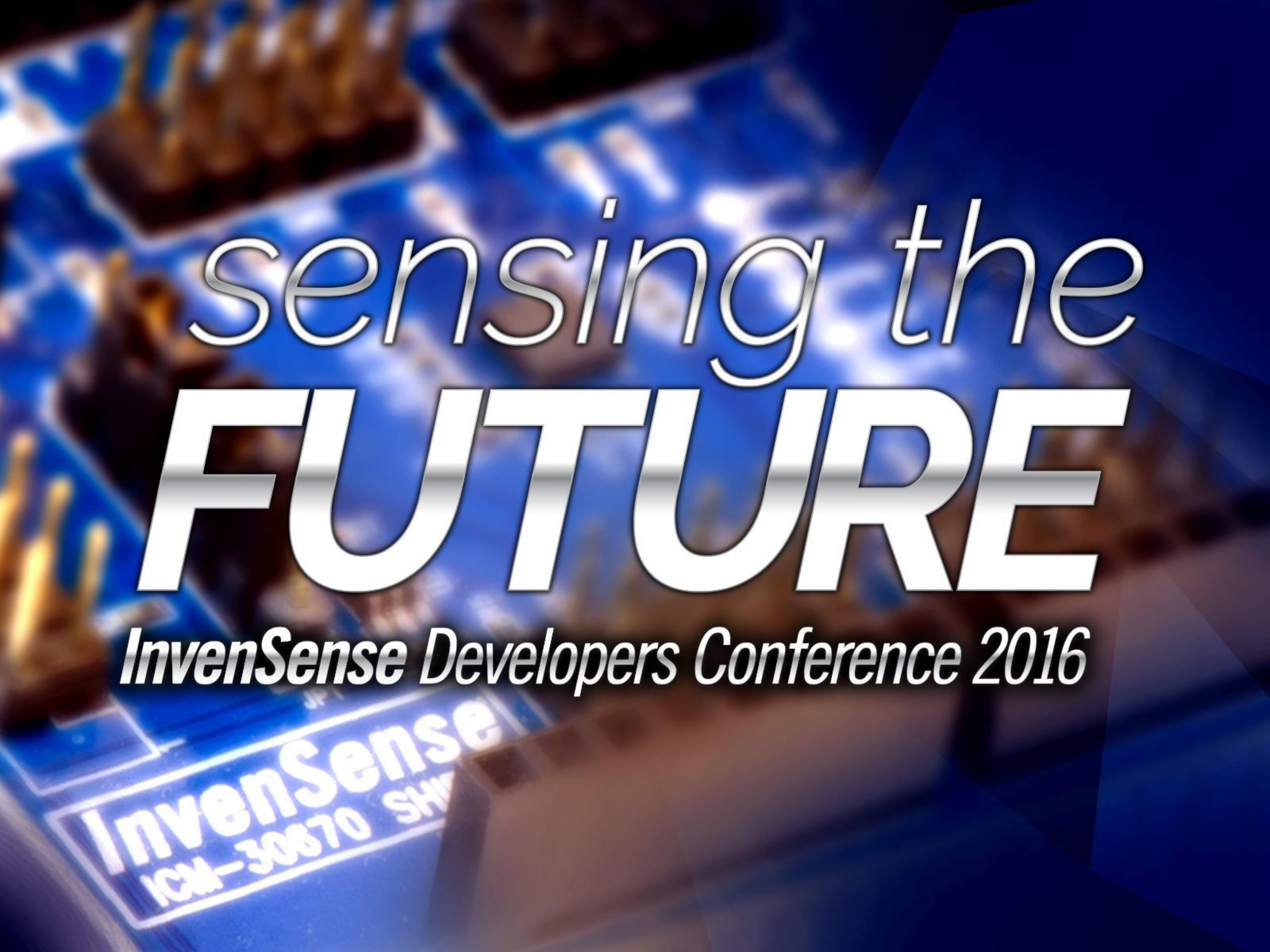
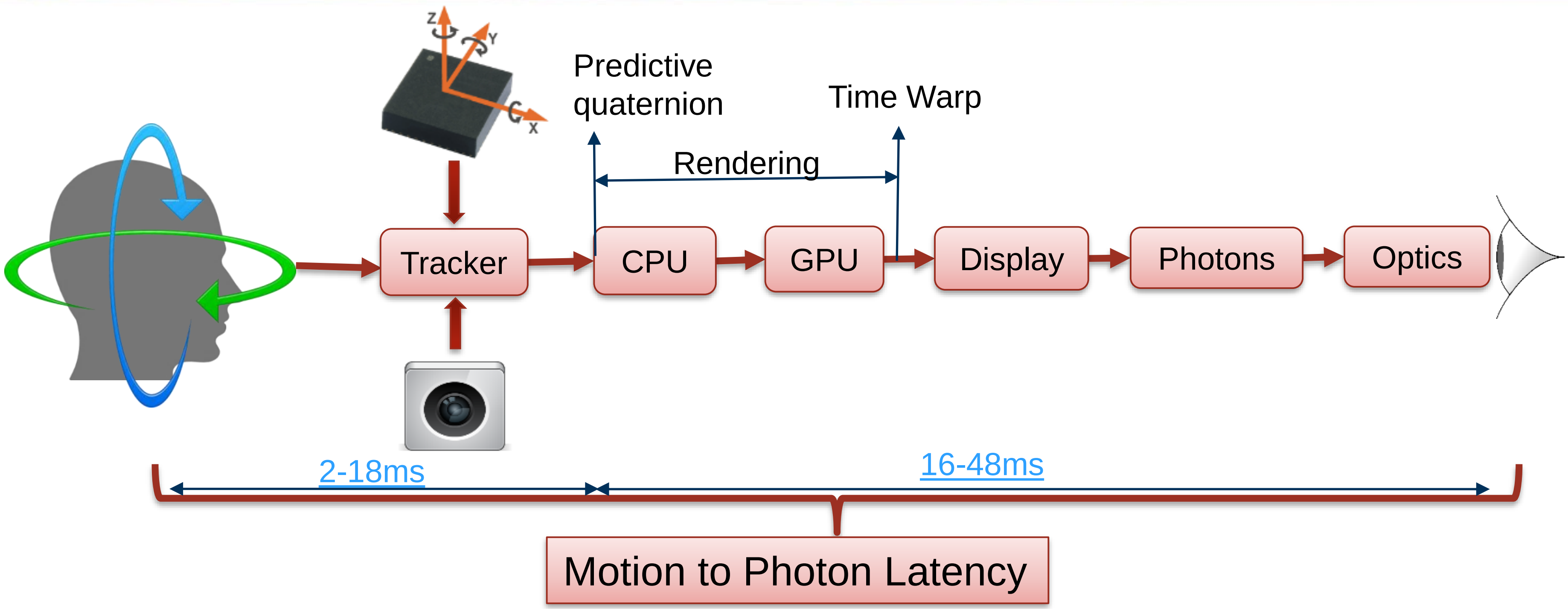

sensing the
FUTURE
InvenSense Developers Conference 2016
InvenSense
ICM-30670

VR/HMD System

HMD

- **Motion of Eye relative to Head:** Caused by discrete nature of HMD display compared to real world which is continuous. Reduces visual quality considerably, and introduces a choppiness that can be fatiguing and may contribute to motion sickness [1][2].There are many artifacts that arise due to this which is known as Judder, strobe
    - **Solution**: Low persistent display and higher frame rate
- **Motion to photon Latency:** Time it takes from actual movement to time the display reaches eyes. [2] The effect of this is difference in the image person is expecting to what is displayed. This causes disorientation and nausea attributing to yet again motion sickness.
    - Solution: Higher frame rate, lower latency in Motion detection, Time warping and predictive quaternion and fusion with translation detection.

Motion to photon latency (accuracy)



- **Motion to photon Latency:** [2] Difference in person's expectation to what is displayed
  - **Issue:** Disorientation and nausea attributing to motion sickness
  - **Solutions**:
    - Lower latency in Motion detection & fusion
      - Time warping use case
    - Predictive quaternion
    - Higher frame rate (Faster rendering)
    - OLED display for faster refresh rate
    - Accurate motion estimation (6 DOF = 3DOF → Orientation, 3DOF → Translation)

ICM-20603

Integration and Demonstration on the ST-Nucleo platform

Goals of this presentation?

- Introduce the ICM-20603 Hardware development kit
- Present the proposed Software stack and its capabilities
- Demonstrate how to integrate the driver in an embedded platform
- Showcase the capabilities with live demo

Hardware Overview

Reference Kit
Connection to PC

Software Overview

Package content
Architecture
Supported features
Code size / Power consumption / MIPS

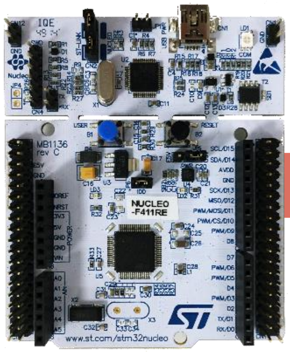
Demo

Overview of the code
Data visualization

Hardware Overview

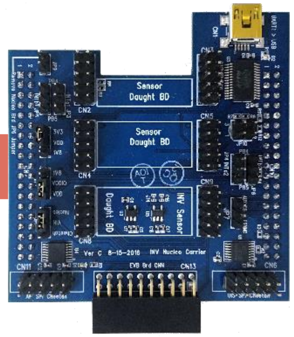
Hardware Overview
Invensense 20603 Reference Kit

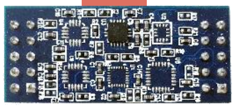
ST Nucleo F411-RE



512 KB Flash
128 KB RAM
Cortex-M4 MCU

Invensense Carrier Board

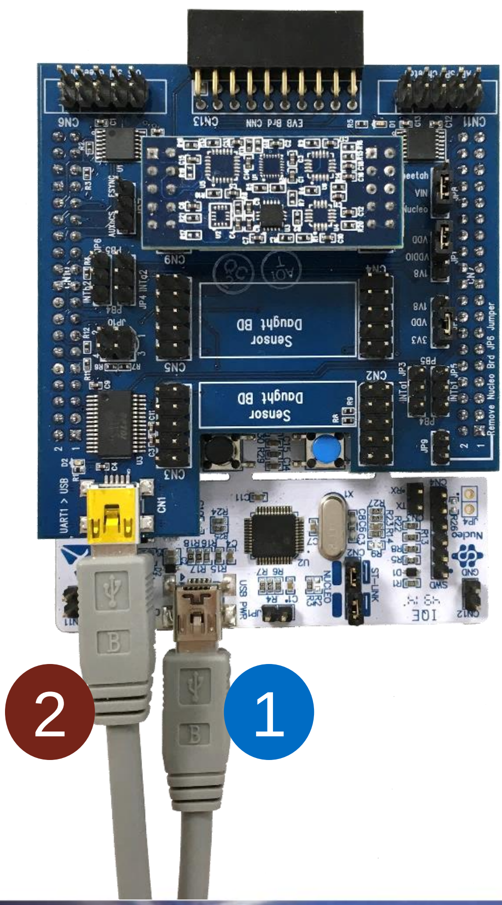




ICM-20603 Daughter Board

Hardware Overview
Connection to PC

- Requires 2 USB 2.0 Cables - A-Male to Mini-B



1 Connected to ST-Link

- Provide powers
- Used for traces

Min latency : **6 msec**

Min latency : **1 msec**

2 Connected to Carrier Board

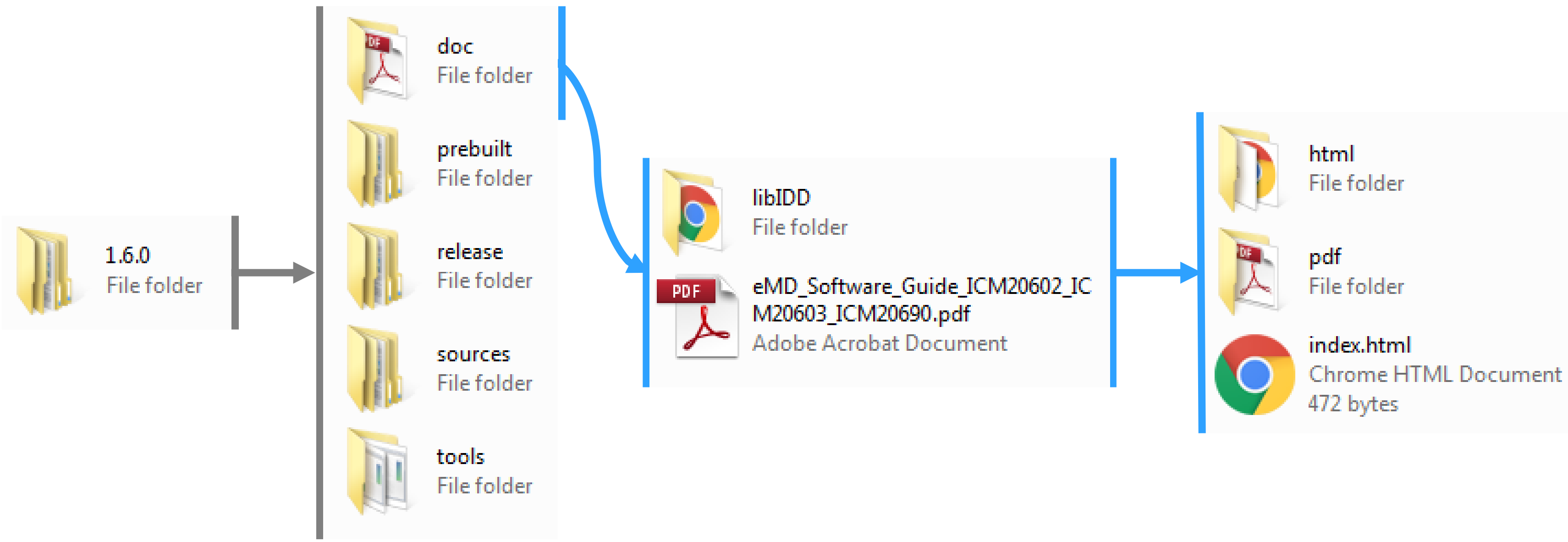
- FT232R USB UART IC
- Used to communicate with the firmware

? **Why using 2 USB port?**
- ST Link USB limitations
- HSE taken from ST-Link

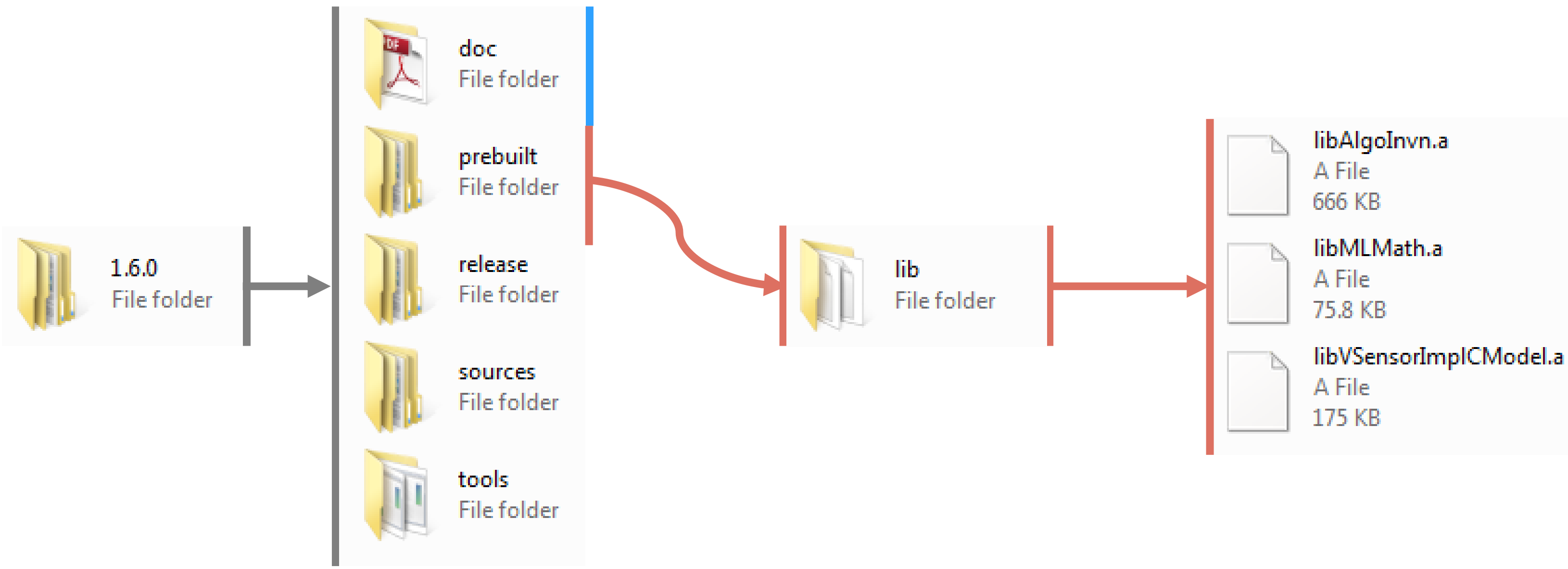
Software Overview

Software Overview
Package content

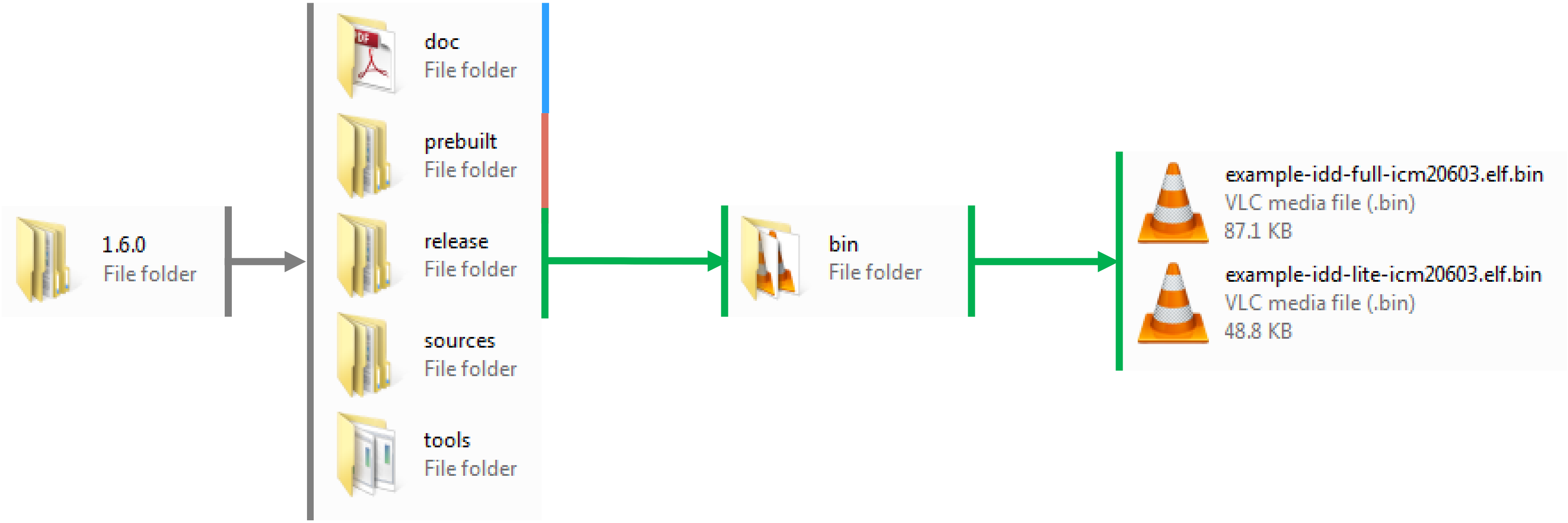
sensing the FUTURE



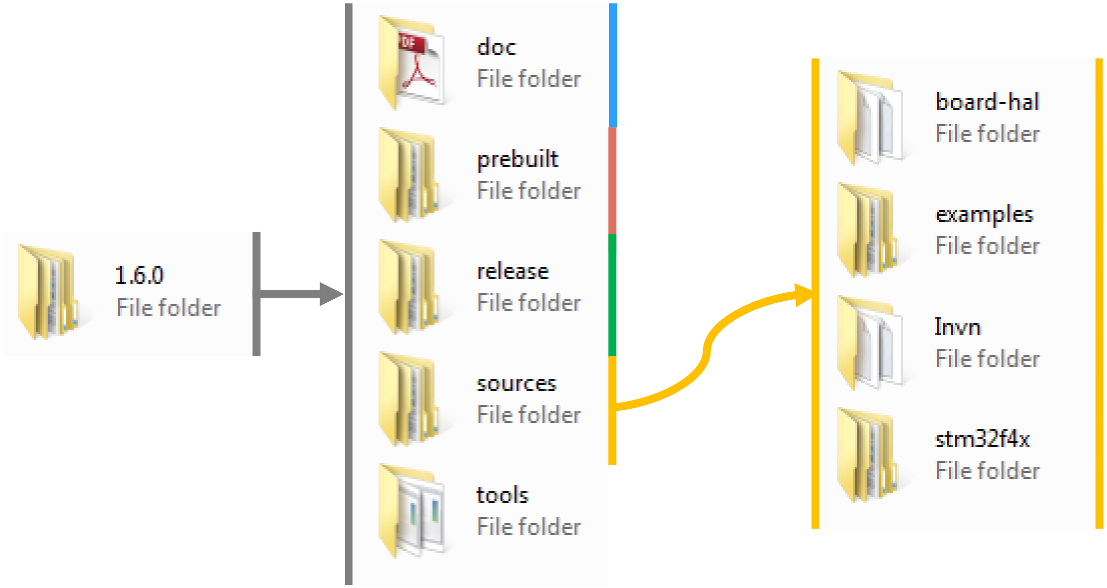
Software Overview
Package content



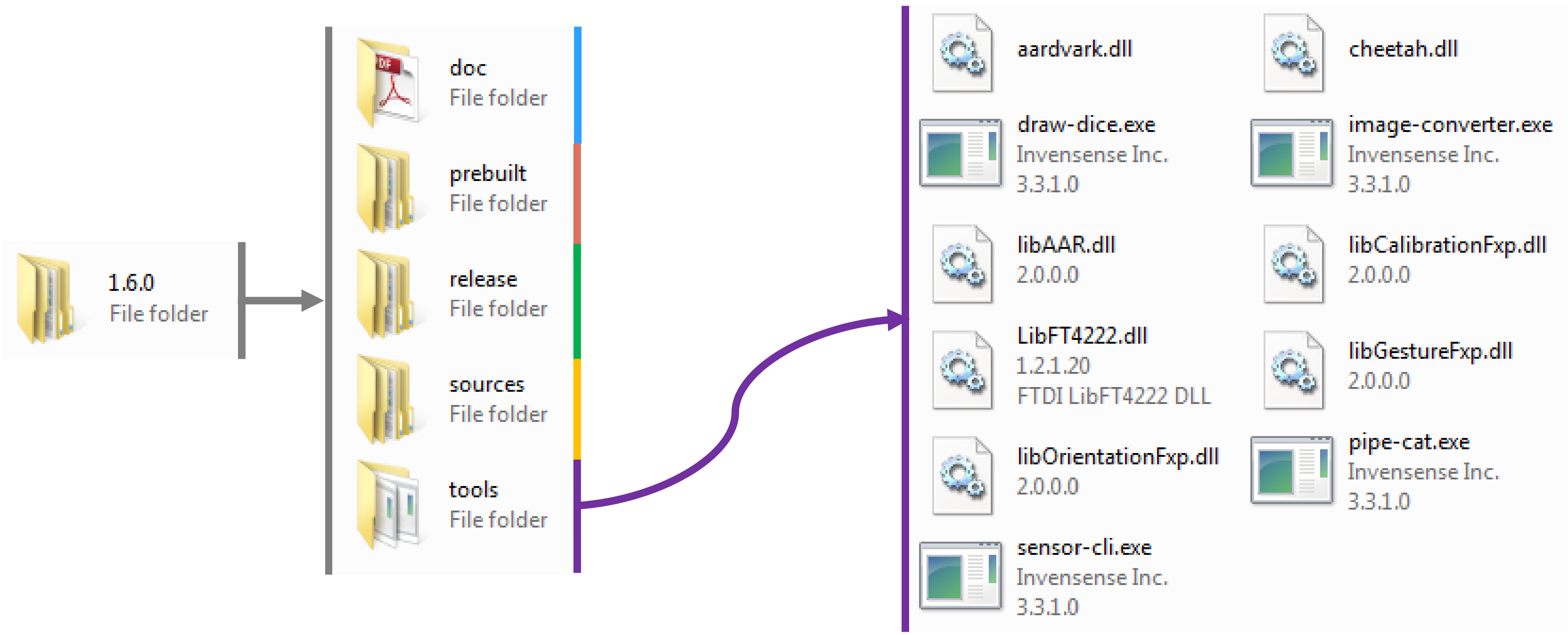
Software Overview
Package content



Software Overview
Package content



Software Overview
Package content



Software Overview
Introduction

sensing the FUTURE

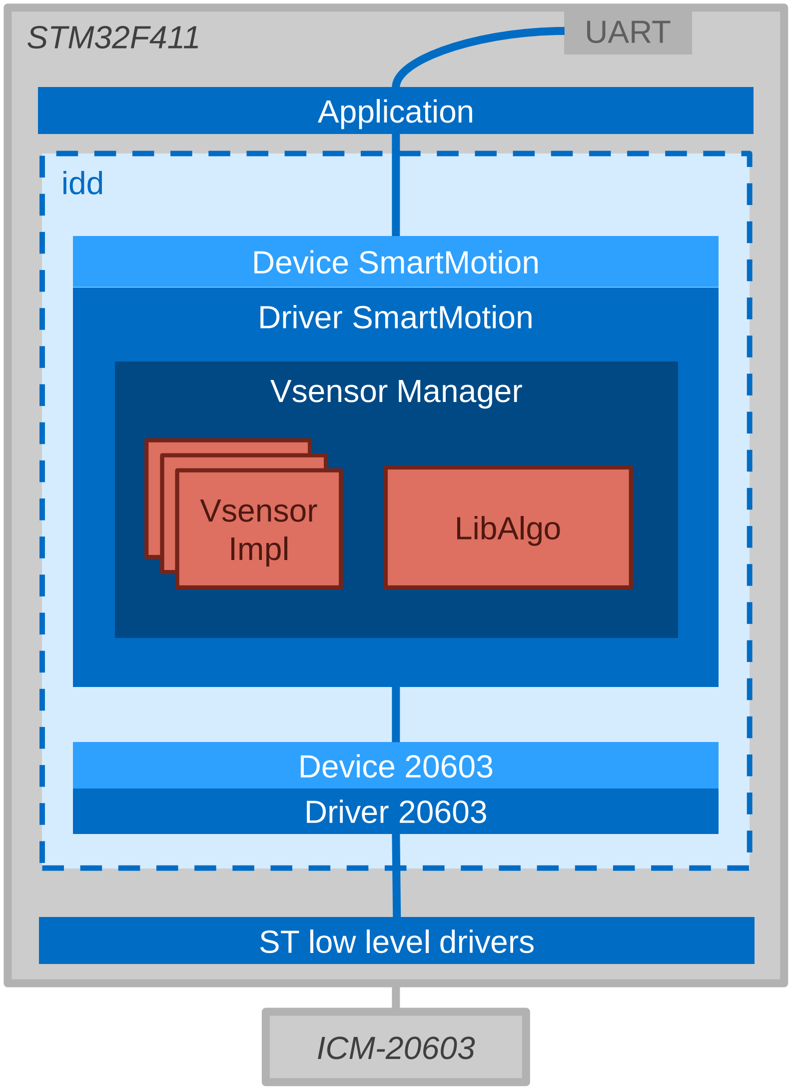
- **IDD** : **I**nvensense **D**evice **D**river
  - *Driver* layer : device specific layer (doesn't include transport)
  - *Device* layer : a common API across all Invensense chips

- 2 packages available
  - **Full** : provides all features with algorithms running within the driver.
  - **Lite** : showcases the integration of the driver only with algorithms running on the application

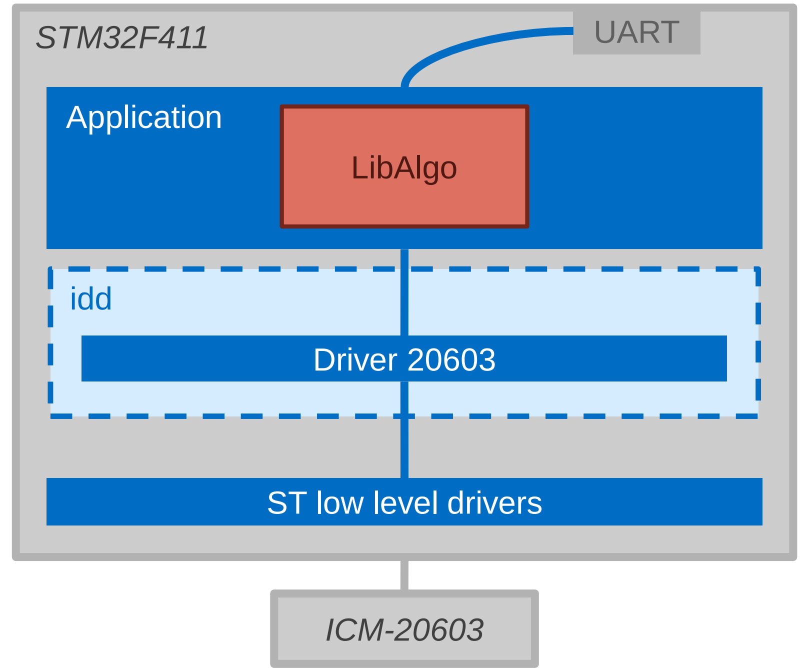
Software Overview
Architecture : Full vs Lite

sensing the FUTURE

Full example



Lite example



Source code is open

Source code is closed

Software Overview
Supported features

sensing the FUTURE

- *Raw Accelerometer*
- *Accelerometer*
- *Raw Gyroscope*
- *Gyroscope*
- *Uncal Gyroscope*
- *Raw Temperature*
- *Raw Magnetometer*
- *Magnetometer*
- *Uncal Magnetometer*
- *Gravity*
- *Linear Acceleration*
- *Game Rotation Vector*
- *Geomag Rotation Vector*
- *Rotation Vector*
- *Orientation*

- **Raw**: Raw data from sensors (no unit)
- **Calibrated** : Processed data, including bias correction, expressed in
  - ‘g’ for *Accelerometer*
  - ‘dps’ for *Gyroscope*
  - ‘uT’ for *Magnetometer*
- **Uncalibrated :** Processed data with bias reported next to the data

$$uncal \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} - bias \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = cal \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}$$

Software Overview
Supported features

sensing the FUTURE

- *Raw Accelerometer*
- *Accelerometer*
- *Raw Gyroscope*
- *Gyroscope*
- *Uncal Gyroscope*
- *Raw Temperature*
- *Raw Magnetometer*
- *Magnetometer*
- *Uncal Magnetometer*
- *Gravity*
- *Linear Acceleration*
- *Game Rotation Vector*
- *Geomag Rotation Vector*
- *Rotation Vector*
- *Orientation*

Gyroscope calibration:

- Requires the device to remain static for 2 to 3 seconds

⇒ **Accelerometer** and **Magnetometer** calibrations leverages *Gyroscope* data to achieve *on-head* calibration.

Accelerometer calibration :

- Requires user to look naturally in different direction (no specific order):
  - Look down, up, left, right, tilt head left, right
  - Each position shall be maintained 1 to 2 seconds

Magnetometer calibration :

- Similar as Accelerometer calibration requirements except that holding position is not necessary
- Magnetometer is usually calibrated while doing the Accelerometer calibration sequence.

This calibration can be stored and reloaded at boot time. Only differential error will be calibrated.

Software Overview
Supported features

- Raw Accelerometer
- Accelerometer
- Raw Gyroscope
- Gyroscope
- Uncal Gyroscope
- Raw Temperature
- Raw Magnetometer
- Magnetometer
- Uncal Magnetometer
- Gravity
- Linear Acceleration
- *Game Rotation Vector*
- *Geomag Rotation Vector*
- *Rotation Vector*
- *Orientation*

Game Rotation Vector (GRV, 6-axis fusion)

- *Accelerometer* and *Gyroscope* based quaternion
- Low latency

Geomag Rotation Vector (GeoRV)

- *Accelerometer* and *Magnetometer* based quaternion
- High latency: convergence time is longer (~5 seconds)

Rotation Vector (RV, 9-axis fusion)

- *Accelerometer*, *Gyroscope* and *Magnetometer* based quaternion
- Low latency

Orientation

- Rotation Vector quaternion translated into Euler angles
  - Yaw
  - Pitch
  - Roll

Gravity

- reports the direction and magnitude of gravity
- When the device is at rest, Gravity output is identical to Accelerometer output

Linear Acceleration

- Reports the linear acceleration of the device, not including the gravity
- When the device is immobile, the output should be close to 0 on all three axis.

Software Overview
Frequencies and MIPS consideration

Sensor	Supported freq (Hz) Min	Supported freq (Hz) Max	Need Accel	Need Gyro	DMIPS @ 1KHz
Raw Accelerometer	4	1000	Yes	No	2.52
Accelerometer	50	1000	Yes	Yes	6.44
Raw Gyroscope	4	1000	No	Yes	2.60
Gyroscope	50	1000	No	Yes	3.49
Uncal Gyroscope	50	1000	No	Yes	3.36
Raw Temperature	4	1000	No	No	-
Raw Magnetometer	4	100	No	No	1.73
Magnetometer	50	100	No	Yes	7.70
Uncal Magnetometer	50	100	No	Yes	7.58
Gravity	50	1000	Yes	Yes	12.90
Linear Acceleration	50	1000	Yes	Yes	13.13
Game Rotation Vector	50	1000	Yes	Yes	12.54
Geomag Rotation Vector	50	100	Yes	No	23.80
Rotation Vector	50	1000	Yes	Yes	38.17
Orientation	50	1000	Yes	Yes	38.91

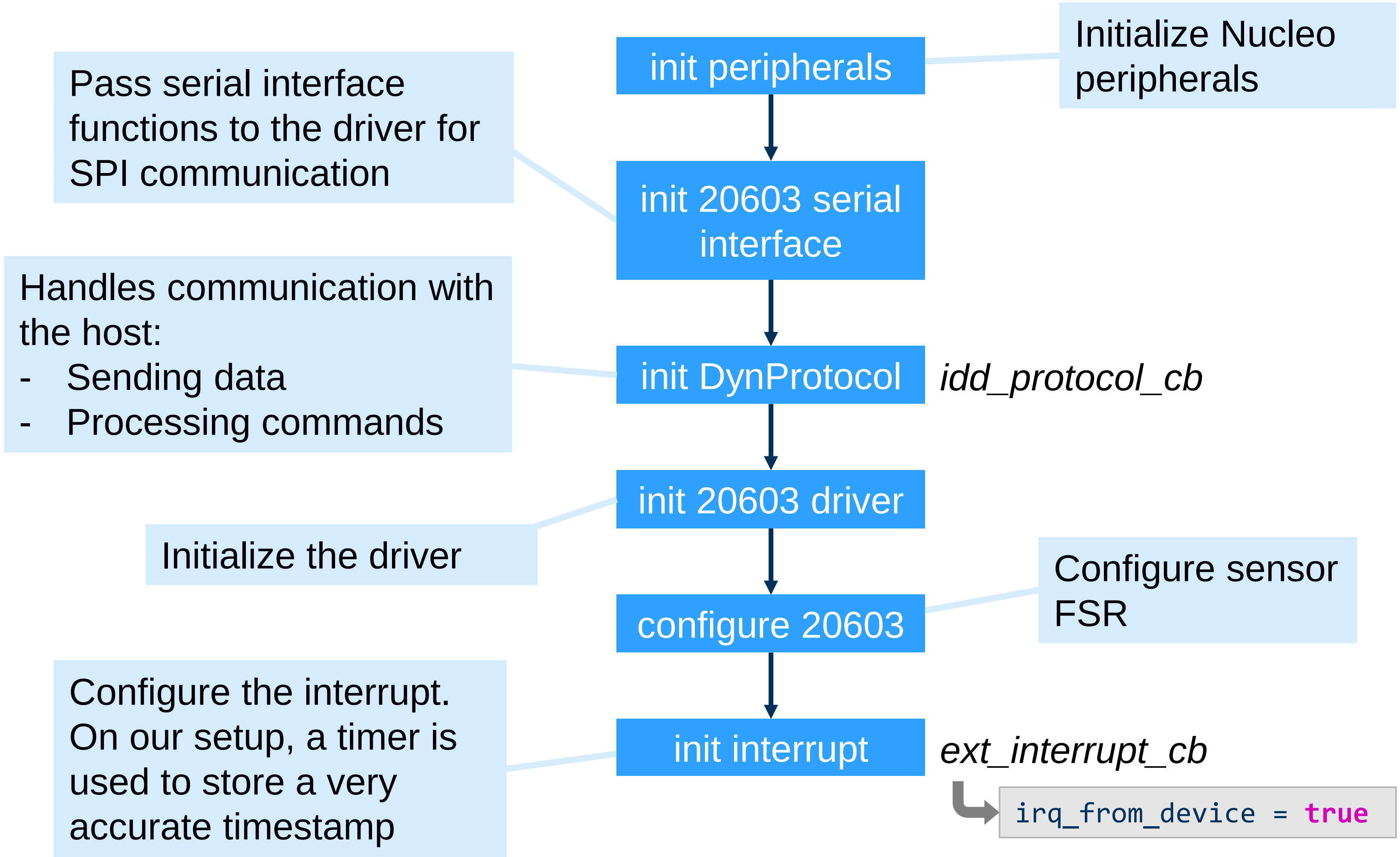
MIPS value are for one sensor enabled alone. Combination of sensors is not necessarily the addition of both.

Software Overview
Code size consideration

Blocks	FULL 20603 (KB) in flash	FULL 20603 (KB) in RAM	LITE 20603 (KB) in flash	LITE 20603 (KB) in RAM
TOTAL	**69.38**	**28.68**	**49.06**	**23.15**
Application	14.84	11.99	30.78	10.65
Low level drivers	12.92	10.01	9.05	10.01
Lib IDD	41.54	4.68	9.14	0.49
Device 20603	2.52		-	
Driver 20603	9.77		**6.53**	
Device SmartMotion	26.63		-	
VSensorFlow	19.56		-	
VSensorMgr	0.78		-	
VSensorImpl	6.24		-	
Algos LibExport	12.54		**12.01**	
Lib Math	1.14		1.14	
Lib AlgoInvn	11.40		10.87	

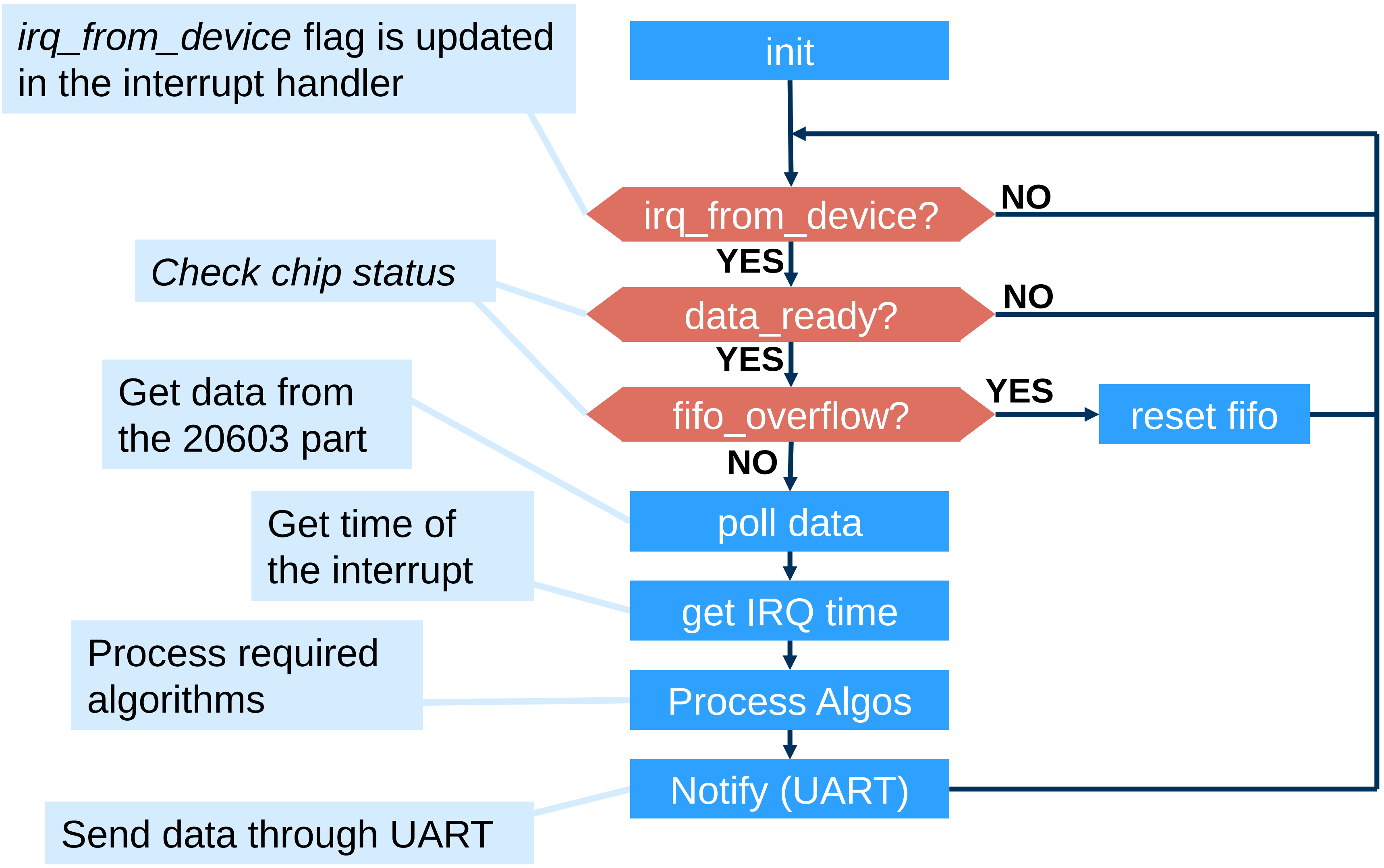
- The algo library is included within the application for the LITE example
- The 20603 driver for the LITE example doesn't include all features (for instance, Self-test API are not provided)

Software Overview
Lite example : Initialization stage



Software Overview
Lite example : Polling data and processing

sensing the FUTURE



Demonstration

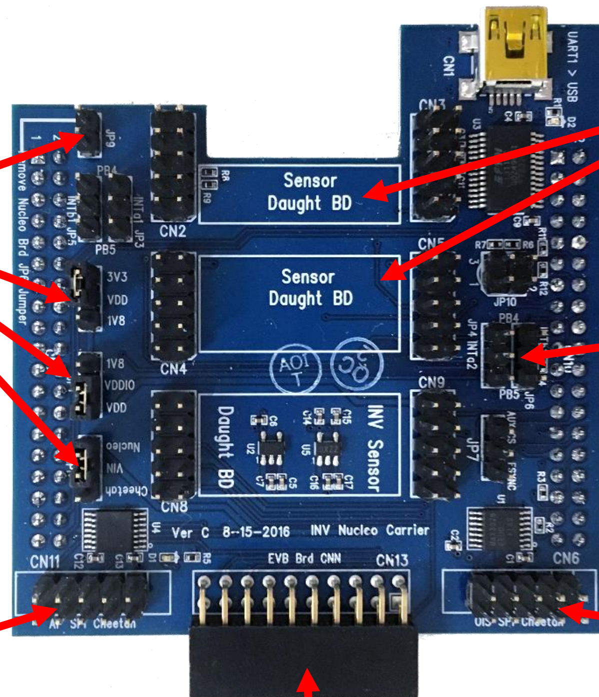
Thank You

Hardware Overview
Carrier Board description

- Additional options offered by the CB (for reference only, will not be covered by this presentation)

Power supply configuration

Auxiliaries sensors
magnetometer



Interrupts configuration
for auxiliary sensors

Cheetah connector
Communication with Windows through SPI

Cheetah connectors
To poll OIS data (ICM-20690 only)

Invensense MSB Connector
To plug additional daughter boards