

# LeapMind's direction for edge computing

Ultra low-bit computation on embedded devices

Atsunori KANEMURA  
2019.11.15



# ABOUT US

The image shows a wall with a large, three-dimensional logo consisting of the letters 'LM' in a stylized, blocky font. Below the logo, the words 'LEAP MIND' are written in a similar three-dimensional, blocky font. The wall is a light, textured color. To the right of the wall, there is a dark, possibly black, wall or door frame. The overall scene is dimly lit, with a spotlight effect on the logo and text.

**2012**

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**Established**

**2019**

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**STAFF**

**85 employees**

**CAPITAL INVESTED 46 million USD  
(From Intel Capital, TOYOTA, etc.)**



**MISSION**

**To create innovative devices  
with machine learning  
and make them available  
everywhere**

## Board members



**CEO**

### Soichi Matsuda

In 2011, Mr. Matsuda launched a service that offered to visualize engineers' skills, then matched those corresponding skills with the needs of the market. Later, he expanded his business to Singapore and eventually transferred his business. He established LeapMind Inc. in 2012.



**CRO**

### Atsunori Kanemura, Ph.D.

Dr. Kanemura holds a Ph.D. in Informatics of Kyoto University, Japan. He has a wide range of research experience and has published about 50 technical papers and delivered about 100 conference presentations. He joined LeapMind Inc. to show the future vision where intelligent machines are embedded everywhere in our society.



**CTO**

### Hiroyuki Tokunaga

Mr. Tokunaga holds a Master's degree from the University of Tokyo. Prior to joining LeapMind inc., he worked for Yahoo! Inc., Preferred Infrastructure Inc., and SmartNews Inc. In 2018, He joined LeapMind Inc. as CTO.



**VPoE**

### Takeo Sawada

Mr. Sawada holds a Master's degree from the Graduate School of Information Science and Technology, the University of Tokyo. Prior to joining LeapMind Inc., he served as an SRE at Google LLC as well as for Dropbox Inc. In 2018, he joined LeapMind Inc. as the VP of Engineering.



**CFO**

### Shohei Sasaki

Prior to working in the finance and accounting department at Aeria Inc., Mr. Sasaki joined Acquire Ltd. as CFO where he was in charge of buyouts. He joined LeapMind Inc. as CFO in 2018 after co-funding Cloudworks Co., Ltd. as CFO.



# Forbes Japan

Jan. 3, 2018



# Bloomberg

Jun. 18, 2019



# LinkedIn

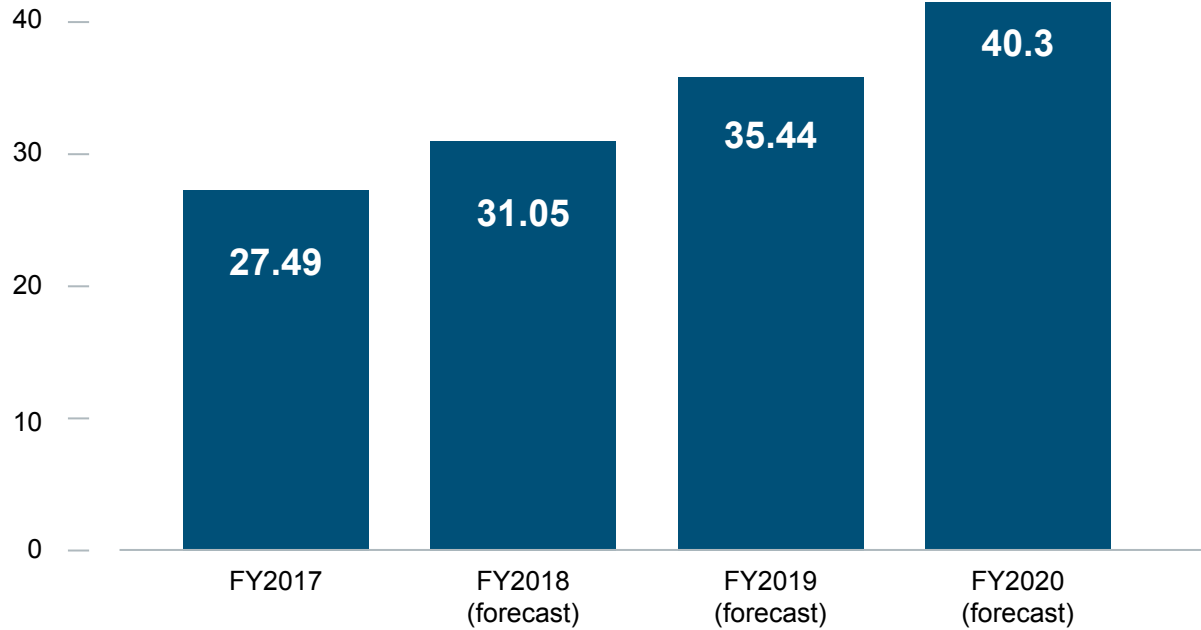
Sep. 3, 2019



# The growth of IoT devices and the need for intelligent data processing on them

## Trend and forecast of the number of IoT devices in the world

(unit: 1 billion)



\*Ministry of Internal Affairs and Communications, Japan "WHITE PAPER Information and Communications in Japan" 2018.  
<http://www.soumu.go.jp/johotsusintokei/whitepaper/eng/WP2018/2018-index.html>



## Global IoT and connected device market

# After 2020



**50+** billion  
Devices

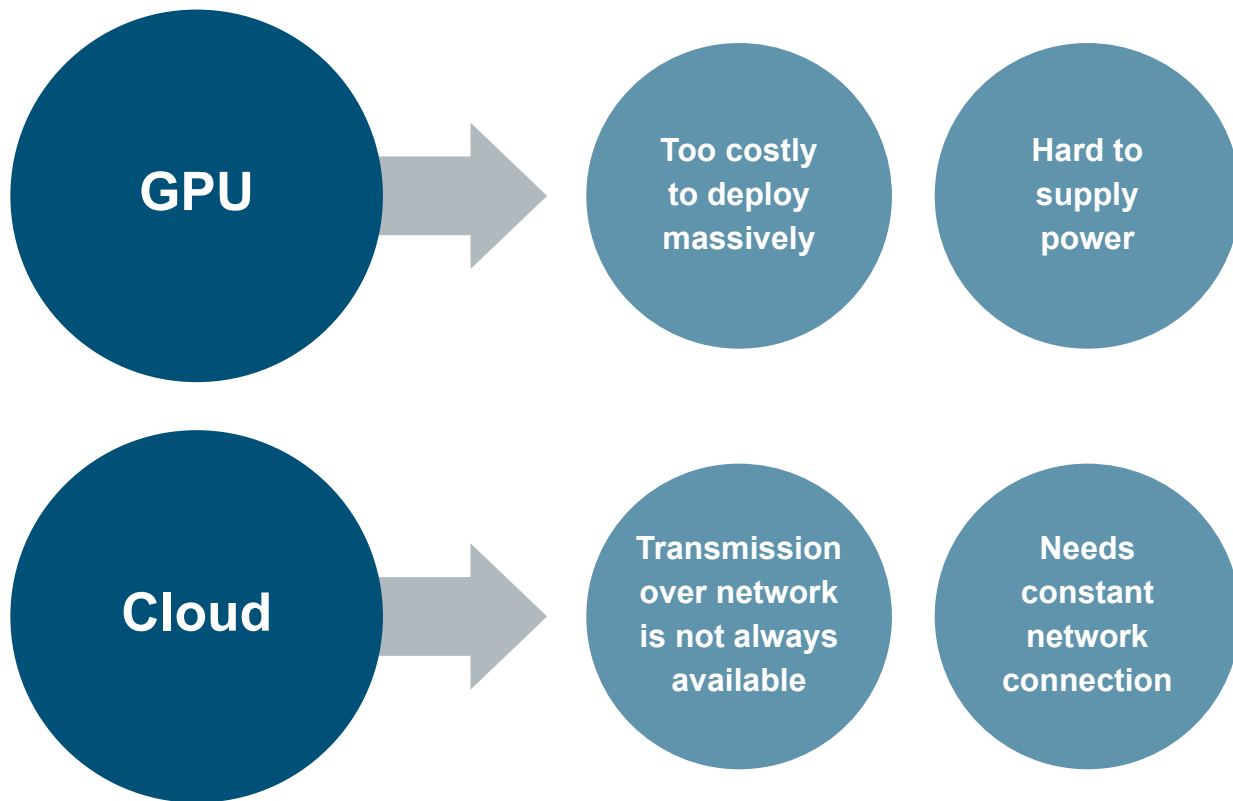


**\$700** trillion  
Market size



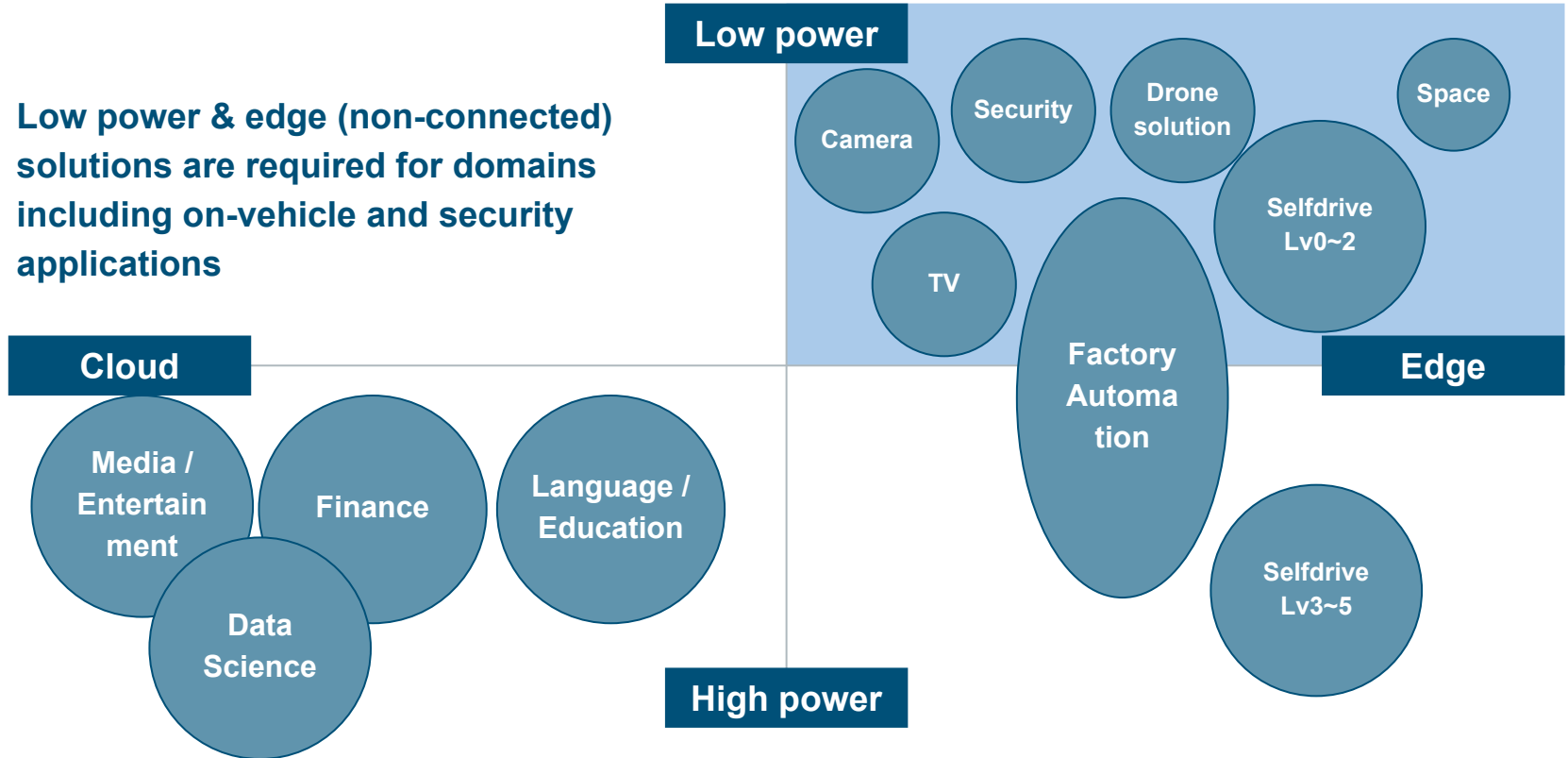
**44** ZB  
Data generated annually

## Conventional approaches and their issues



## Market segments

Low power & edge (non-connected) solutions are required for domains including on-vehicle and security applications



# Smart watch to detect heart symptoms

M. V. Perez et al. (Apple Heart Study Investigators), "Large-scale assessment of a smartwatch to identify atrial fibrillation," *New England Journal of Medicine*, November 14, 2019. <https://www.nejm.org/doi/full/10.1056/NEJMoa1901183>

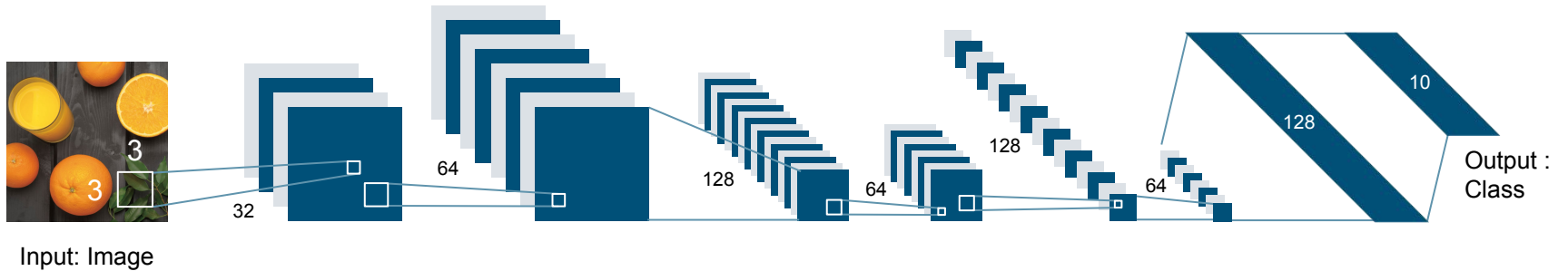
- Early detection of atrial fibrillation can prevent further cardiovascular diseases like strokes
- A wearable, non-invasive measurement with a smartwatch
- Pulse data from 419,297 people over 8 months
- 84% of the people who got irregular pulse notification had actually atrial fibrillation

**LeapMind's Direction:  
Compact neural networks and  
their hardware acceleration**



# Deep learning

## Neural networks for image recognition



## Deep learning for edge devices



**Small size,  
low power  
consumption**

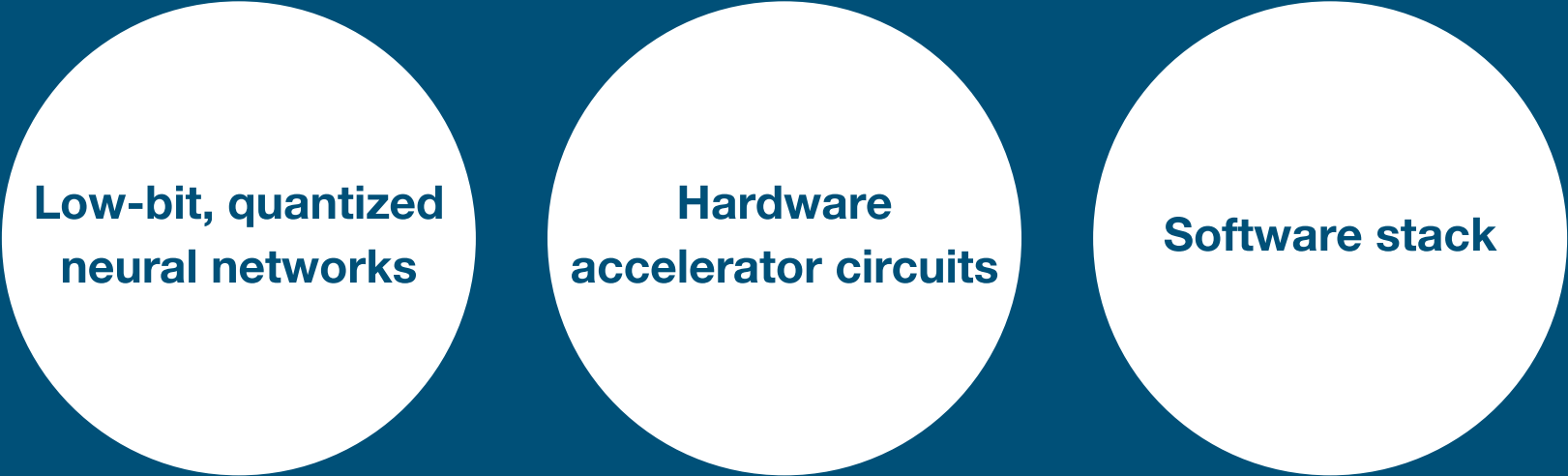


**Real-time response**



**Don't require  
network connection**

- Run with limited power resources
- Fast response thanks to on-device processing
- Available without network connection



**Low-bit, quantized  
neural networks**

**Hardware  
accelerator circuits**

**Software stack**

# Projects

## Example of past projects in LeapMind



Driving support



Defection screening



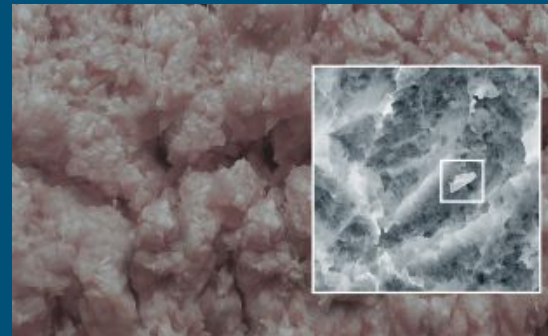
Drone control support



Crack detection



Danger alert



Contamination inspection



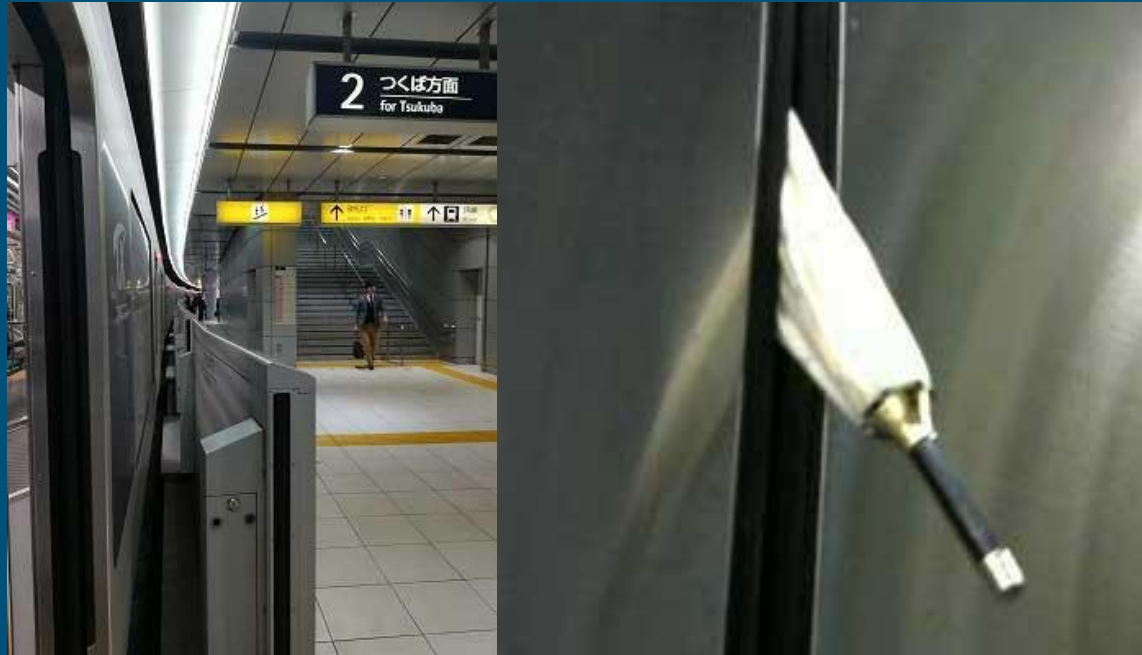
# Four projects

1. With Kawasaki Heavy Industries
2. With JAXA
3. With NTT DATA
4. With RIKEN

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 **Kawasaki**  
Powering your potential

# Small objects caught in the train door



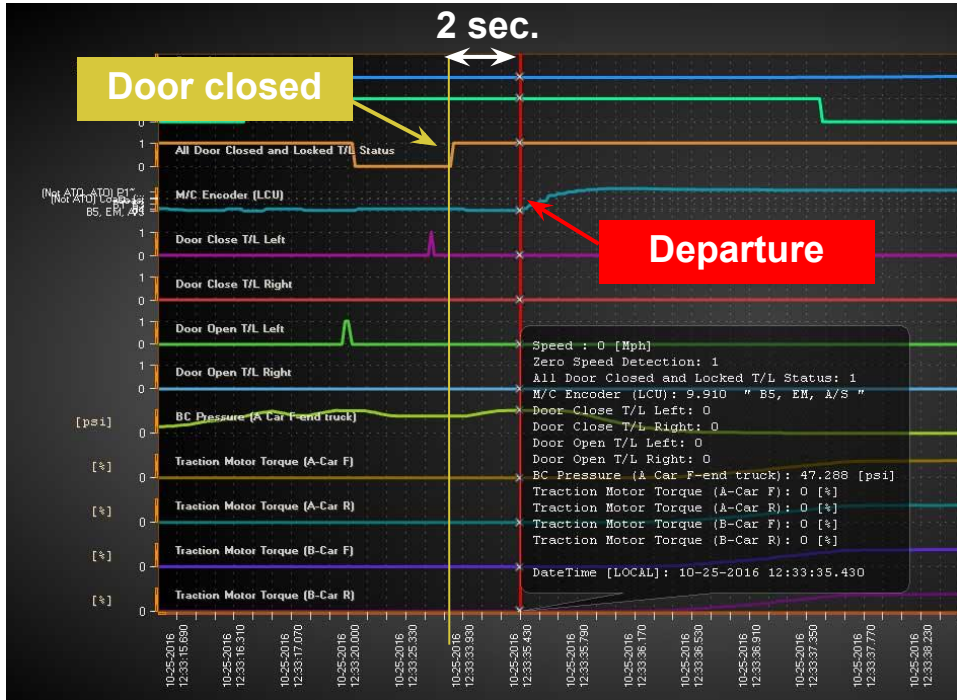
© 2016 Kawasaki Heavy Industries, Ltd.

## Real-time response

After the doors are closed,

only **2 seconds**

before the train departure



© 2016 Kawasaki Heavy Industries, Ltd.

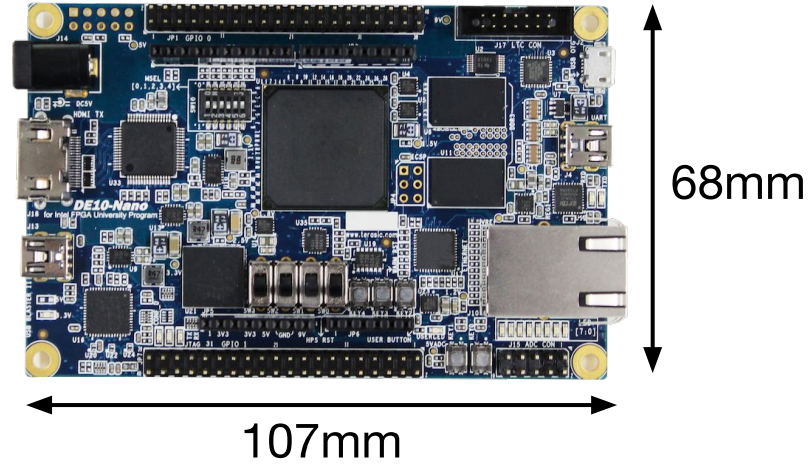
```
graph LR; A((Fast response is required)) --> B((Processing with edge device))
```

**Fast  
response is  
required**

**Processing  
with edge  
device**

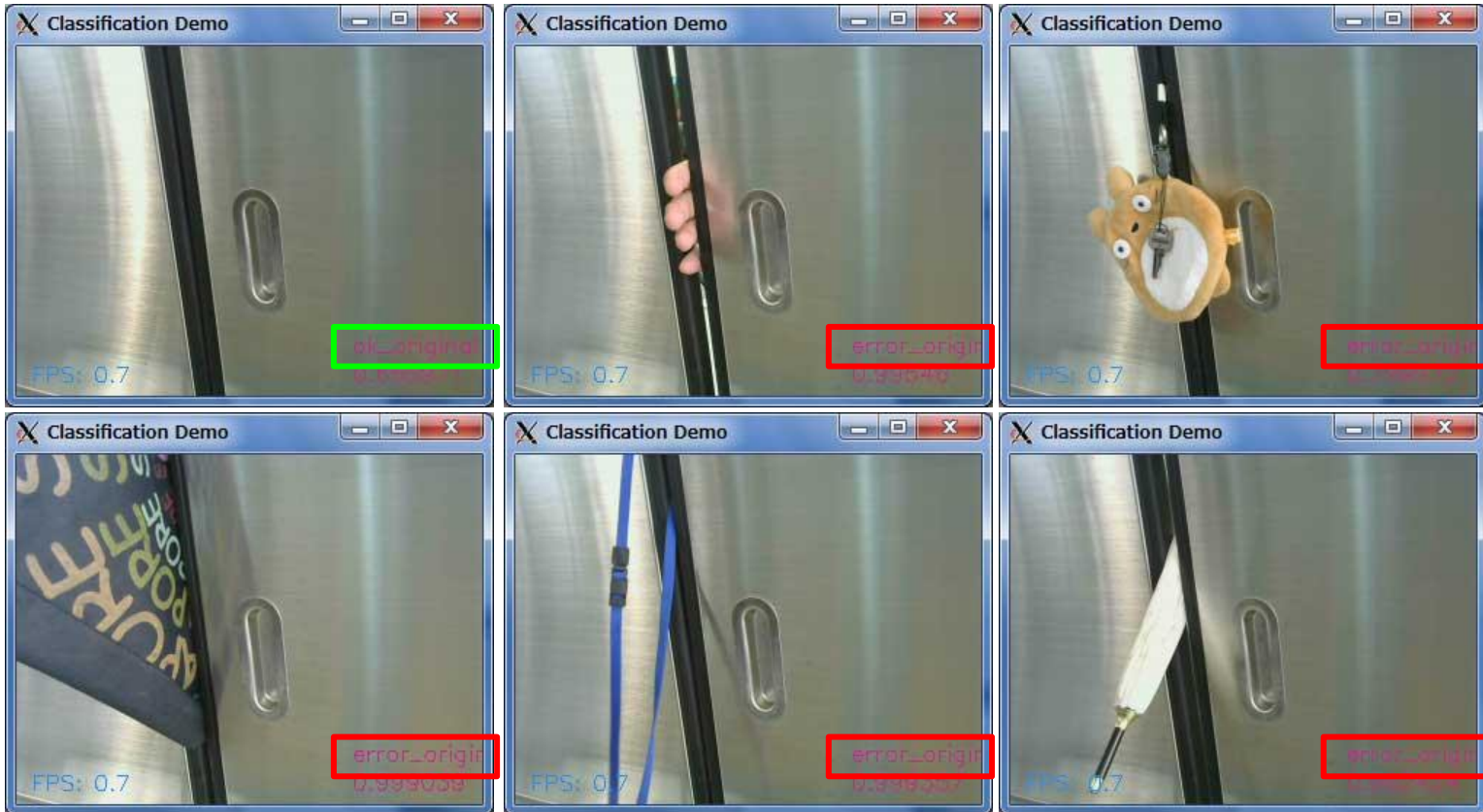


## Target device



Terasic DE10-Nano with Intel Cyclone® V SoC

# Accuracy



© 2016 Kawasaki Heavy Industries, Ltd.

## Speed



Door close

1.24 sec.



Alert

© 2016 Kawasaki Heavy Industries, Ltd.

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## An extreme edge case: Space

Data transmission and power resources are severely limited in the space



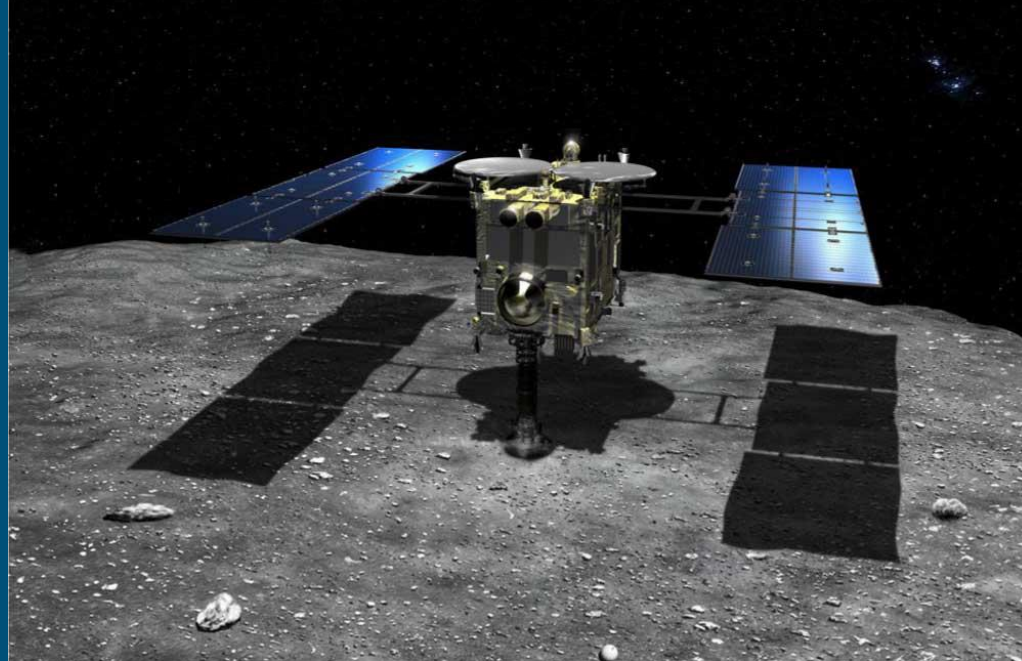
Cannot take GPU or cloud approaches



© JAXA

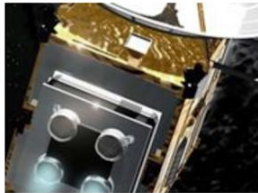
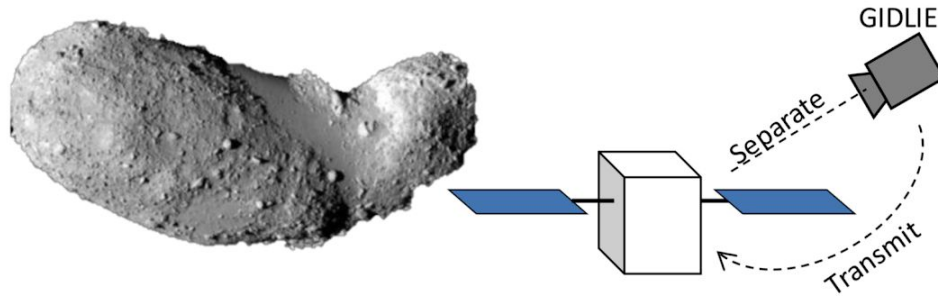


# Spacecraft × deep learning: “Spacecraft selfie”

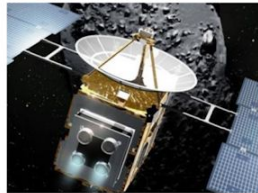


© JAXA

# GIDLIE: the Greatest Imaging Device for seLfIE



Score:0.4



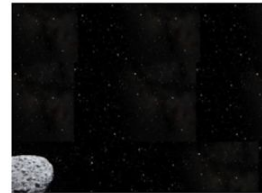
0.7



0.9



0.6

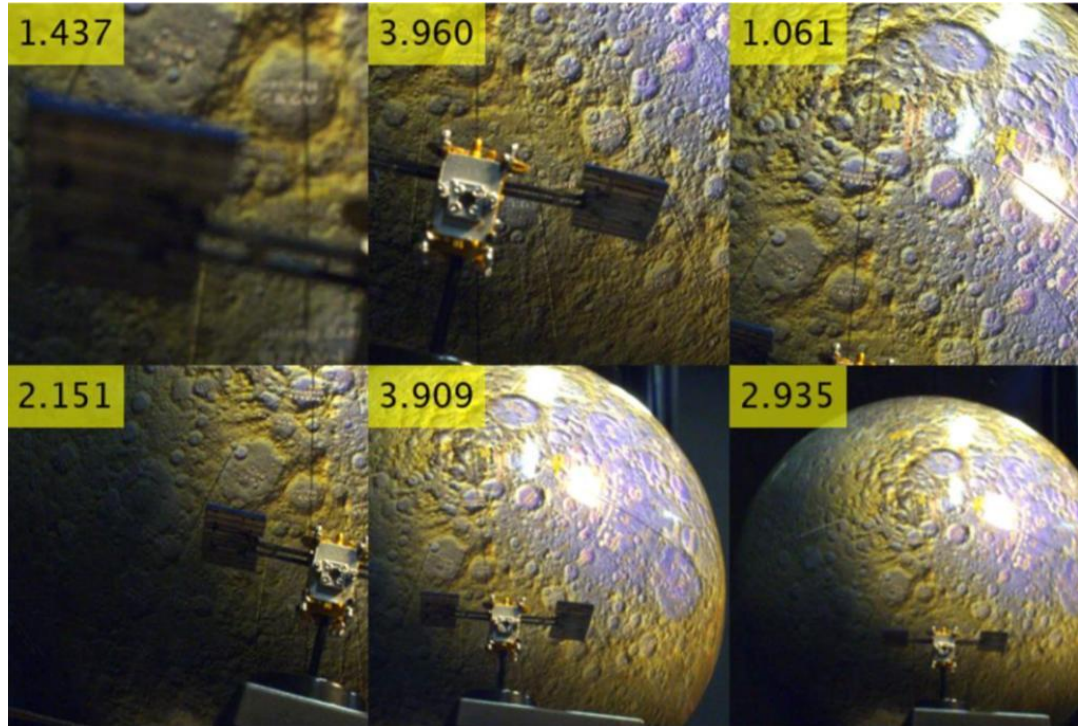


0.1

**Submit**

© JAXA

## GIDLIE: the Greatest Imaging Device for seLfIE



© JAXA

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**NTT Data**

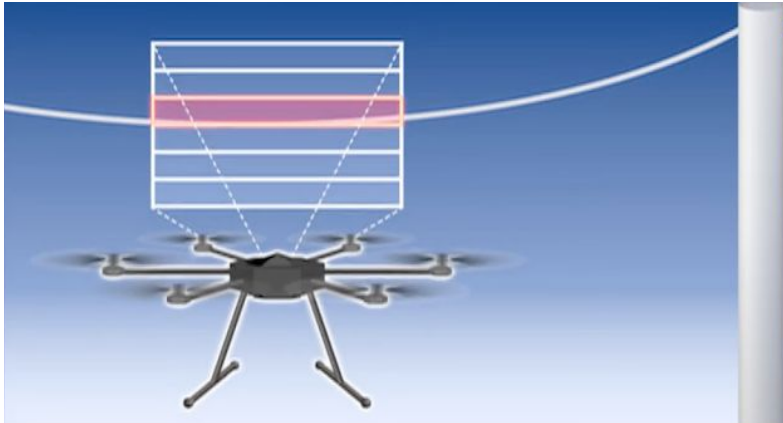
# Automatic electrical wire tracking by a drone



© NTT DATA



## Automatic electrical wire tracking by drone



© NTT DATA



© NTT DATA

 LEAPMIND

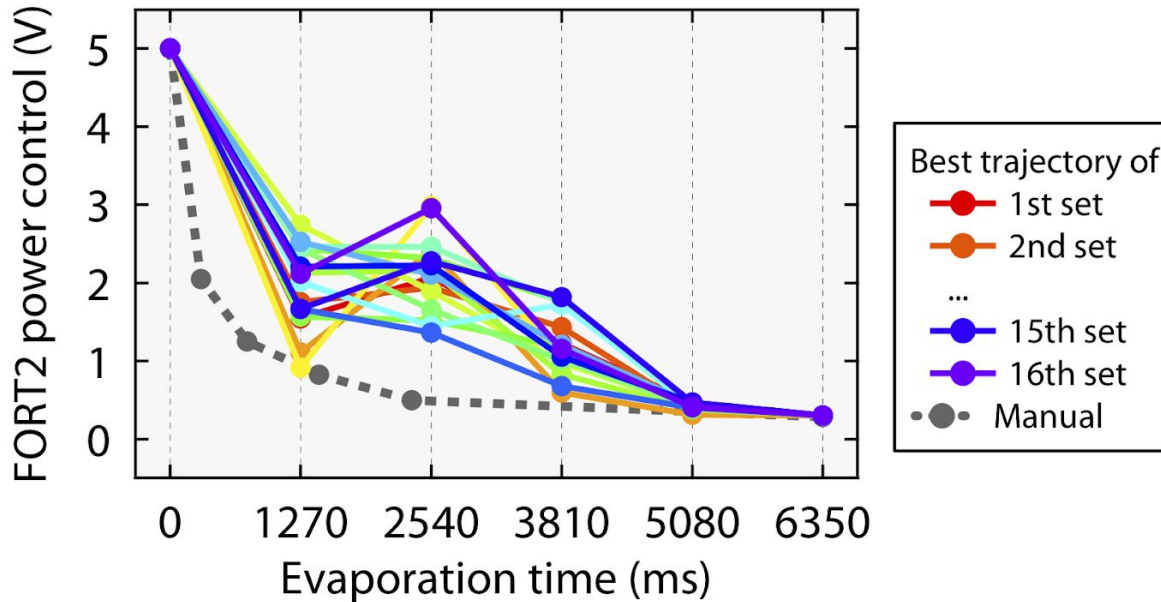


# Machine learning applied to physics

I. Nakamura, A. Kanemura, T. Nakaso, R. Yamamoto, T. Fukuhara,

"Non-standard trajectories found by machine learning for evaporative cooling of 87Rb atoms,"

*Optics Express*, vol. 25, no. 15, pp. 20435–20443, 2019. <https://doi.org/10.1364/OE.27.020435>



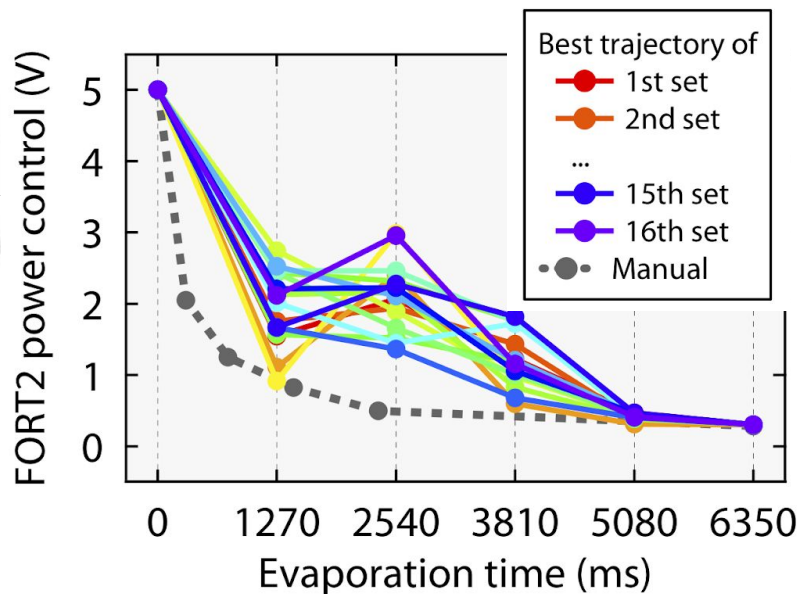
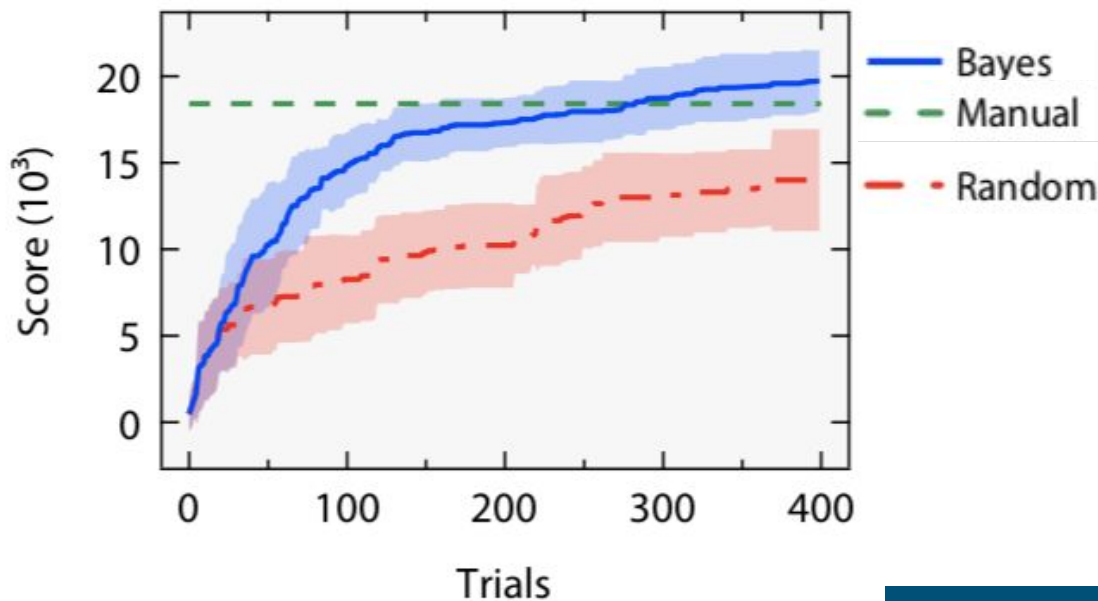
"it possibly hints at the BO search **discovering new physics beyond the conventional approach** to evaporative cooling, and would open an avenue for further study."

—Reviewer 1



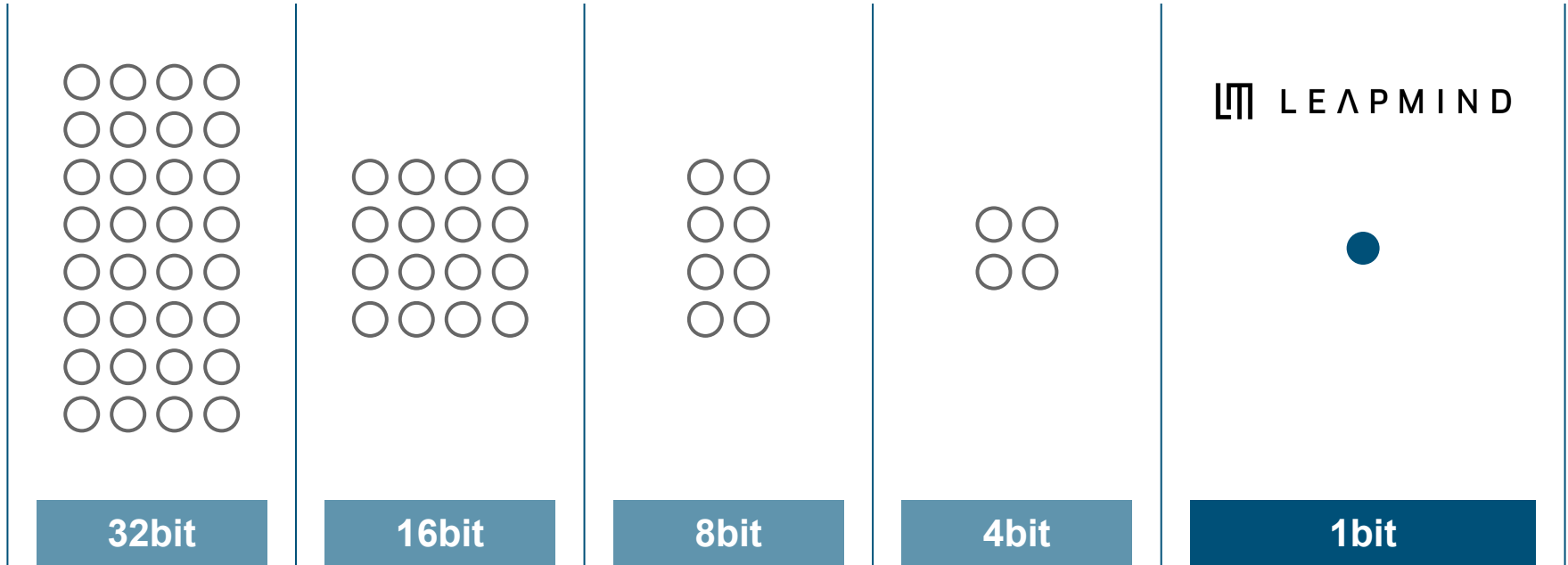
# New physics discovery (potentially)

- Non-standard curves yielded better results
  - Why the potential goes up in the middle of cooling operation?
- Why do not know why (yet).

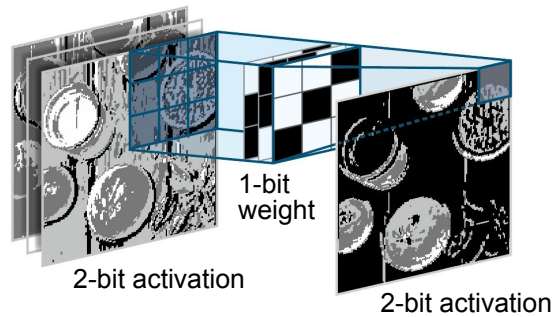
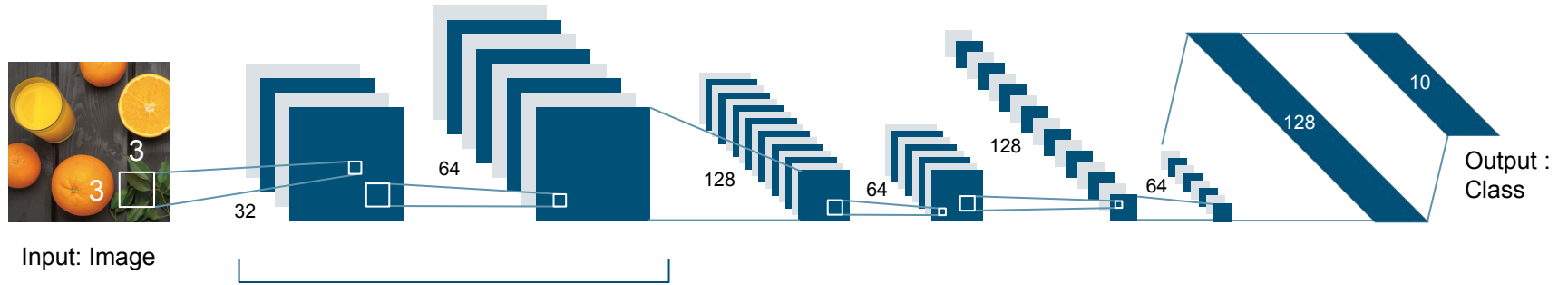


**LeapMind's Technology:  
Quantizing neural networks  
to ultra low bit**

## Quantization to low-bit

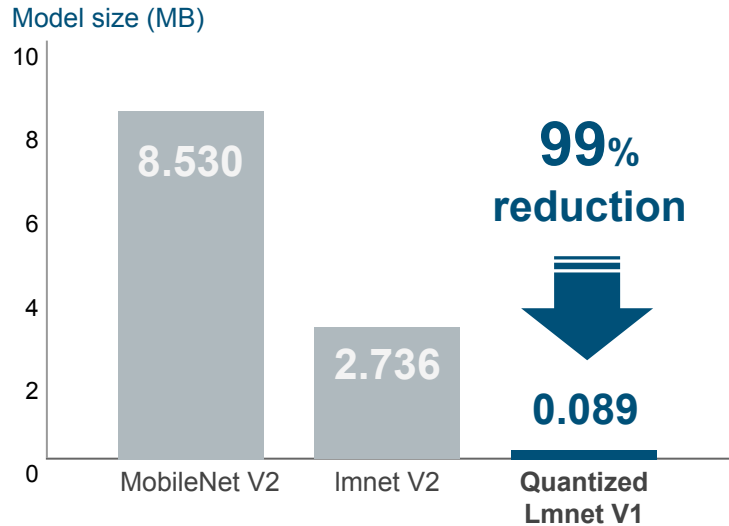


# 1-bit weights and 2-bit activations in neural networks



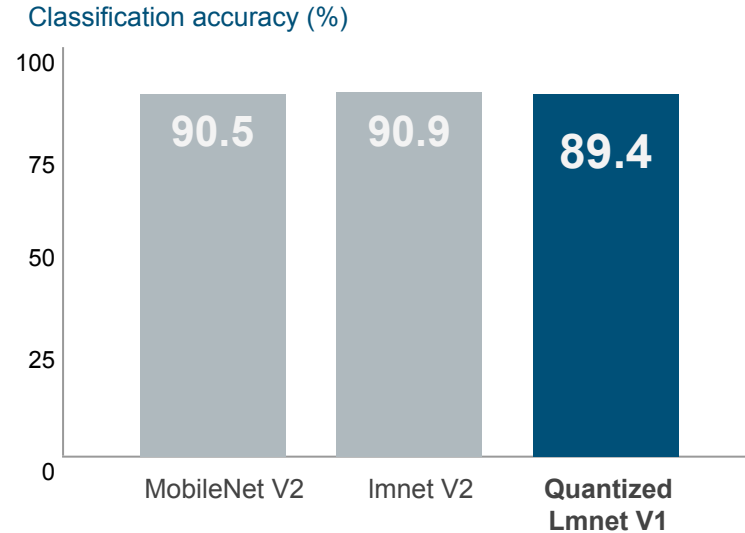
# Model size / accuracy tradeoff

## Big reduction of model size



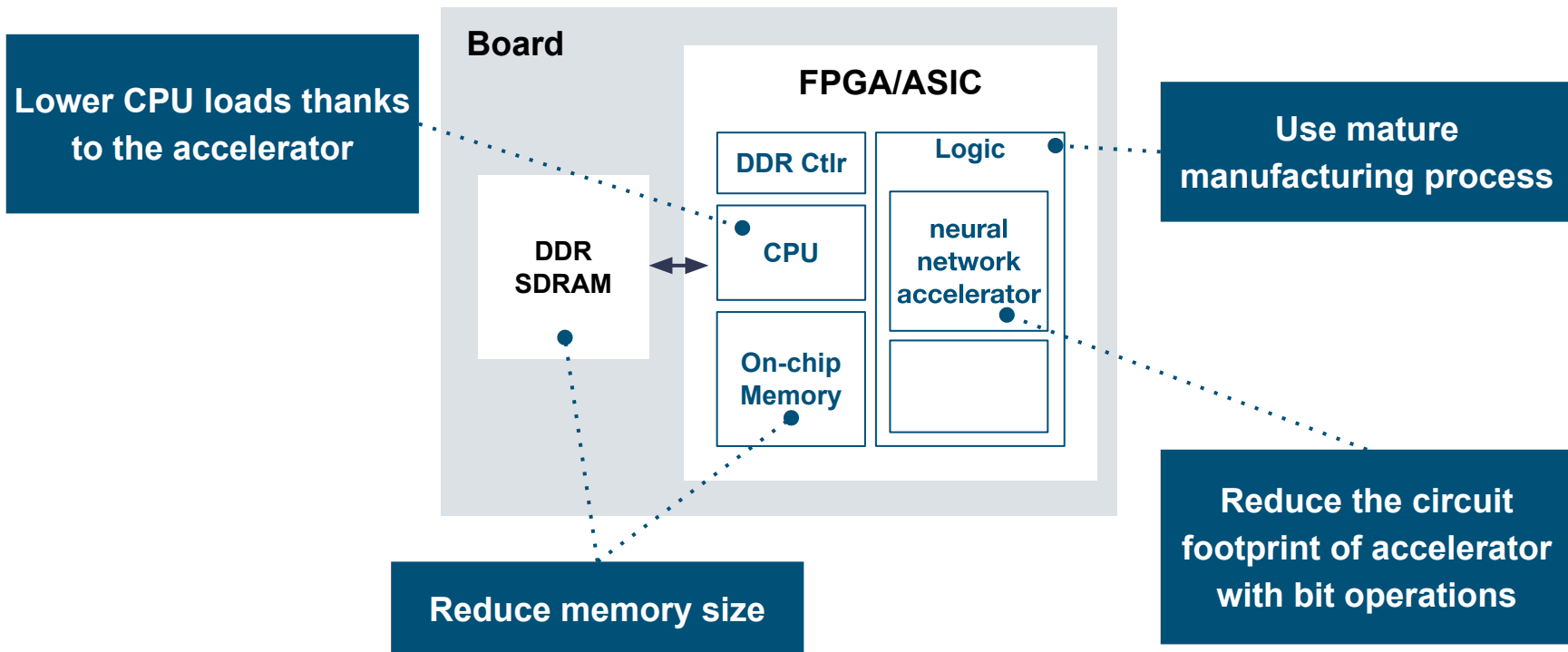
※ Used the same FPGA board

## Accuracy degradation is minimal



※ With CIFAR-10 dataset

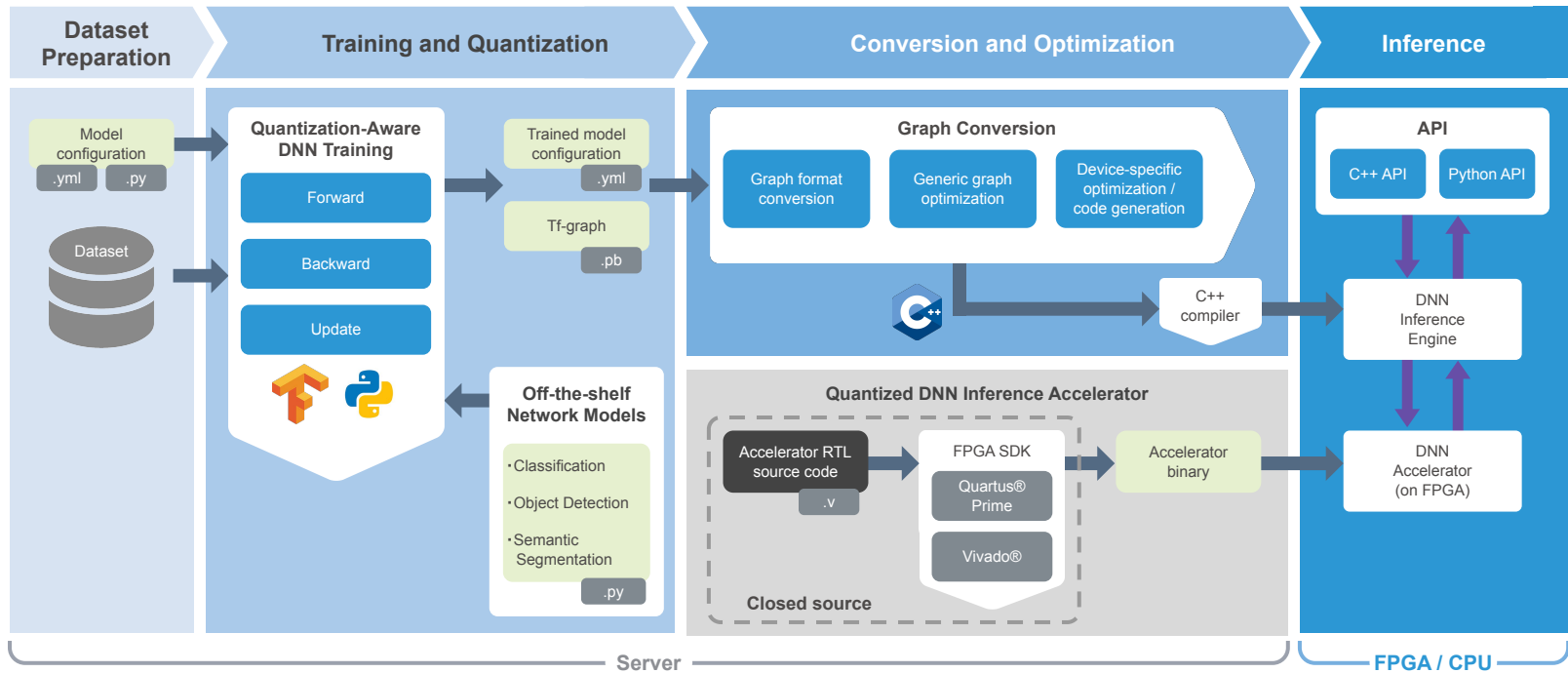
# Reducing system costs of quantized neural networks



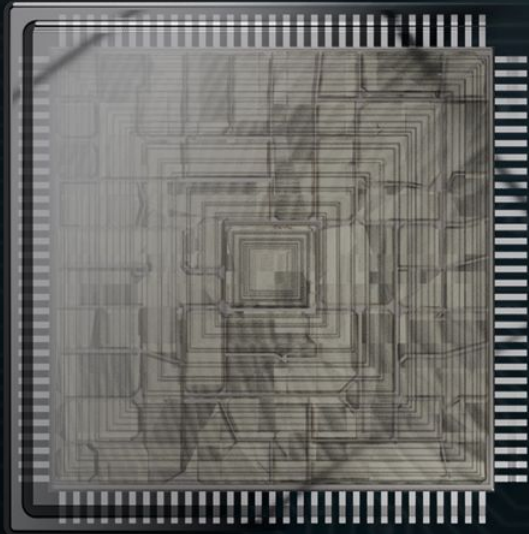


<https://github.com/blue-oil/blueoil>

# A software for quantized neural networks and their hardware acceleration







# LeapMind DNN processor IP

The processor for deep learning using low bit convolution.  
Low power consumption.  
Performance per silicon resource.

**Thank you!**

**Please take a few minutes to fill out this survey.**



[LeapMind] Survey - Autumn public lecture

<https://forms.gle/oRpQcTvQzas8gGpL9>