide Product Offer



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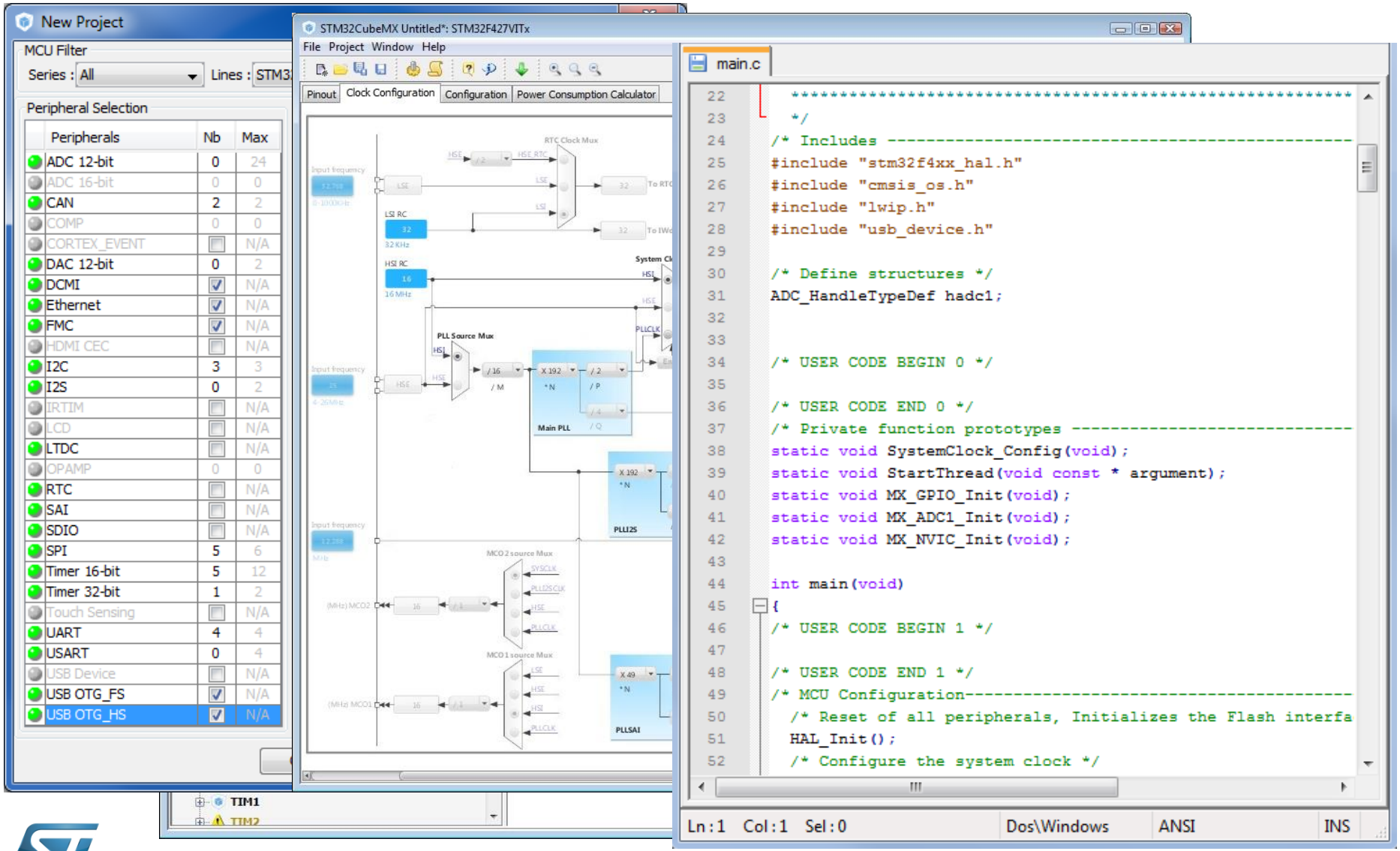
STM32 Nucleo Ecosystem
Software Components

- **STM32Cube**
  - A set of free of charge tools and embedded Software bricks to enable fast and easy development on the STM32
    - PC-based STM32CubeMX for graphical configuration of the STM32
    - Hardware Abstraction Layer for easy porting from one STM32 device to another
    - Middleware bricks for the most common functions
    - Hundreds of code use examples are also included

- **STM32Cube Expansion Software**
  - Free of charge for every STM32 Nucleo expansion boards
- **Multiple Development Environments**
  - Compatible with a number of Development Environments including IAR EWARM, Keil MDK, mbed and GCC-based IDEs
- **Develop community and support**
  - Online communities, Development tools, documentation and user guides etc.

STM32CubeMX Configurator



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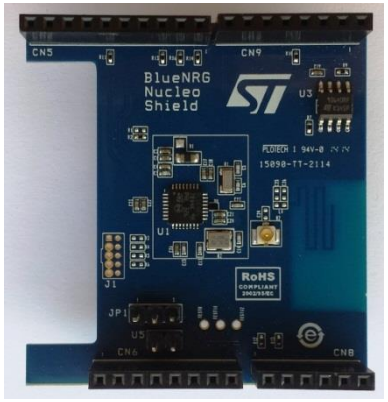
STM32 Nucleo Expansion board examples



Bluetooth

Bluetooth Low Energy Expansion Board based on BlueNRG

Available Now

NFC

Dynamic NFC tag Expansion Board based on M24SR

Available Now

Stepper Motor Driver

Stepper motor driver expansion board based on easySPIN™ L6474

Available Now

Motion & Environmental

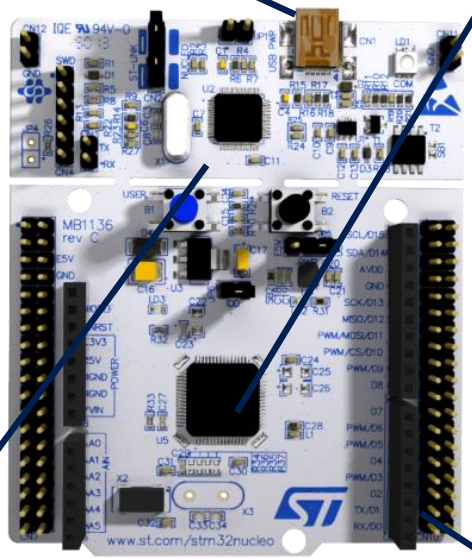
LSM6DS0 3-axis accelerometer + 3-axis gyroscope, the LIS3MDL 3-axis magnetometer, the HTS221 humidity sensor and the LPS25H pressure sensor.

Available Now

STM32 Nucleo Development Board

Flexible power supply through USB or external source

Integrated debugging and programming probe



STM32 microcontroller

STM32 F2 STM32 F4 STM32 F7

STM32 F0 STM32 F1 STM32 F3

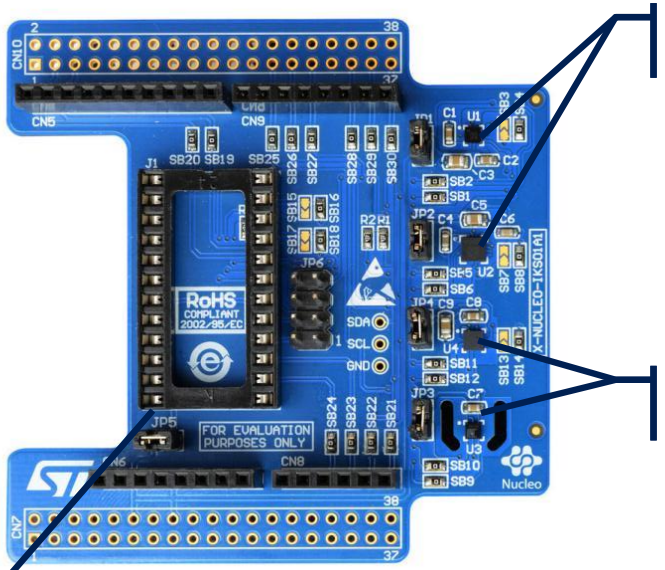
STM32 L0 STM32 L1

complete product range from ultra-low power to high-performance

Morpho and Arduino™ expansion headers

Sensor Expansion Board
X-NUCLEO-IKS01A1

Available now



Motion MEMS sensors

LIS3MDL **LSM6DS0**

Environmental sensors

LPS25H **HTS221**

DIL24 support for new devices i.e. **LSM6DS3**

www.st.com/mems

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ST free Apps for MEMS

Open.MEMS MotionFX went live Nov.11, 2014

www.st.com/openmems

Open.MEMS flow

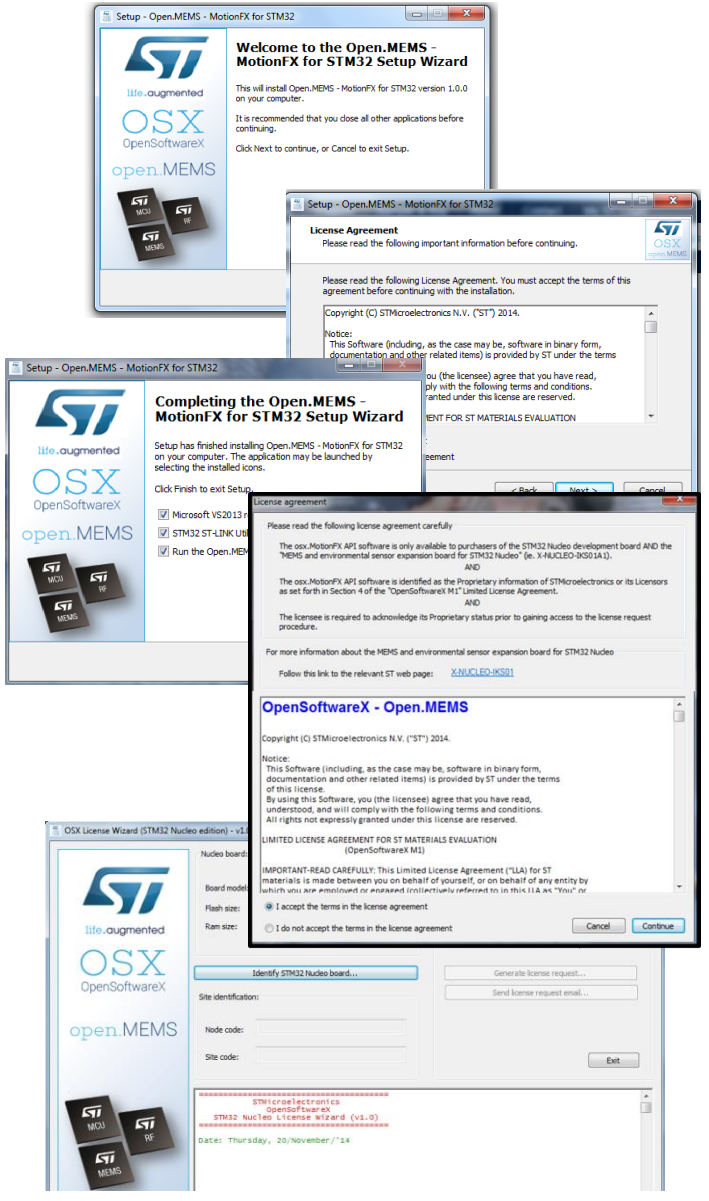
- **Download and execute X-CUBE-MEMS2 from ST Web**

  (http://www.st.com/web/en/catalog/tools/FM147/CL1818/SC1998/PF261431#)

- **Follow the Wizard instructions**
- **Read and accept the license agreement to install the SW**

- **Run the license wizard**

- **Connect the Nucleo board and generate the sensor fusion license request**



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STM32 Nucleo Expansion Boards

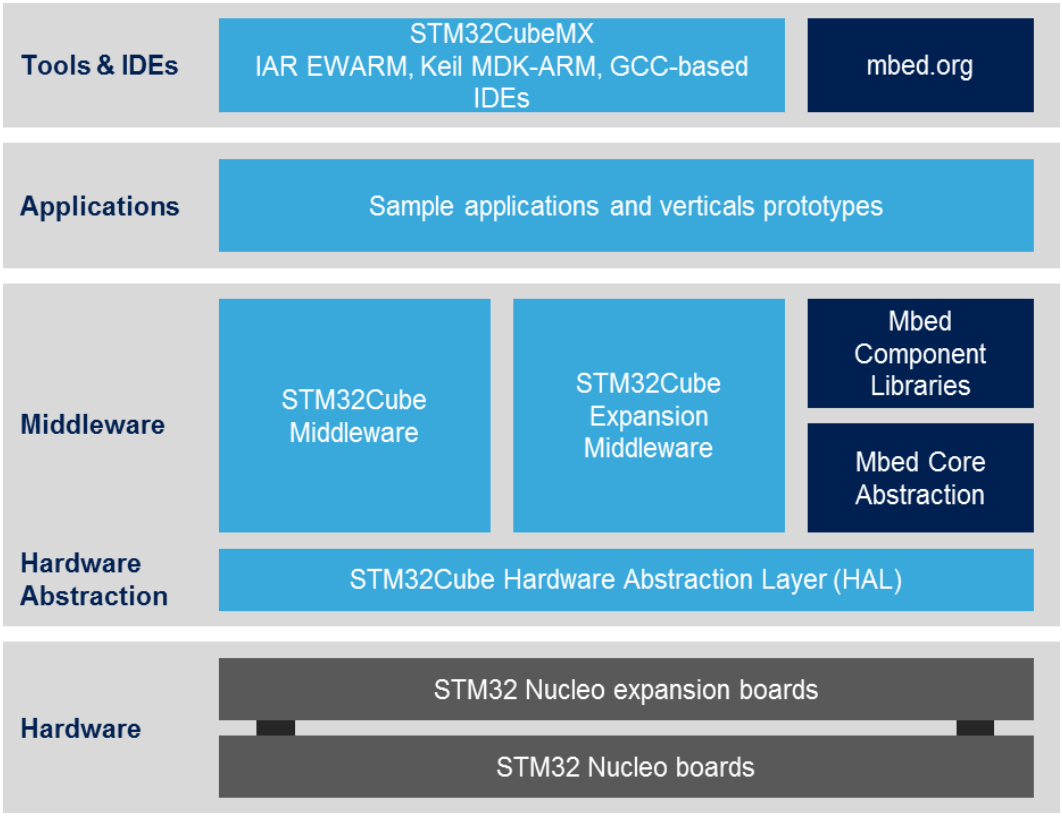
Addressing the Functional Needs

What do you want to do?	What you need	Availability
Sense motion, pressure, humidity, temperature, light, sound	Motion sensors	ST (Q4 2014)
	Environmental sensors	ST (Q4 2014)
	Proximity sensors	ST (Q4 2014)
	Microphone	ST (Q1 2015)
Connect wireless or wired	Bluetooth Low Energy	ST (available now)
	Wi-Fi	ST (Q1 2015)
	Sub-GHz radio	ST (Q4 2014)
	NFC	ST (available now)
	GNSS	ST (H1 2015)
	Cellular	Third party
	Ethernet	Third party
Move/actuate	Stepper motor driver	ST (available now)
	DC & BLDC motor driver	ST (Q1 2015)
	Relay	Third party
Power	Energy management & battery	ST (Q1 2015)
Translate	Audio amplifier	ST (Q4 2014)
	OpAmp	ST (Q1 2015)

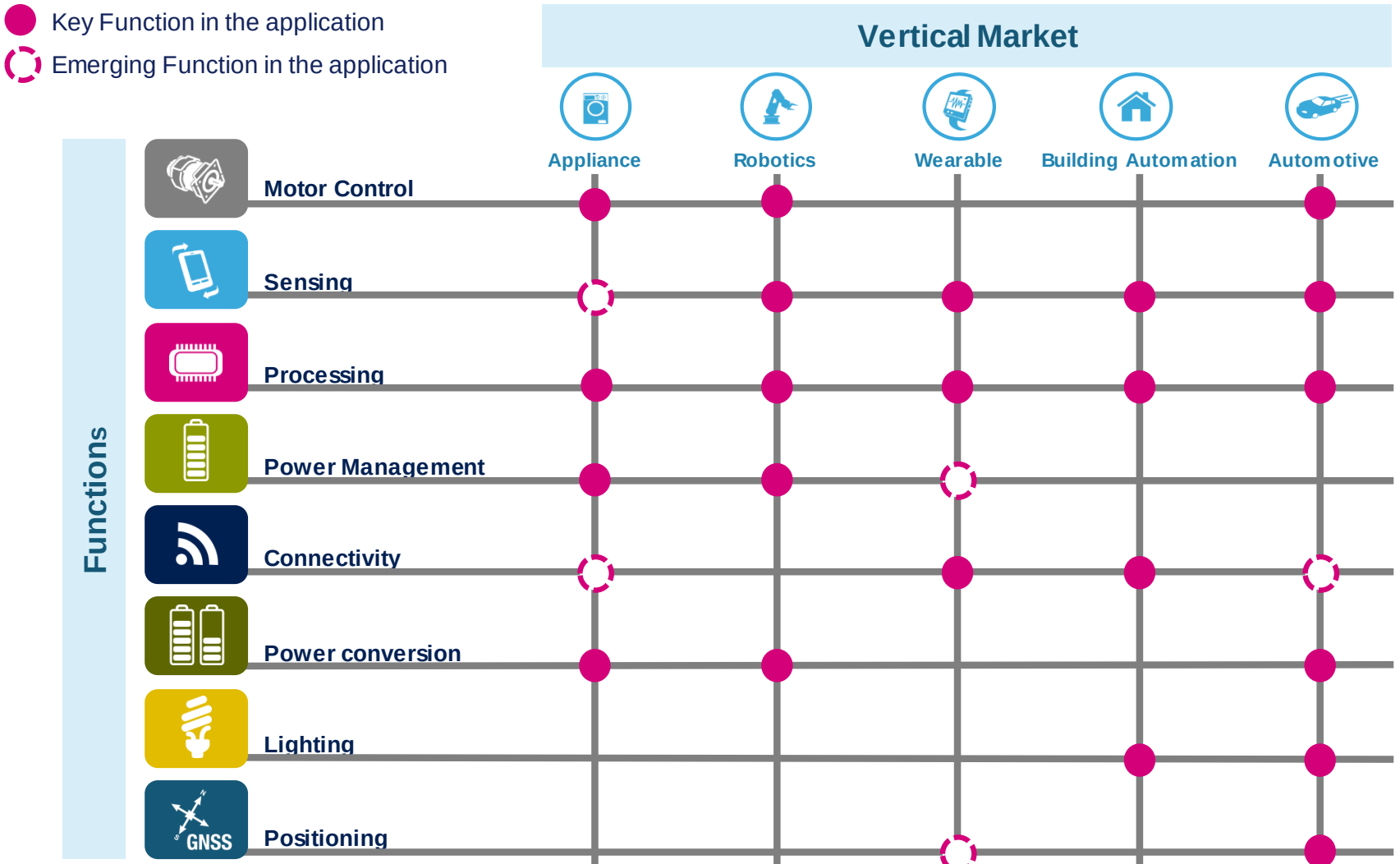
STM32Cube Expansion SW

Each Nucleo Expansion board leverages STM32Cube expansion SW that enables users to start coding their application from day one

- Cube HAL pre-integrated drivers
- Specific middleware libraries
- Relevant application examples, with ready-made IDE projects
- Example of “vertical prototypes” integrating functionalities from several expansion boards/SW
- Released in source code with permissive license (with a few exceptions)



Serving the needs of vertical markets



Lowering the Barriers for Developers

Easy Access to technology

Idea

Rapid
Device & SW
Development

Closer to final
Form factor
Device

Field
Test

Final
Device
Form factor

Production
SW

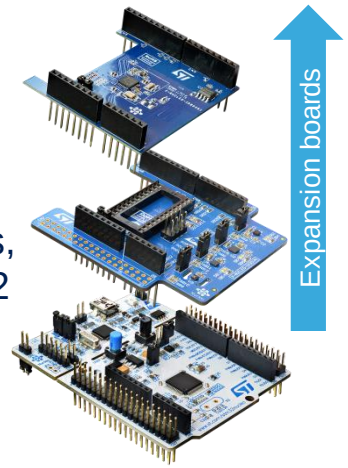
Market

Fast, flexible, affordable and based on commercial components

Ready to Use Solutions for Vertical Markets

Rapid Prototyping with STM32 Nucleo Development Ecosystem

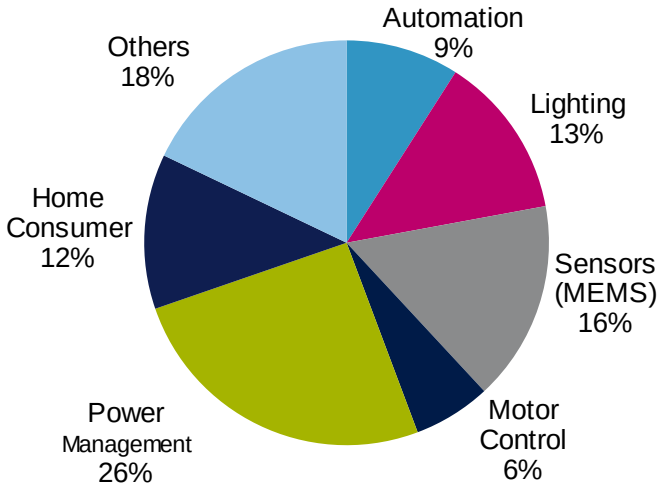
- Modular hardware enables broad deployment through a standardized development framework
- Stack multiple expansion boards to add power management, sensors, connectivity and more to the STM32 Nucleo development boards
- Intuitive software tools offer code examples and documentations to get up and running quickly
- Price competitive boards



STM32 Nucleo

STM32 Cube

A wide offer of evaluation boards (STEVAL) to address Vertical Markets



>410 Evaluation Boards

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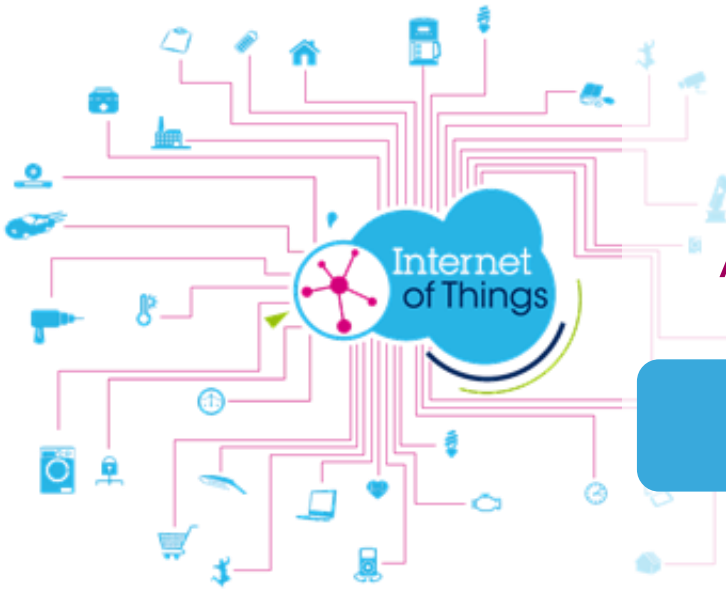
Takeaways

Big opportunity as electronics penetrate new sectors with the IoT



Little electronics skills

Need easy access

All the key components are already here

ST has a solution to make access to electronics easy

Fast

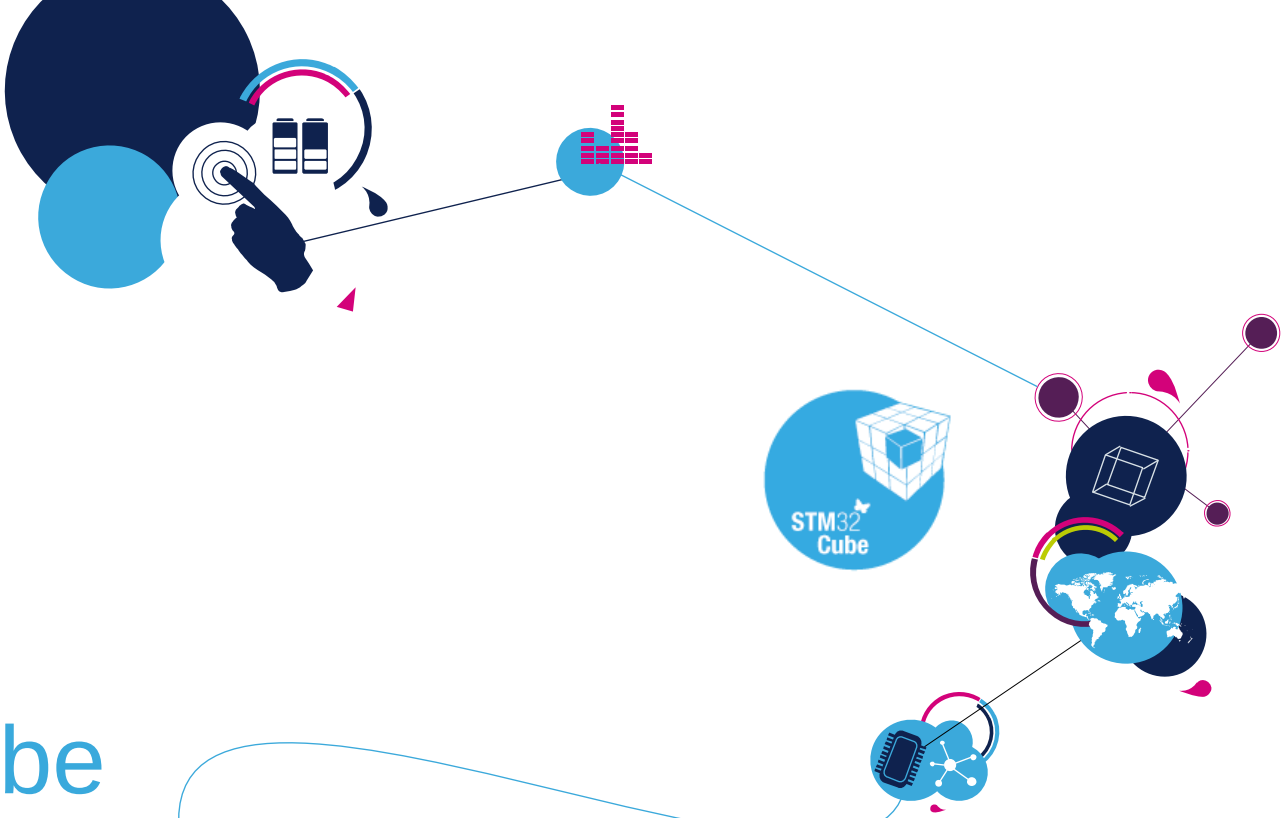
Easy

STM32 Nucleo Ecosystem

Open licenses

Affordable

Commercial grade components



STM32Cube

STM32Cube FW solution presentation with focus on HAL and STM32CubeMx

Slim Jallouli

slim.jallouli@st.com

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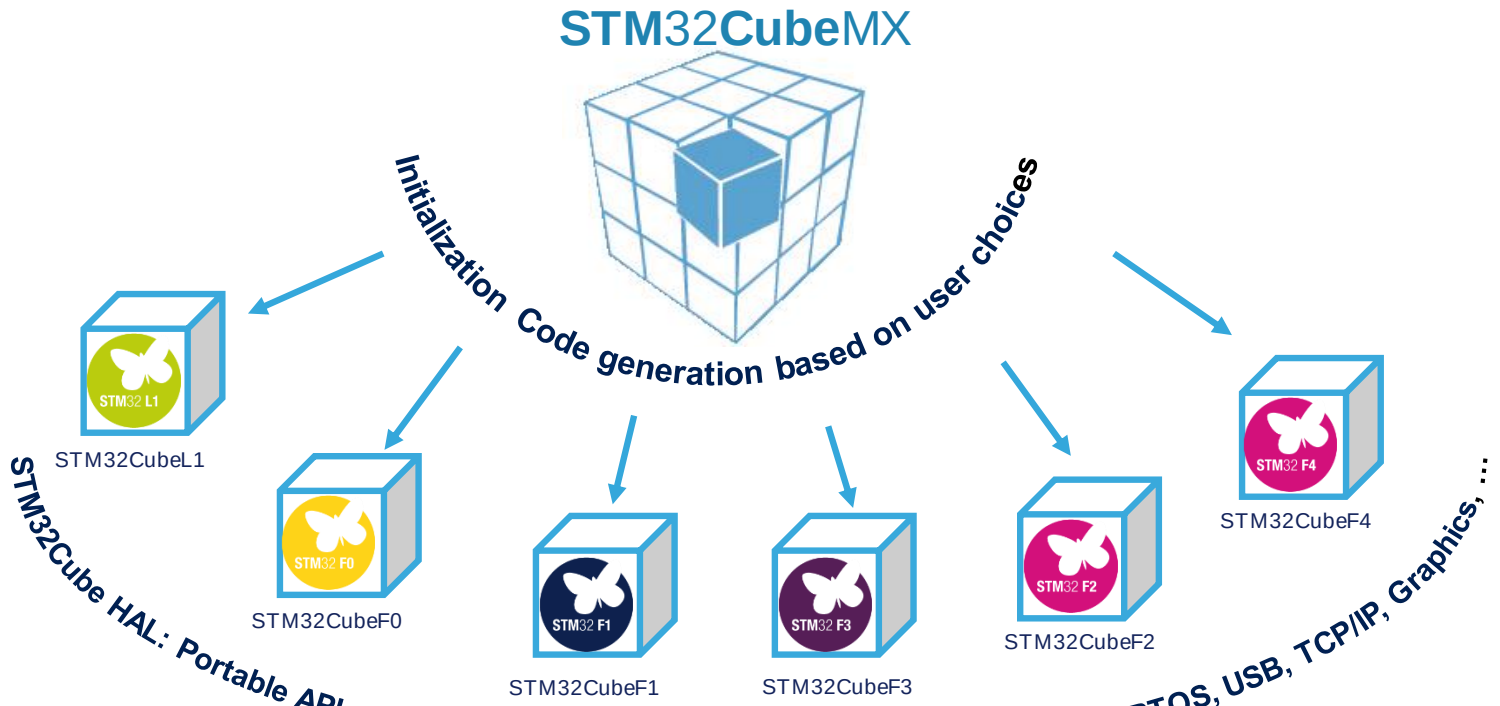
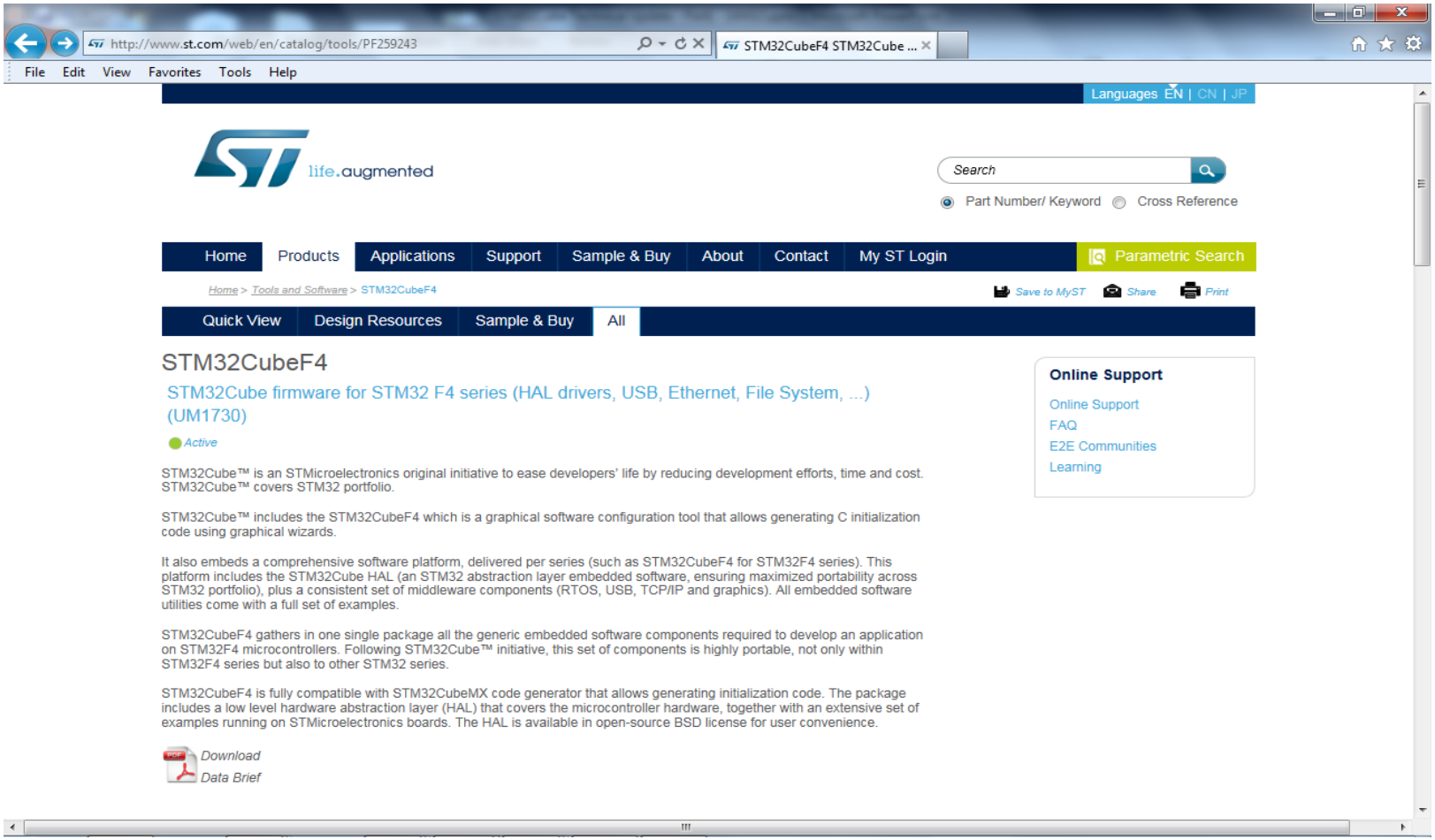
STM32Cube™ Introduction

- STM32Cube™ includes:
  - A configuration tool, STM32CubeMX generating initialization code from user choices
  - A full embedded software offer, delivered per series (like STM32CubeF4) with:
    - An STM32 Abstraction Layer embedded software: STM32Cube HAL
    - A consistent set of Middlewares: RTOS, USB, TCP/IP, Graphics, …



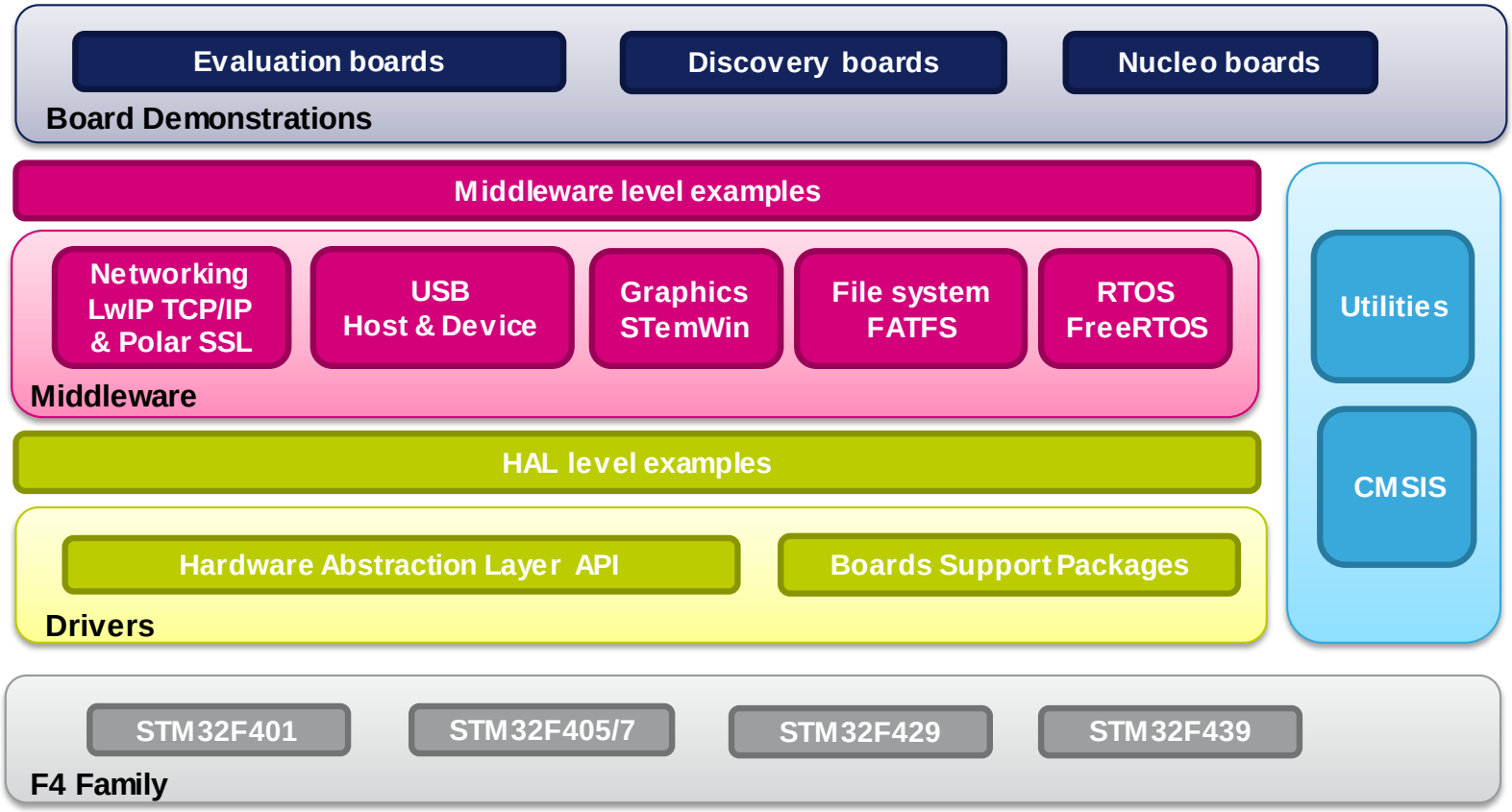
Link for STM32CubeF4

http://www.st.com/web/en/catalog/tools/PF259243

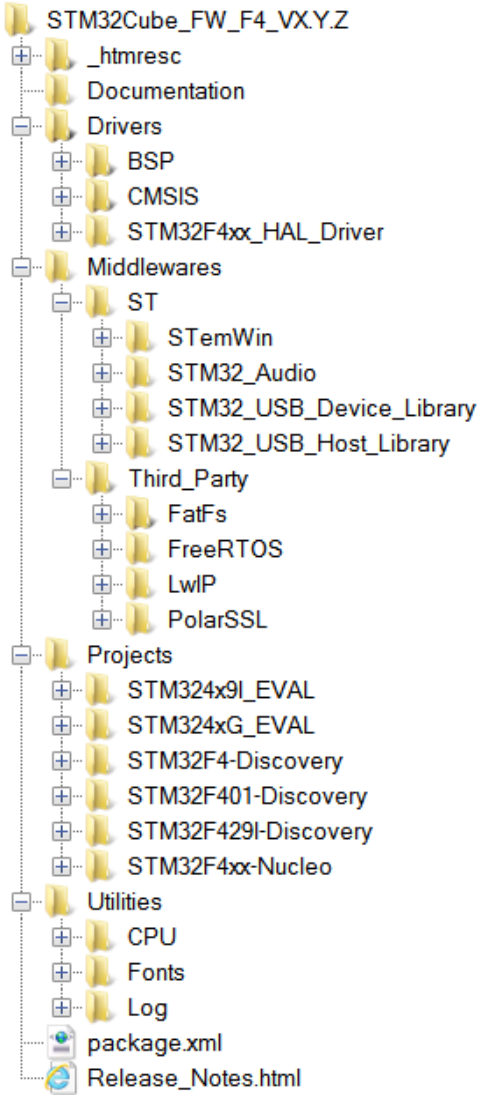


STM32Cube FW package presentation

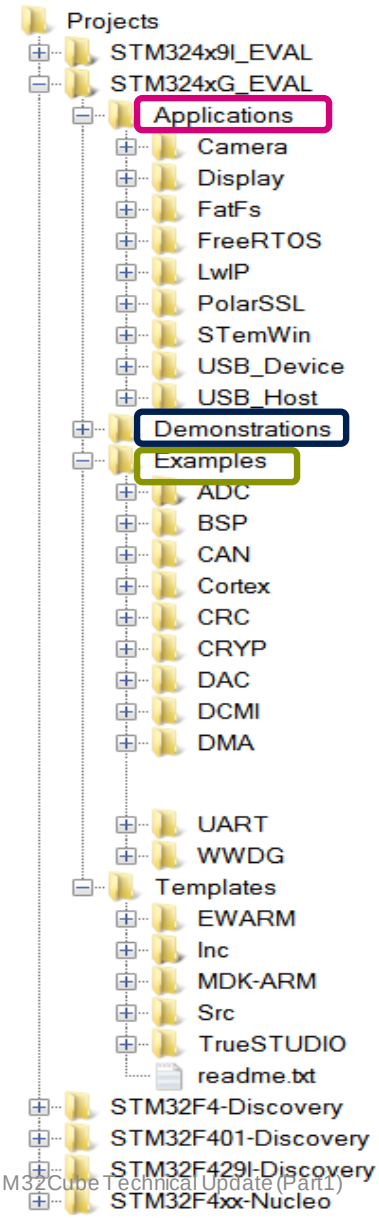
STM32Cube FW package block view



STM32Cube folders organization



STM32Cube projects folder organization



STM32Cube versioning and maintenance

- STM32Cube_FW_[Product family]_VX.Y.Z
  - X: STM32Cube version: V1 « Consistent » (next to come : V2 « Integrated »)
  - Y: major enhancements and/or bug fixes
  - Z: minor enhancements and/or bug fixes
- Components of the STM32Cube have their own version number which can be found in the release note document available with each component
- The STM32Cube FW package will be maintained regularly through
  - Full release
  - Patch release
    - Patches allow to fix or enhance an STM32Cube component (or a set of components)
    - The patch contains new release of the component(s)
    - Any released patch will include all previous patches relative to current STM32Cube release
- The updater tool available with STM32CubeMX PC tool allows automatic notification and download of new STM32Cube release or patch

STM32CubeF4 Documentation Status

- UM1730 Getting Started with STM32Cube Firmware package for STM32F4xx series ➔ Available on the web
- UM1721 Developing Applications on STM32Cube with FatFs ➔ Available on the web
- UM1722 Developing Applications on STM32Cube with RTOS ➔ Available on the web
- UM1725 HAL Driver ➔ Will be available on the web 14W14
- UM1734 STM32Cube USB Device library ➔ Will be available on the web 14W14
- UM1720 STM32Cube USB Host library ➔ Will be available on the web 14W15
- UM1723 STM32Cube PolarSSL example ➔ Will be available on the web 14W13
- UM1709 STM32Cube Ethernet IAP example ➔ Will be available on the web 14W13
- UM1713 STM32Cube interfacing with LwIP and examples ➔ Will be available on the web 14W13
- UMxxxx How to migrate an STM32 Application from StdLib to STM32Cube ➔ Will be available on the web 14W14
- UMxxxx STM32CubeF4 Demonstration ➔ Will be available on the web 14W14

STM32Cube Hardware Abstraction Layer (HAL)

HAL overview

HAL overview
Introduction to HAL

- The STM32Cube Hardware abstraction layer (HAL) replaces the standard peripheral library
- The hardware abstraction allows to offer
  - **User friendly and portable APIs** that hides the HW complexity
  - **An easy and quick migration** of user's application from a product family to another
- The HAL covers all product peripherals including advanced peripherals like USB, Ethernet,…
- The HAL comes with an extensive set of examples running on available boards (evalboard, discovery, Nucleo) with ready projects for three toolsets (IAR, Keil, Attolic)
- All HAL drivers passed CodeSonar C code verification tool

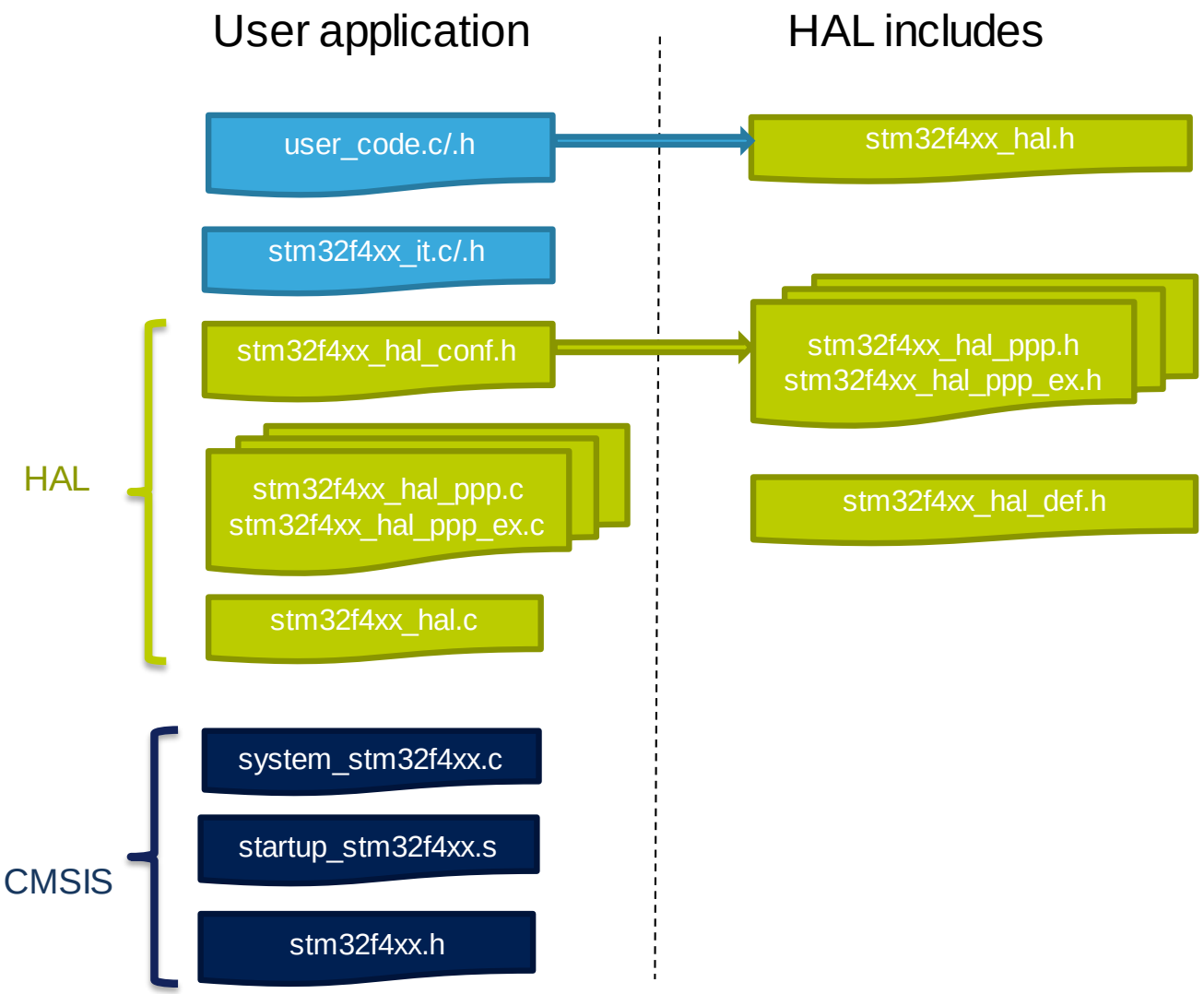
HAL overview
HAL APIs main features

- Cross-family portable API set for the common peripheral features and extension APIs in cases of specific peripheral features
- HAL drivers support three API programming models : polling, interrupt and DMA
- APIs are RTOS compliant
  - Fully reentrant APIs
  - Systematic usage of timeouts when doing polling
- Peripheral multi-instance support
  - Allows concurrent API call for different instance of a peripheral (USART1, USART2,..)
- HAL APIs implement user callback functions mechanism
  - Peripheral Init/DeInit HAL APIs call user callback function to do peripheral system level intialization/DeInitialization (clock, GPIOs, interrupt, DMA)
  - Peripherals interrupt events
  - Error events

HAL overview
HAL file components

File	Description
stm32f4xx_hal_ppp.c/.h	peripheral driver with portable APIs
stm32f4xx_hal_ppp_ex.c/.h	extended peripheral features APIs
stm32f4xx_hal.c	contains HAL common APIs (HAL_Init, HAL_DeInit, HAL_Delay,…)
stm32f4xx_hal.h	HAL header file, it should be included in user code
stm32f4xx_hal_conf.h	config file for HAL, should be customized by user to select the peripherals to be included
stm32f4xx_hal_def.h	contains HAL common typedefs and macros
stm32f4xx_ll_ppp.c	implements low level functions in case of some complex peripherals, they are called from stm32f4xx_hal_ppp.c

HAL overview
HAL inclusion in user application



HAL common APIs

- Implemented in file stm32f4x_hal.c, main APIs are
  - HAL_Init() , need to be called at application startup
    - Initializes data/instruction cache and pre-fetch queue
    - Sets Systick to generate interrupt each 1ms (based on HSI clock) with lowest priority
    - Sets priority grouping to 4 preemption bits
    - Calls function HAL_MspInit() which a is user callback function to do system level initializations (clocks, gpios, DMA, interrupts). HAL_MspInit() is defined as “weak” empty function in HAL
  - HAL_DeInit()
    - Resets all peripherals
    - Calls function HAL_MspDeInit() which a is user callback function to do system level De-Initalizations
  - HAL_GetTick()
    - Get current tick counter (incremented in systick interrupt)
    - Used by peripherals drivers to handle timeouts
  - HAL_Delay()
    - Implements a delay in ms (using systick)
- Note: in some particular cases systick interrupt priority need to be changed in order to handle delay management inside peripherals interrupt handlers/callbacks

HAL system peripherals

HAL system peripherals
RCC HAL driver

- Two main functions for clock configuration
  - HAL_RCC_OscConfig (RCC_OscInitTypeDef *RCC_OscInitStruct)
    - Configures/Enables multiple clock sources (HSE, HSI, LSE, LSI, PLL)
  - HAL_RCC_ClockConfig (RCC_ClkInitTypeDef *RCC_ClkInitStruct, uint32_t FLatency)
    - Selects system clock source
    - Configures AHB, APB1 and APB2 clock dividers
    - Configures Flash wait states
    - Updates systick config following HCLK clock changes
- Other functions in RCC HAL driver include
  - Clock de-init function HAL_RCC_DeInit() : allows to return to reset state clock configuration
  - Get clock functions to get various clock configs (system clock, HCLK, PCLK1, PCLK2, …)
  - MCO config function
- A set of macros are defined in stm32f4xx_hal_rcc.h
  - Allow elementary operations on RCC block registers like for example peripherals clock gating/reset control
    - Peripheral clock enable/disable: __SPI1_CLK_ENABLE() / _DISABLE()
    - Peripheral reset control : __SPI_FORCE_RESET() / _RELEASE_RESET()

HAL system peripherals
GPIO HAL driver

- GPIO HAL APIs are
  - HAL_GPIO_Init() / HAL_GPIO_DeInit()
  - HAL_GPIO_ReadPin() / HAL_GPIO_WritePin ()
  - HAL_GPIO_TogglePin ()

- In addition to standard modes for GPIO (input, output, analog), pin mode can be configured as EXTI with interrupt or event generation
  - When selecting EXTI mode with interrupt generation, user need to call HAL_GPIO_EXTI_IRQHandler() from stm32f4xx_it.c file and implement callback function HAL_GPIO_EXTI_Callback()

- GPI0_InitTypeDef stucture

```
/**
  * @brief   GPIO Init structure definition
  */
typedef struct
{
  uint32_t Pin;       /*!< Specifies the GPIO pins to be configured.
                           This parameter can be any value of @ref GPIO_pins_define */

  uint32_t Mode;      /*!< Specifies the operating mode for the selected pins.
                           This parameter can be a value of @ref GPIO_mode_define */

  uint32_t Pull;      /*!< Specifies the Pull-up or Pull-Down activation for the selected pins.
                           This parameter can be a value of @ref GPIO_pull_define */

  uint32_t Speed;     /*!< Specifies the speed for the selected pins.
                           This parameter can be a value of @ref GPIO_speed_define */

  uint32_t Alternate;  /*!< Peripheral to be connected to the selected pins
                            This parameter can be a value of @ref GPIO_Alternat_function_selection */
}GPIO_InitTypeDef;
```

HAL system peripherals
DMA HAL driver

DMA HAL APIs	Description
HAL_DMA_Init	Initializes a DMA channel
HAL_DMA_DeInit	De-initalizes a DMA channel
HAL_DMA_Start	Starts DMA channel
HAL_DMA_Start_IT	Starts DMA channel with interrupt generation at end of transfer or half transfer or on DMA error
HAL_DMA_Abort	Aborts a DMA transfer
HAL_DMA_PollForTransfer	Blocking function that polls for transfer complete or half complete, this function can also return a Timeout or a DMA error
HAL_DMA_IRQHandler	Interrupt handler for DMA
HAL_DMA_GetState	Gets DMA channel state
HAL_DMA_GetError	Gets DMA error code

HAL system peripherals
Cortex HAL driver

- Cortex HAL driver provides APIs for handling NVIC and Systick, supported APIs include
  - HAL_NVIC_SetPriorityGrouping
  - HAL_NVIC_SetPriority
  - HAL_NVIC_EnableIRQ /HAL_NVIC_DisableIRQ
  - HAL_SYSTICK_Config
  - HAL_SYSTICK_CLKSourceConfig

HAL system peripherals
PWR HAL driver

- PWR HAL driver handles power management features
  - PVD configuration, enabling/disabling and interrupt handling
    - HAL_PWR_PVDConfig()
    - HAL_PWR_EnablePVD() / HAL_PWR_DisablePVD()
    - HAL_PWR_PVD_IRQHandler()
    - HAL_PWR_PVDCallback()
  - Low power mode entry
    - HAL_PWR_EnterSLEEPMode()
    - HAL_PWR_EnterSTOPMode()
    - HAL_PWR_EnterSTANDBYMode()
- Extension function are available, these are
  - Flash overdrive control and flash power-down (for F429/F439 only)
    - HAL_PWREx_ActivateOverDrive()
    - HAL_PWREx_EnableFlashPowerDown()
  - Backup domain registers enable/disable
    - HAL_PWREx_EnableBkUpReg() / HAL_PWREx_DisableBkUpReg

Peripherals HAL driver model

Peripheral HAL driver model
HAL peripheral Handle

- A handle structure is allocated for each instance of a peripheral
- The handle structure allows to save particular parameters for a peripheral instance (peripherals current config/initialization parameters, global variables, peripheral state, DMA channel handles)
- The handle structure is peripheral dependent, the following is an example for the USART handle (members in green should be initialized before calling function HAL_PPP_Init():

Field	Type	Description
Instance	USART_TypeDef*	Pointer to the register base address
Init	USART_InitTypeDef	USART communication initialization parameters: will be initialized when calling HAL_USART_Init()
pTxBuffPtr	uint8_t*	Pointer to Transmit buffer
pRxBuffPtr	uint8_t*	Pointer to Receive buffer
TxXferSize	uint16_t	Usart Tx Transfer size
RxXferSize	uint16_t	Usart Rx Transfer size
TxXferCount	uint16_t	counter of the transmitted data
RxXferCount	uint16_t	counter of the received data
Lock	HAL_LockTypeDef	Lock object : used internally
State	USART_StateTypeDef	USART peripheral state
ErrorCode	unit8_t	Error code
hdmatx	DMA_HandleTypeDef*	DMA handle for Tx: should be initialized in case DMA will be used for USART transmit operation
hdmarx	DMA_HandleTypeDef*	DMA handle for Rx : should be initialized in case DMA will be used for USART receive operation

Peripheral HAL driver model
Driver API groups

- Peripheral drivers APIs are organized in four groups
  - Initialization and de-initialization functions
  - I/O operation functions
  - Peripheral control functions
  - Peripheral State and Errors functions

API group	examples
Initialization and de-initialization	HAL_USART_Init() HAL_USAR_DeInit()
I/O operation (or process)	HAL_SPI_Receive() HAL_USART_Transmit_DMA()
Peripheral control	HAL_ADC_ConfigChannel() HAL_TIM_OC_ConfigChannel()
Peripheral state and error	HAL_I2C_GetState() HAL_I2C_GetError()

Peripheral HAL driver model
Interrupt handler & callback functions

- Besides the APIs, HAL peripheral drivers implement
  - The peripheral interrupt handler: should be called from stm32f4xx_it.c
  - User callback functions
- User callback functions are defined as empty functions with “weak” attribute they need to be redefined in user code
- Three types of user callbacks functions are defined
  - Peripheral system level initialization/ de-Initialization callbacks: HAL_PPP_MspInit()/_DeInit
  - Process complete callbacks : HAL_PPP_ProcessCpltCallback
  - Error callback: HAL_PPP_ErrorCallback

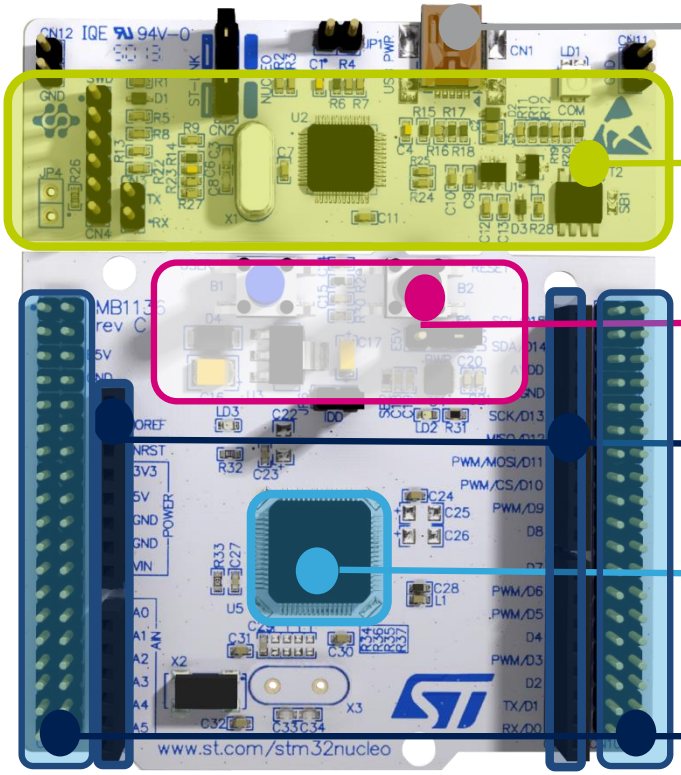
Callback functions	Example
HAL_PPP_MspInit() / _DeInit()	Ex: HAL_USART_MspInit() Called from HAL_PPP_Init() API function to do peripheral system level initialization (GPIOs, clock, DMA, interrupt)
HAL_PPP_ProcessCpltCallback	Ex: HAL_USART_TxCpltCallback Called by peripheral or DMA interrupt handler on process complete
HAL_PPP_ErrorCallback	Ex: HAL_USART_ErrorCallback Called by peripheral or DMA interrupt handler on error occurrence

Peripheral HAL driver model
Process API types

- Blocking polling process APIs
  - blocks until end of process, timeout or error
  - Ex: HAL_USART_Receive()
- Non blocking process APIs
  - Case of Start APIs: exits directly after starting the process
  - Ex: HAL_ADC_Start()
- Non blocking process APIs with peripheral interrupt generation at end of process
  - User notification of end of process or error through user callback functions
  - Ex: HAL_USART_Receive_IT()
- Non blocking APIs with DMA transfer and DMA interrupt generation at end of transfer
  - User notification of end of process or error through user callback functions
  - Ex: HAL_USART_Receive_DMA()
- **Note**: user callbacks are the same in case of peripheral or interrupt DMA
  - Ex: HAL_USART_RxCpltCallback() is called from both peripheral and DMA interrupt handlers

STM32 Nucleo Board

STM32F072 Nucleo Board



Flexible board power supply :
through USB or external source

Integrated ST-Link/V2-1:
mass storage device flash programming + USB Virtual Com Port

2 push buttons, 2 color Leds

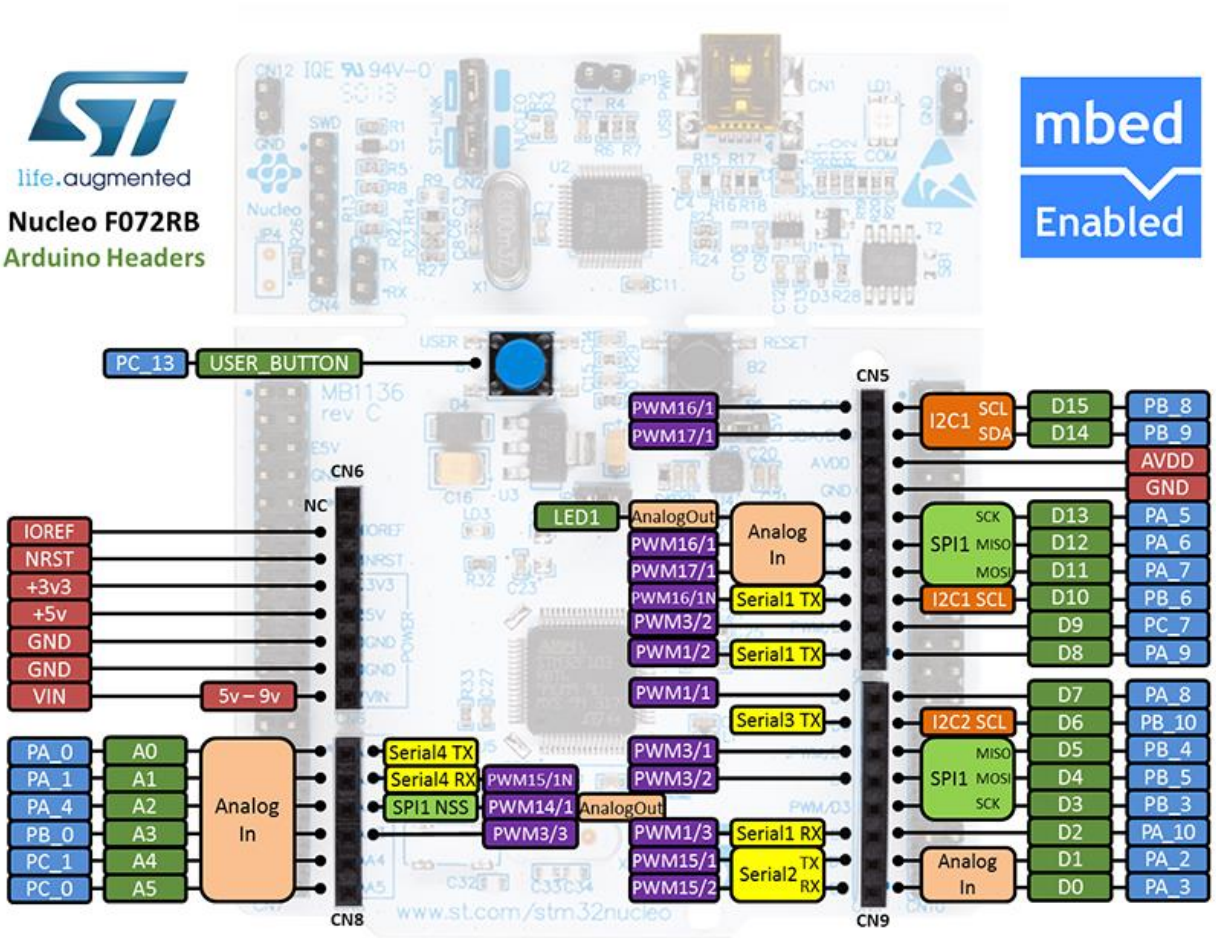
Arduino extension connectors :
easy access to add-ons

STM32 MCU with 64 pins

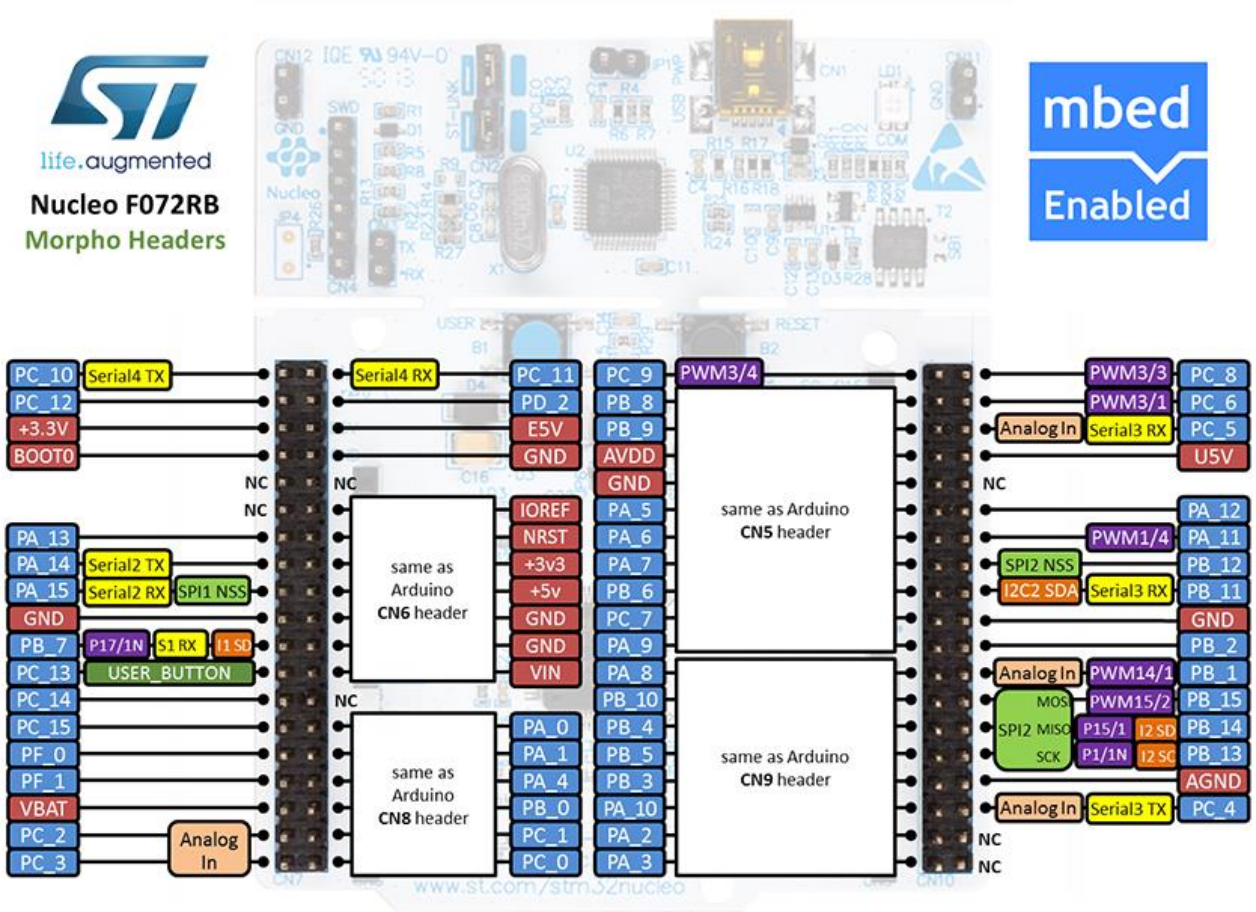
Morpho extension headers :
direct access to all MCU I/Os

www.st.com/stm32nucleo

Arduino Compatible Header



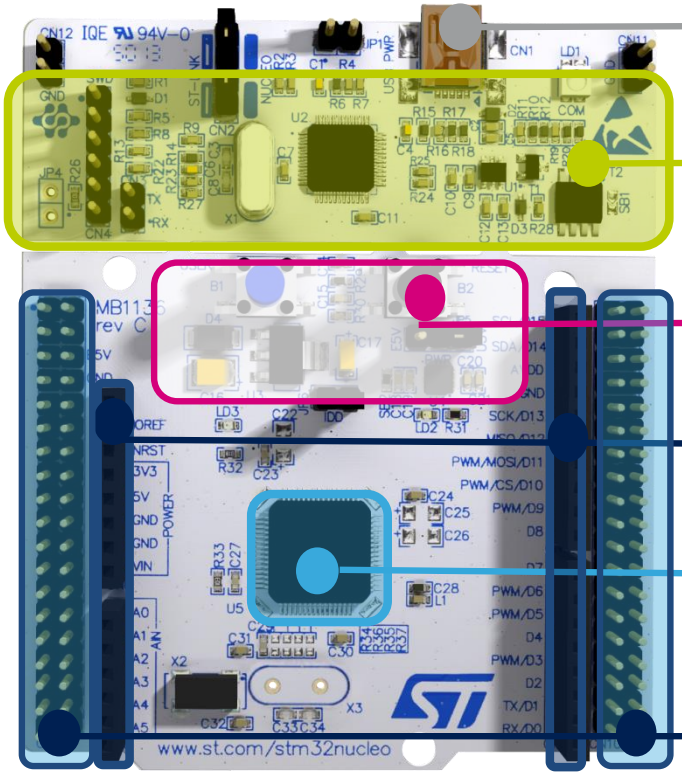
Morpho Headers



STM32CubeMX Demo

Demo and Presentation of mbed

STM32F072 Nucleo Board



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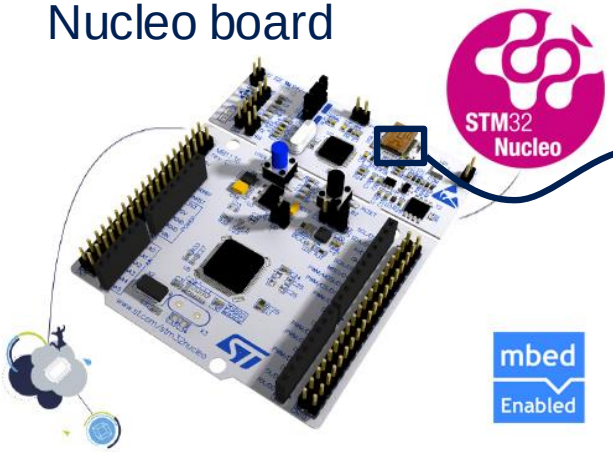
The Development Environment

- This innovative rapid development environment makes it easy for you to quickly create your connected device

STM32
Nucleo board



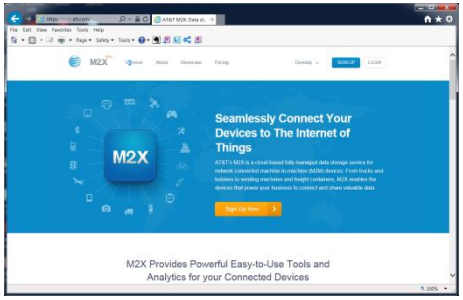
USB cable

Laptop

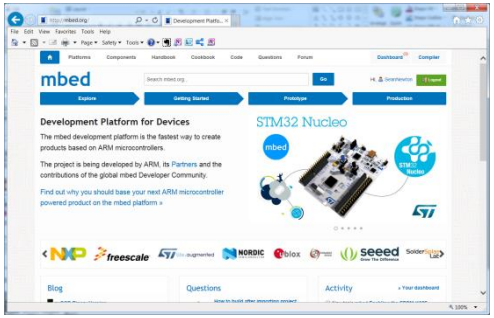
5 Steps to achieve a connected device

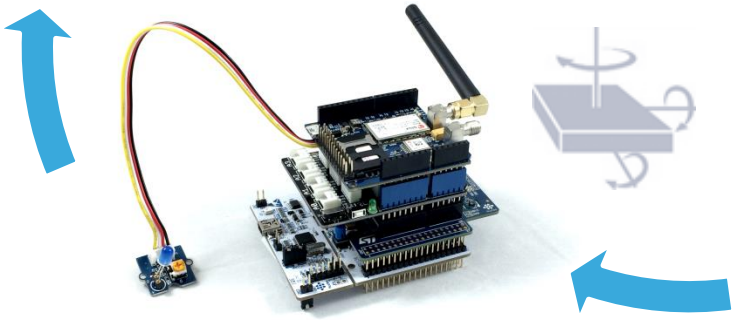
1. You need a Nucleo board and USB cable

2. Go to: http://www.mbed.org and connect to the ST Nucleo platform



5. Connect your device to the cloud (https://m2x.att.com) , phone or other device



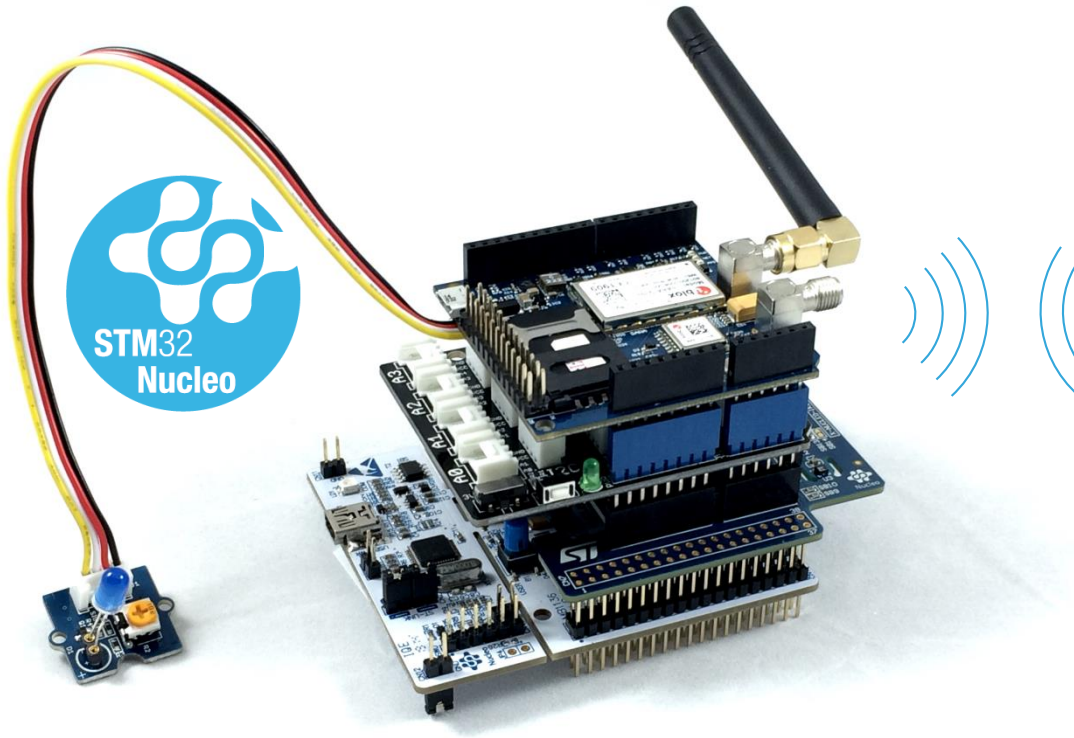


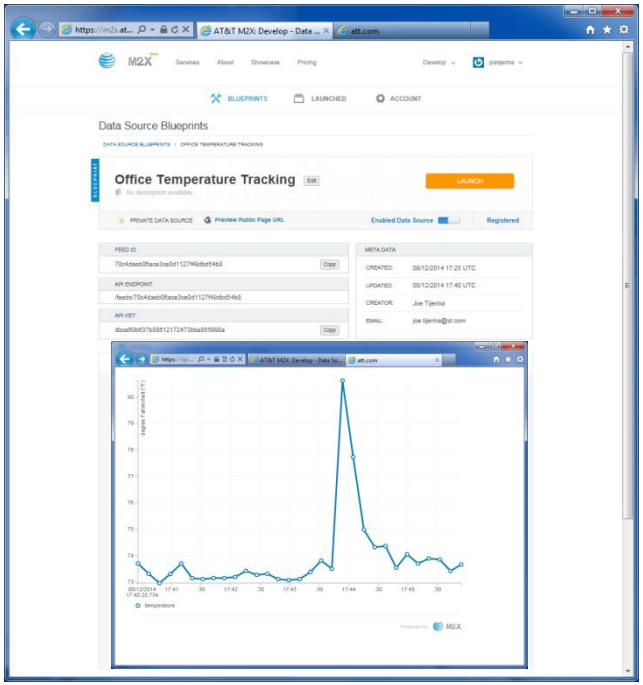
4. Find and attach sensors

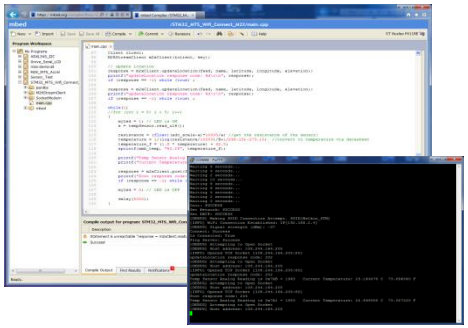
3. Add a connectivity module

life.augmented

The Creature







mbed Enabled

AT&T M2X Cloud Services

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Connectivity and Sensor Options

mbed ready connectivity modules

Bluetooth LE

Cellular Modem

LoRa Radio

NFC Radio

WiFi

- **Sensor and I/O Options**

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