

tinyML[®] Foundation

Enabling Ultra-low Power Machine Learning at the Edge

tinyML.edu 2.0 from the industry-academia perspective
and Call to Action

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evgeni@tinyML.org



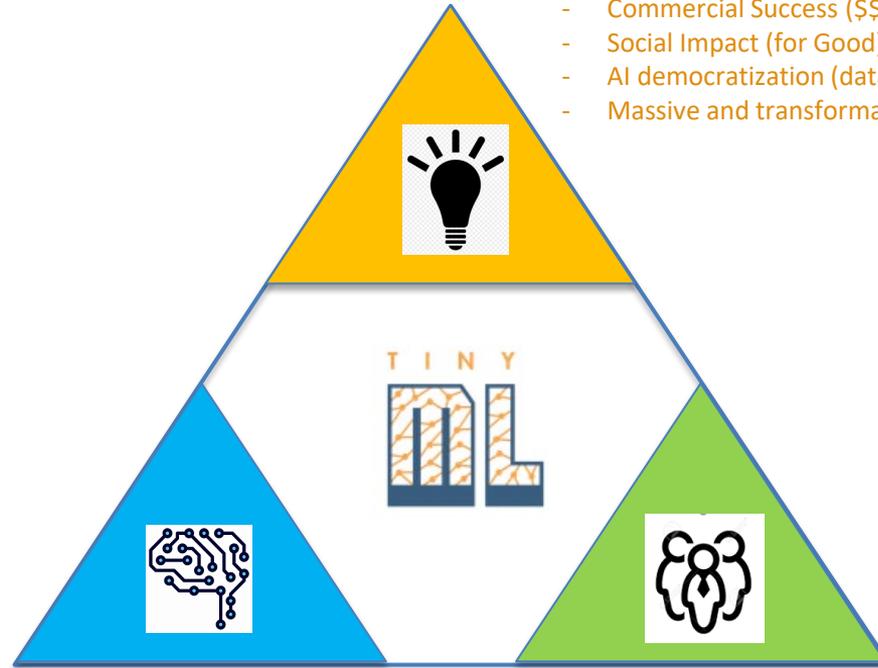
www.tinyML.org

Outline:

- **tinyML Foundation and its ecosystem**
- **tinyML: from the industry perspective**
- **Call to Action for tinyML.edu 2.0**



tinyML Phenomenon*:



Impact:

- Commercial Success (\$\$\$\$)
- Social Impact (for Good)
- AI democratization (data ownership)
- Massive and transformational !!!

Technology:

- Dedicated tinyML HW
- tiny NN models and algos
- tools and SW (autoML, NAS, etc.)
- Enabling tech (NVM, LP sensors, etc.)

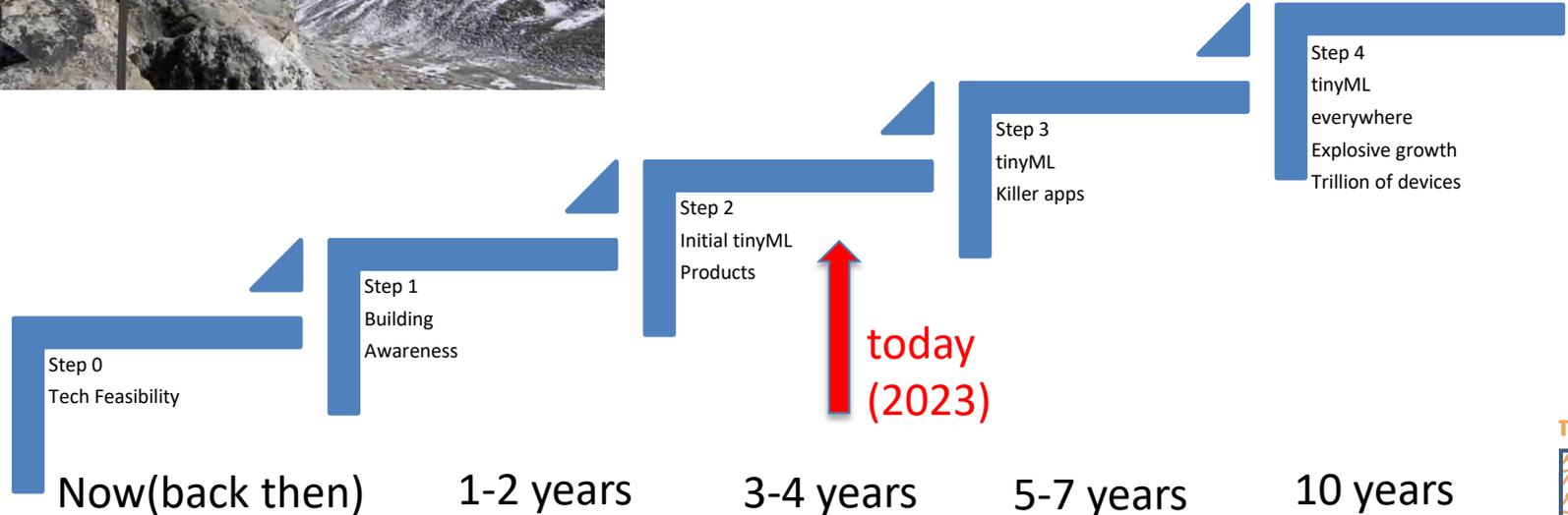
Talent:

- Global Community
- Diverse and interdisciplinary Ecosystem
- tinyMLedu
- Hi-energy & passion

tinyML: Happy 5th Birthday !



Climbing up tinyML mountain (from 1st, 2019 Summit)



tinyML Summits are growing fast

	2019 Summit <i>(March 2019)</i>	2020 Summit <i>(Feb 2020)</i>	2021 Summit <i>(March 2021)</i>
Attendees	160	400+	5000+
Companies	90	172	1000+
LinkedIn members	0	798	~ 2000
Meetups members	0	1140	~ 5000
YouTube subscribers	0	0	~ 4000

also started in Asia: tinyML WeChat and Bilibili



2018



2019



2020



2021



2022

tinyML growth drivers:

- More developed energy efficient HW
- Energy efficient algos/NN
- More mature SW infrastructure and tools
- Diverse ecosystem
- Growing number of applications
- Corporate and VC investment
- Increased start-up and M&A activity



2018



2019



2020



2021



2022

Interested in joining tinyML ecosystem?

www.tinyML.org



Summit 2020



tinyML Summit 2020

Enabling ultra-low Power Machine Learning at the Edge

Register now

Show all information



tinyML Foundation Vision*:



We see a new world with **trillions of intelligent devices enabled by tinyML technologies** that sense, analyze and autonomously act together to create a healthier and more sustainable environment for all

*adopted at tinyML Strategy leadership meeting on Dec 14, 2019



About us

tinyML Foundation is a non-profit organization* with the mission to accelerate the growth of a prosperous and integrated Global Community of HW, SW and SYS scientists, engineers, designers, product and business application people developing leading edge energy efficient machine learning computing. The goal is to connect various technologies and innovations in this domain of machine intelligence to enormous product and business opportunities and value creation across the whole ecosystem.



* tinyML Foundation is a non-profit, 501c3, organization registered in Los Altos, CA, USA

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tinyML Foundation Mission:

FOUNDATION

- to grow a prosperous and integrated Global Community of HW, SW and SYS scientists, engineers, designers, product and biz people, both experts and newcomers, developing leading edge tinyML technologies
- to educate and to promote and stimulate knowledge exchange between tinyML researchers to allow the field to move ahead at a high pace
- to inspire on the capabilities of tinyML and its potential of changing the way machine intelligence and data analytics at the very edge of the physical and digital world occur
- to connect tinyML technologies and innovations to enormous product and business opportunities and value creation across the whole ecosystem and industry verticals



tinyML “DNA”

- Highest **Quality**: prime tinyML community, events and projects
- Industry focused & driven, with strong academic participation & influence
- “Full stack”/E2E coverage: HW-SYS-Algo-SW-Apps
- Deeply technical
- Diverse (in a very broad sense) and collaborative; all inclusive and non-discriminatory
- Open and transparent



tinyML Global Community

(“snapshot” , as of July 1, 2023)



- 14.5k tinyML meetup members in 49 groups in 40 countries (~ 2x YoY)
- 10k youtube.com/tinyML subscribers, 589 videos, 345k views (~ 50% YoY)
- 3.7k members + 13k followers on LinkedIn (~ 2x YoY)
- WeChat group and Bilibili tinyML channel in Asia
- 3 major global events annually:
 - Summit in March (5K attended in 2021) , EMEA in June (1.6k in 2021), Asia in Nov. (1.8k in 2020)
- Almost weekly tinyML Talks, LIVE
- Massive educational initiative, tinyMLedu (e.g. 90k students enrolled, from 177 countries)
- Healthy M&A and VC activities
- 80+ sponsors; amazing diversity, 40 sponsors for the Summit
- 31 Companies have decided to join Strategic Partnership Program
- Partnerships with other orgs, non-profits, academia and NGOs underway
- tinyML Brand widely recognized in the industry !





tinyML meetups global growth

(15.5k members in 40 countries)

<https://www.meetup.com/pro/tinyml/>

FOUNDATION



tinyML

Members	Groups	Countries
15,486	49	40





tinyML Groups in Africa

3000+ members (as of 7/1/2023)

<https://www.meetup.com/pro/tinyml/>

FOUNDATION



tinyML Nigeria	827 members
tinyML Morocco	683 members
tinyML Kenya	752 members
tinyML Ghana	421 members
tinyML Rwanda	74 members
tinyML South Africa	133 members
tinyML Tanzania	102 members
tinyML Egypt	37 members



Key Dates 2023-4



Date	Event	Location
June 25, 2023	SPAB	in-person @ EMEA
June 26-28, 2023	tinyML EMEA	Amsterdam, The Netherlands
Sept 12-13, 2023	Vertical Focus - Consumer Electronics	virtual
Sept 14, 2023	SPAB meeting	in-person SF Bay Area?
Q4	tinyML4Good Forum	virtual
November 16, 2023	tinyML Asia	Seoul
Nov / Dec 2023	Vertical Focused Event	virtual
December 2023	SPAB meeting	virtual
April 9-11, 2024	embedded world	Nuremberg, Germany
April 22, 2024	SPAB	in-person @ Summit
April 22-24, 2024	tinyML Summit & Research Symposium	Burlingame, CA

tinyML Summit 2023

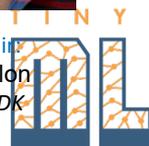
- March 27-29, 2023
- 3 days - **In-Person** - **Burlingame, CA**
 - Focused on tinyML end-users and applications
 - Mon Mar 27: Research Symposium & demo tables (“tinyML Open House” open to public)
 - Tues Mar 28 & Wed Mar 29: plenary keynotes & presentations; posters; demo tables



Chair: Davis Sawyer
Deeplite



Vice-Chair
Elias Fallon
Qeexo/TDK



tinyML Summit 2022 – back to normal !





tinyML Applications, Products and End-Users



tinyML Pavilion @embedded world 2023

March 14-16, 2023, Nuremberg, Germany

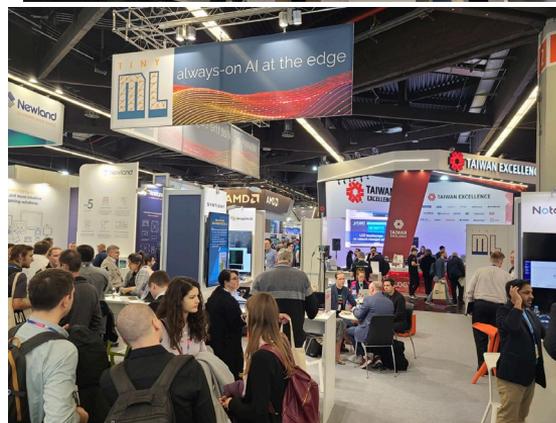
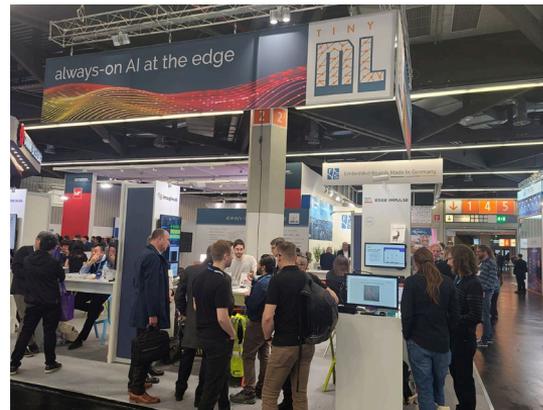
~10 Strategic Partners; Fully furnished podiums

Plus tinyML tech sessions

(chaired by Prof. Daniel Mueller-Gritschneider, TU-Munich)

~ 23k attendants at EW-2024

tinyML Pavillion committed at EW-2024, April 9-11





tinyML Community on LinkedIn

(~ 3.7k members & 13k followers)

tinyML Community

<https://www.linkedin.com/groups/13694488/>

Listed group



Home
My Network
Jobs
Messaging
Notifications
Me
More


tinyML Foundation
Super admin view

[All Pages](#)
Products
Content
Analytics
Activity

Set up your Page for success

Complete these steps to get established, increase reach and drive engagement. On average, completed Pages see up to 30% more traffic. [Learn more](#)



tinyML Foundation

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IT Services and IT Consulting · Los Altos, CA · [9,887 followers](#)

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tinyML YouTube Channel

www.youtube.com/tinyML



tinyML
5K subscribers

589 videos with 345k views, as of July 1, 2023

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tinyML Summit 2021 tiny Talks: Using Neural... 16:03

tinyML Summit 2021 Keynote: Adaptive Neural... 55:15

tinyML Summit 2021 Keynote: millijoules for... 39:43

tinyML Summit 2021 Market Opportunities for Edge AI 51:28

tinyML BiliBili Channel In Asia



主站 ▾ 番剧 游戏中心 直播 会员购 漫画 赛事 bilibili 下载APP

为什么娱乐圈这样了?



主页



动态



投稿 132



频道 10



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01:04:30

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124

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【软件】Stuart_Feffer 【软件】-tinyML不仅仅是建模

▶ 22

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【应用+视觉】Orlando_Moreira-利用稀疏

▶ 25

🗨 4-28



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【算法】Moshe_Haiut-用于小型低功耗设备的创新型卷

▶ 16

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【应用|建筑】Martin_Croome-tinyML在智

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【系统】Mallik_Moturi-tinyML不再弱小_210323

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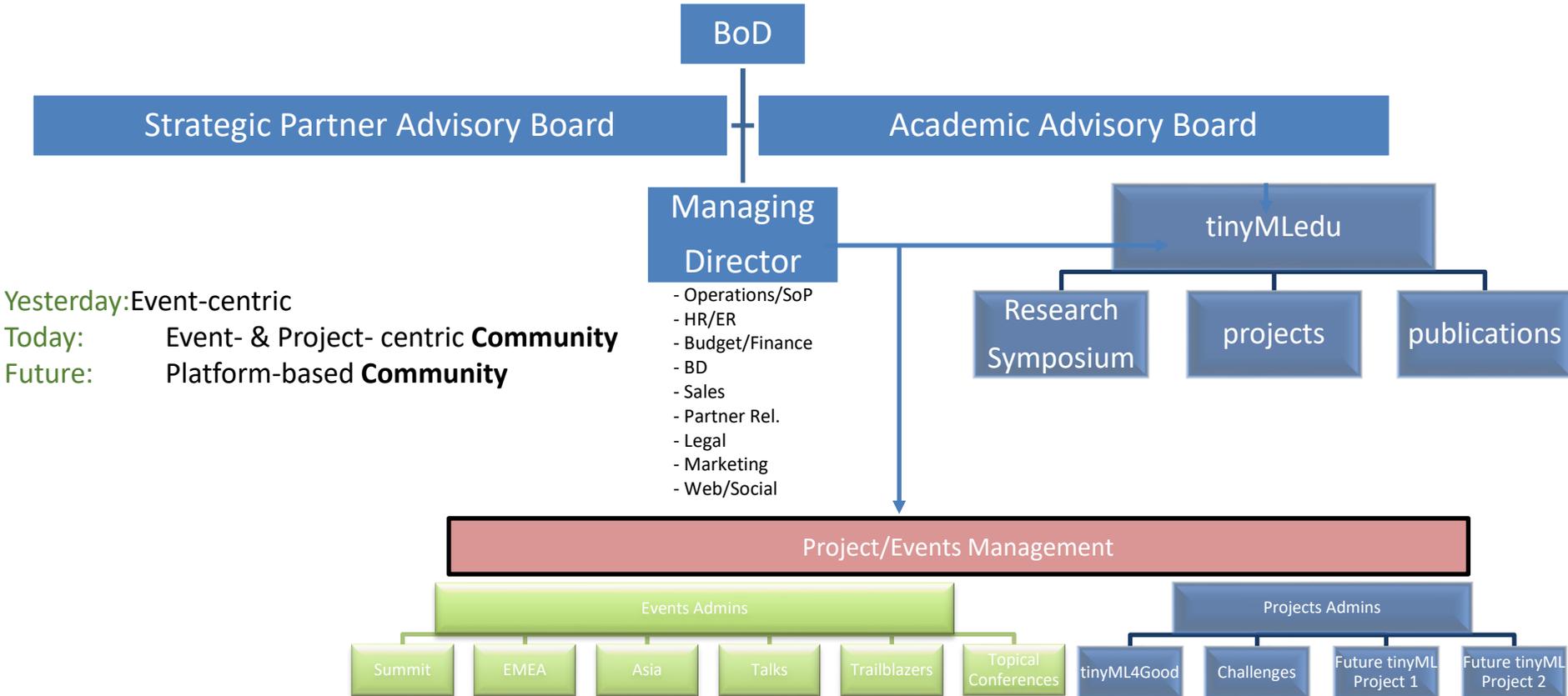
**Industry Perspective
and
Industry-Academia Partnership**

A photograph showing two white puzzle pieces being held by hands. The piece on the left is labeled 'Industry' and the piece on the right is labeled 'Academia'. The pieces are positioned as if they are about to be joined together. The background is a plain, light color.

Industry

Academia

tinyML Org Dev't to support strategy and scale-up



Yesterday: Event-centric

Today: Event- & Project- centric **Community**

Future: Platform-based **Community**

tinyML Sponsors:



Thank you, tinyML Strategic Partners*



* as of April 1, 2023; several more under final reviews

Why tinyML opportunity is so enormous?

Data is a new oil(electricity) and ML is a way to produce it



Cloud ML

- DNN on the cloud
- HW: TPU, FPGA, GPU, CPU



Edge ML

- Optimized algos and CNN-light
- SoC (with NPUs/NSP accelerators)



tiny ML

- CNN-micro
- MCU w/ HW accelerators



CMOS
cameras



IR
cameras



IMUs



Audio
mics



Environ/
chemical



Temperature



Optical
sensors

Data Sources:

1%

Storage and sharing

User provided: **4%**

1. Pics
2. Audio
3. Clicks/likes
4. GPS, Location based

95%

Real-time in the
physical world



tinyML enabled DEVICES – 2030 Forecast

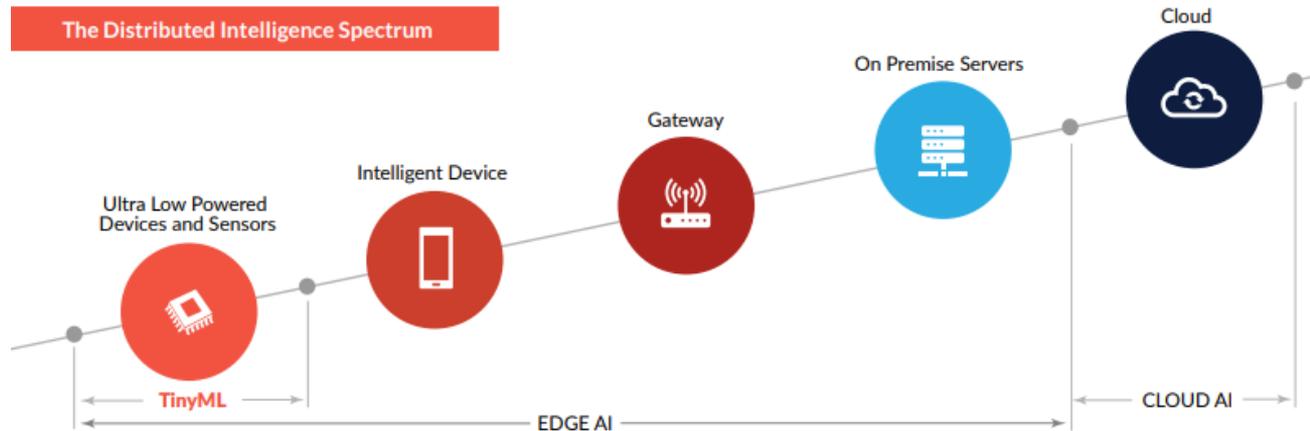
ABIresearch[®]
TRUSTED INTELLIGENCE SINCE 1999



TinyML:
The Next Big
Opportunity
in Tech



The Distributed Intelligence Spectrum

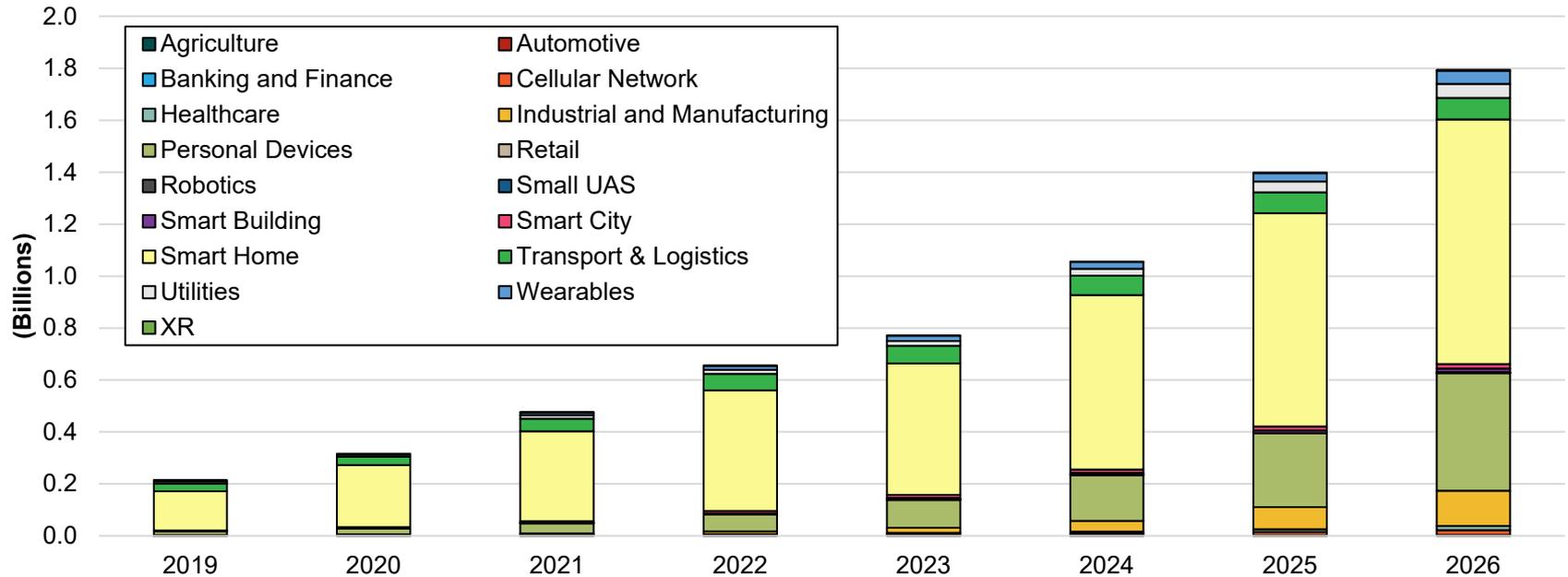


- tinyML is recognized as a separate market category
- 1B tinyML devices shipped in 2024, installed based of 5.4B tinyML devices in 2026
- High double-triple digit YoY growth
- Includes device shipment only; total value (incl. SW/services) 5-10x more

Source: ABI Research, *TinyML: The Next Big Opportunity in Tech* and MD-AIML-107, 2 QTR 2021



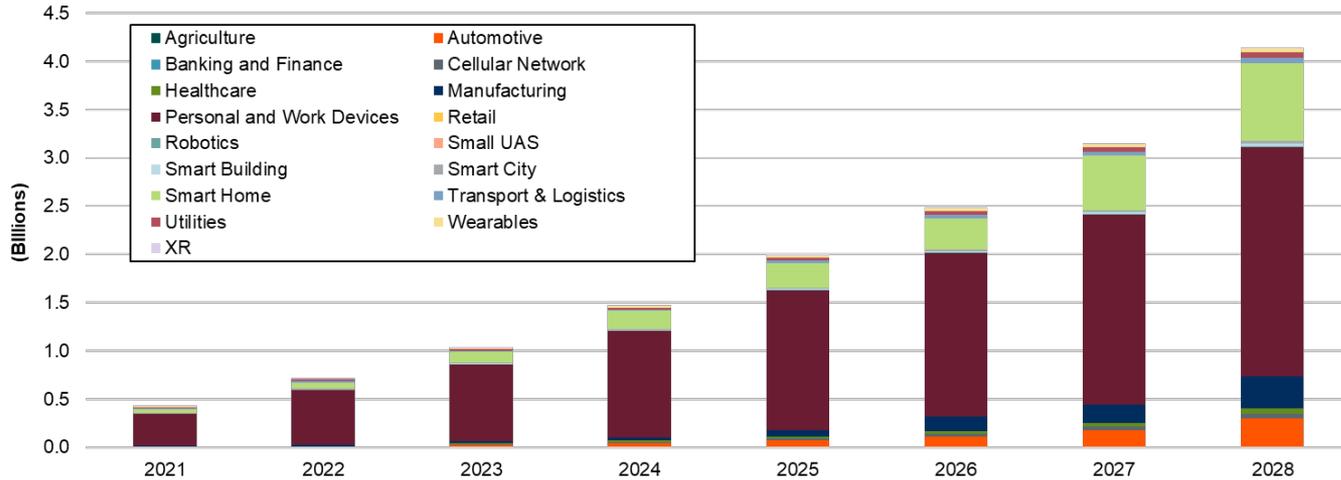
tinyML 2026 Forecast, by verticals



Source: ABI Research, Artificial Intelligence and Machine Learning, 2 QTR 2021



TinyML Device Shipment to Exceed 4 Billion/Y by 2028



2022 forecast:
11B installed devices
by 2030

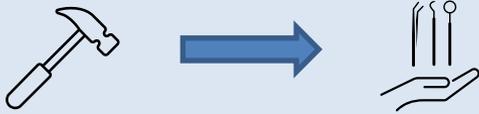
Revised 2023 forecast:
16.1B devices by 2030

- **Consumer market remains the largest segment** – Lead by tinyML use cases in smartphone, hearables, laptops, and smart home devices. Wide range of use cases covering machine vision, sound and language processing, and ambient sensing.
- Automotive, smart building, and manufacturing could be the next big market due to the need for always-on machine vision, condition monitoring, and predictive maintenance.



— Evolution of Edge AI SaaS and Turnkey Service

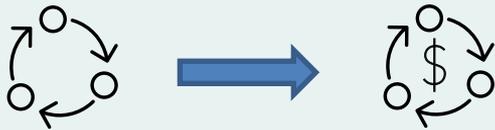
Present vs. Future



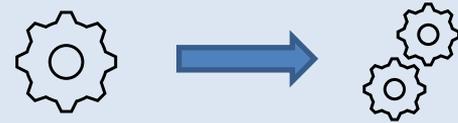
- **Tools to Vertical Solutions** – Offering bespoke models, tools and libraries highly targeted at specific verticals, such as automotive, robotics, and healthcare.



- **Expanded Edge AI Chipset Support** – Independent software vendors are supporting more edge AI chipsets beyond the traditional MCU, GPU, and FPGA.



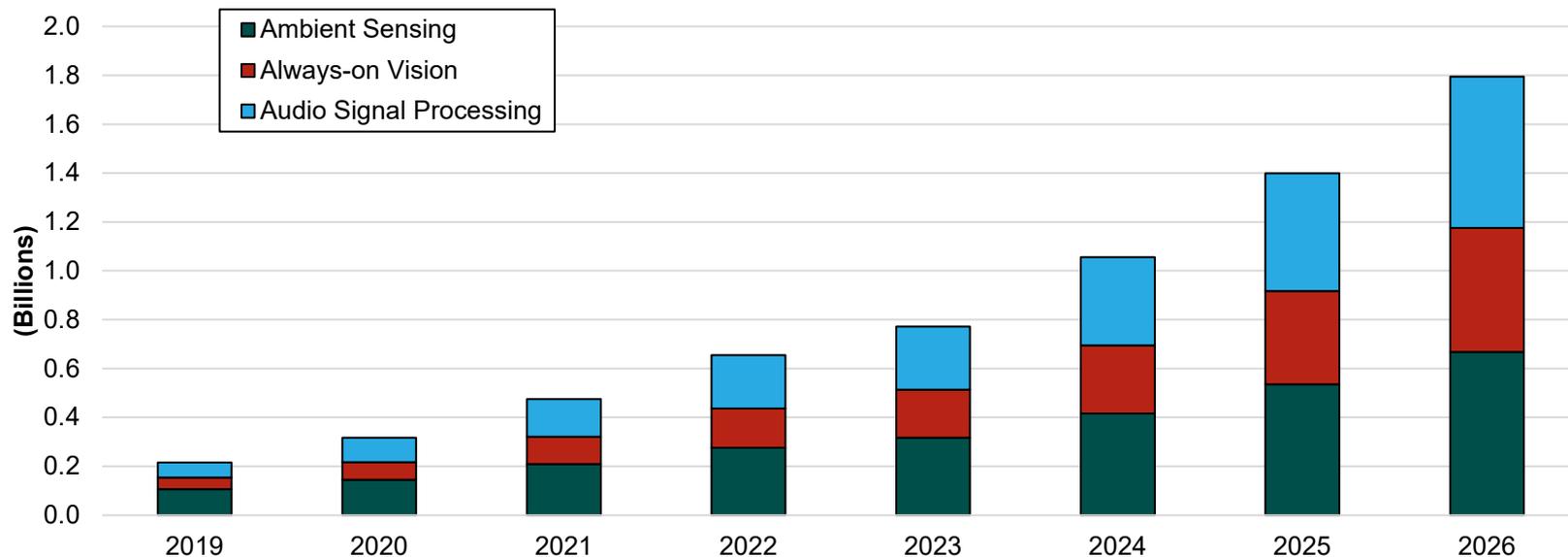
- **More to Focus on Monetization** – More edge AI chipset vendors to monetize their software capabilities, setting up potential clash with independent software vendors.



- **More Industry Partnerships** – Actively forging new partnership with distributors and system integrators with strong industrial connections.



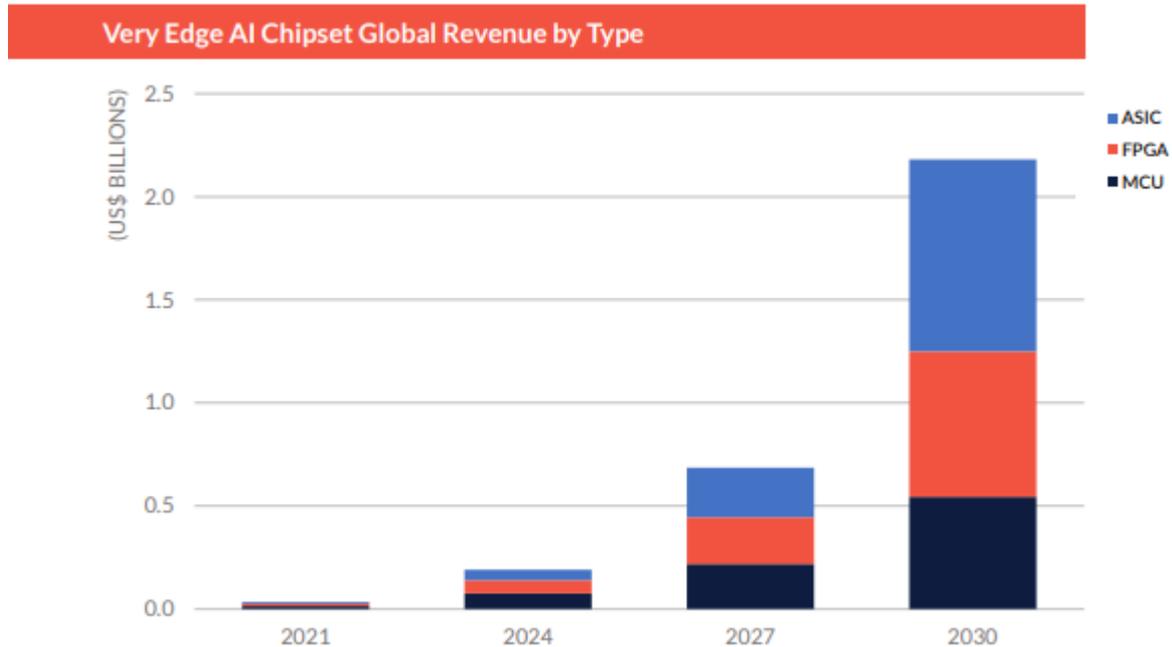
tinyML 2026 Forecast by use cases



Source: ABI Research, Artificial Intelligence and Machine Learning, 2 QTR 2021



tinyML 2030 Forecast by processor type

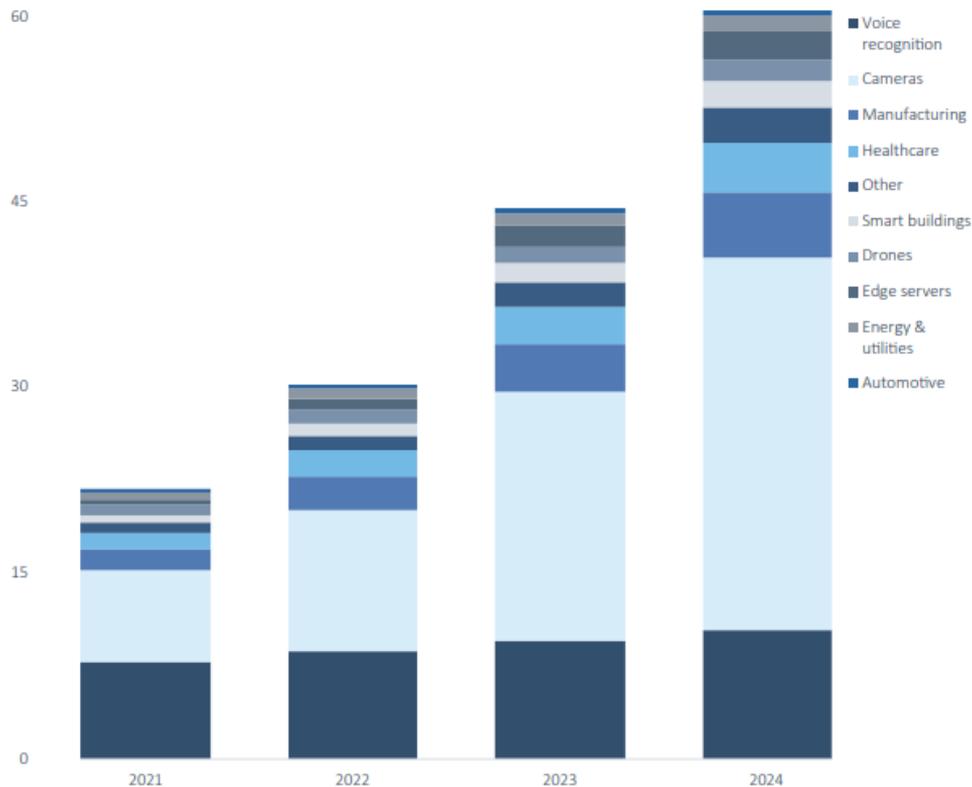


Source: Lian Jye Su, Principal Analyst, ABI Research, 2020



tinyML enabled DEVICES (\$) –near-term forecast

TinyML-compatible device revenue forecast by end market (\$B)



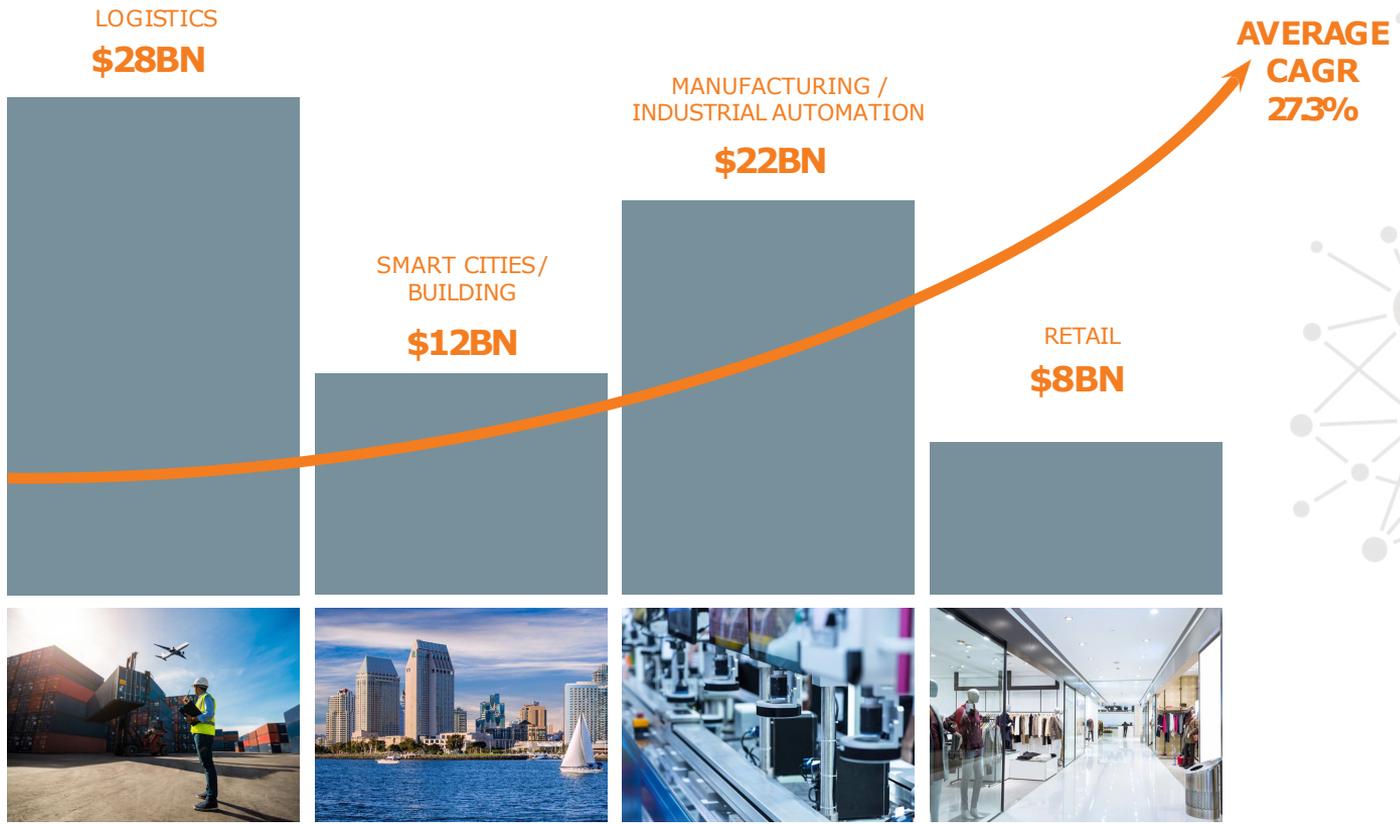
Source: PitchBook

- \$60B market by 2024 (devices only)
- 41% CAGR growth

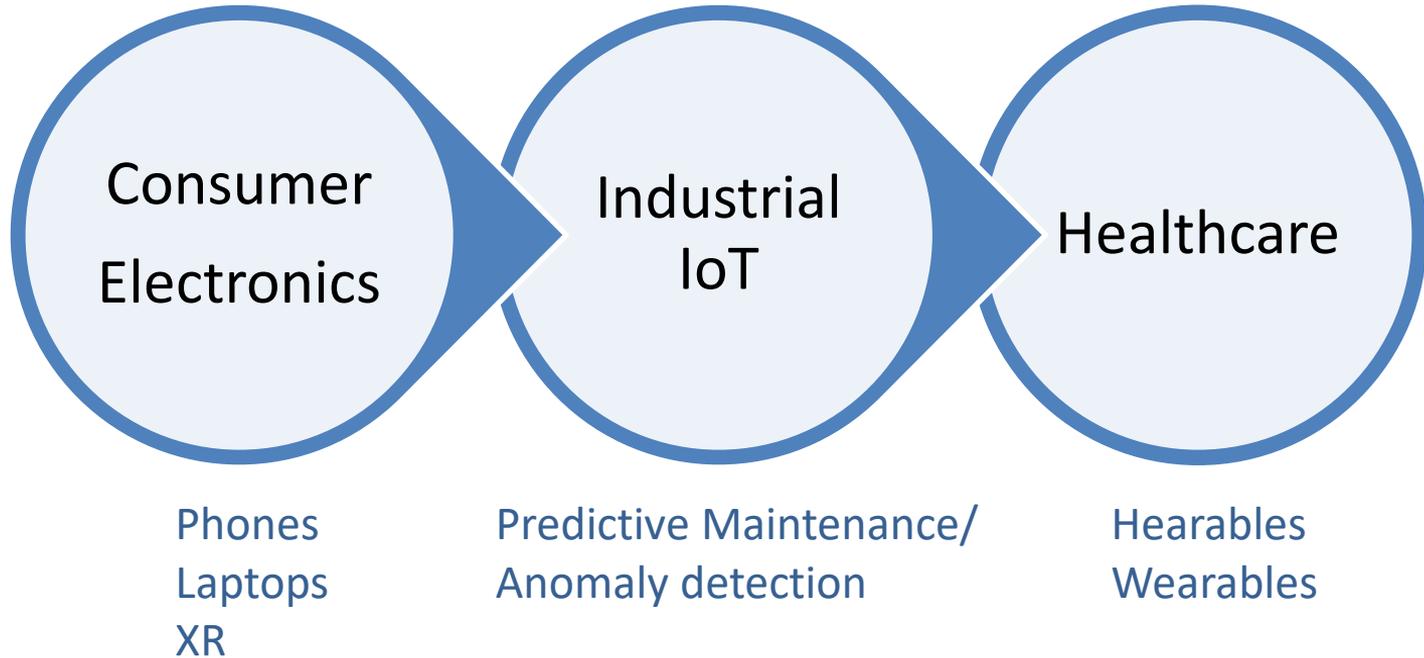




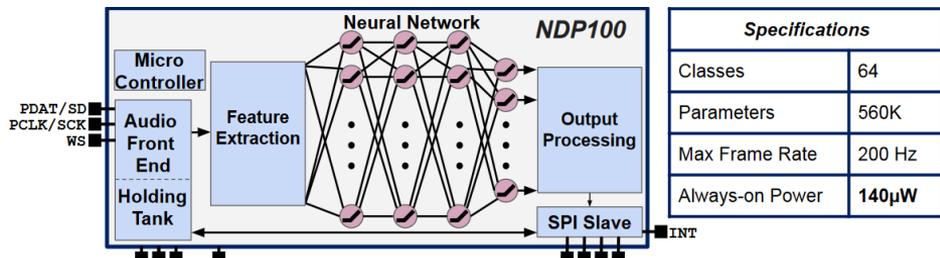
In the next 5 years tinyML can unleash over \$70BN* in economic value



Leading use cases/verticals



Example: tinyML for Always-On Voice



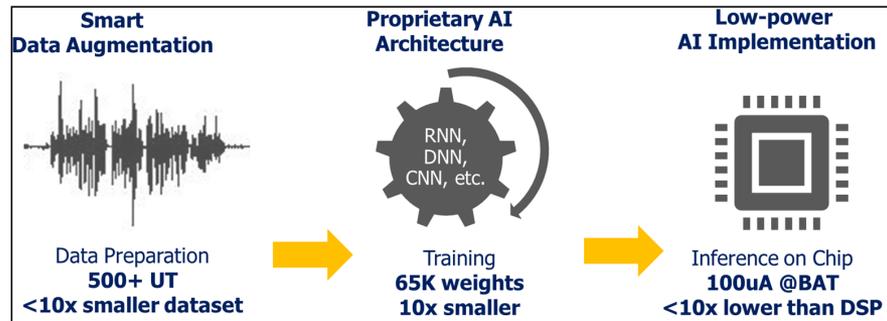
Specifications	
Classes	64
Parameters	560K
Max Frame Rate	200 Hz
Always-on Power	140 μ W

NDP100
1.4mm X 1.8mm



Courtesy: David Garrett, VP, HW

SYNTIANT



AONdevices
AI | DSP | ASIC

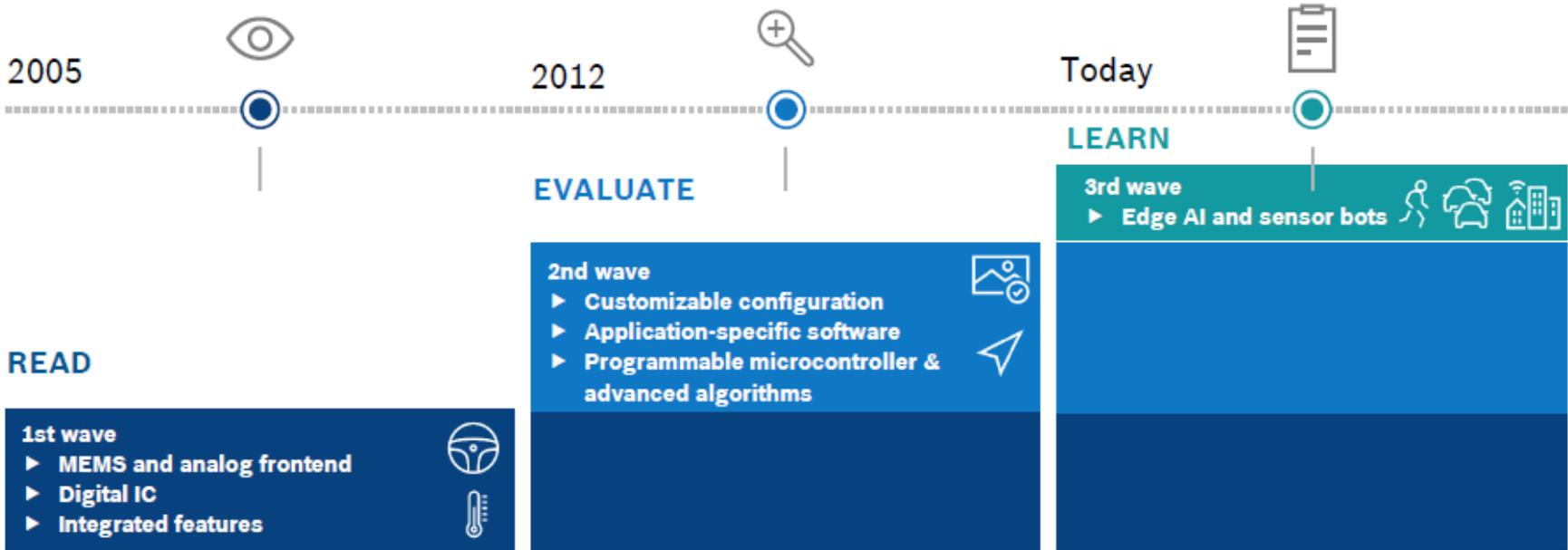
SAM: 8B Units devices by 2023

Courtesy: Mouna Elkhatib, CEO



Example: tinyML using MEMS sensors

Three waves of software evolution



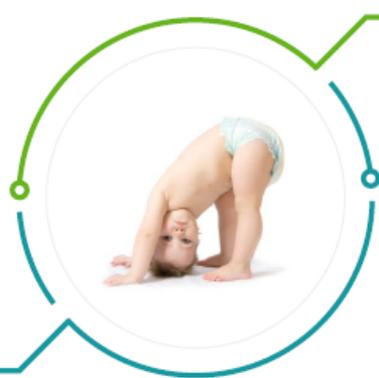
- ▶ Software adds value not only to the sensor but also to the entire system.
- ▶ Software is becoming increasingly intelligent, enabling AI inside the sensor itself.



Example: tinyML using environmental sensors

What environmental sensor hardware in a diaper delivers

- ▶ Raw temperature
- ▶ Raw pressure
- ▶ Raw humidity
- ▶ Raw gas sensor signals



What the user wants

- ▶ Diaper state:
 - ▶ Clean
 - ▶ Dirty
 - ▶ Wet

What small sensor nodes can provide

- ▶ Temperature, pressure, humidity, air flow,...
- ▶ Gas sensor signals (from air quality up to smell patterns)
- ▶ Present devices (people!)

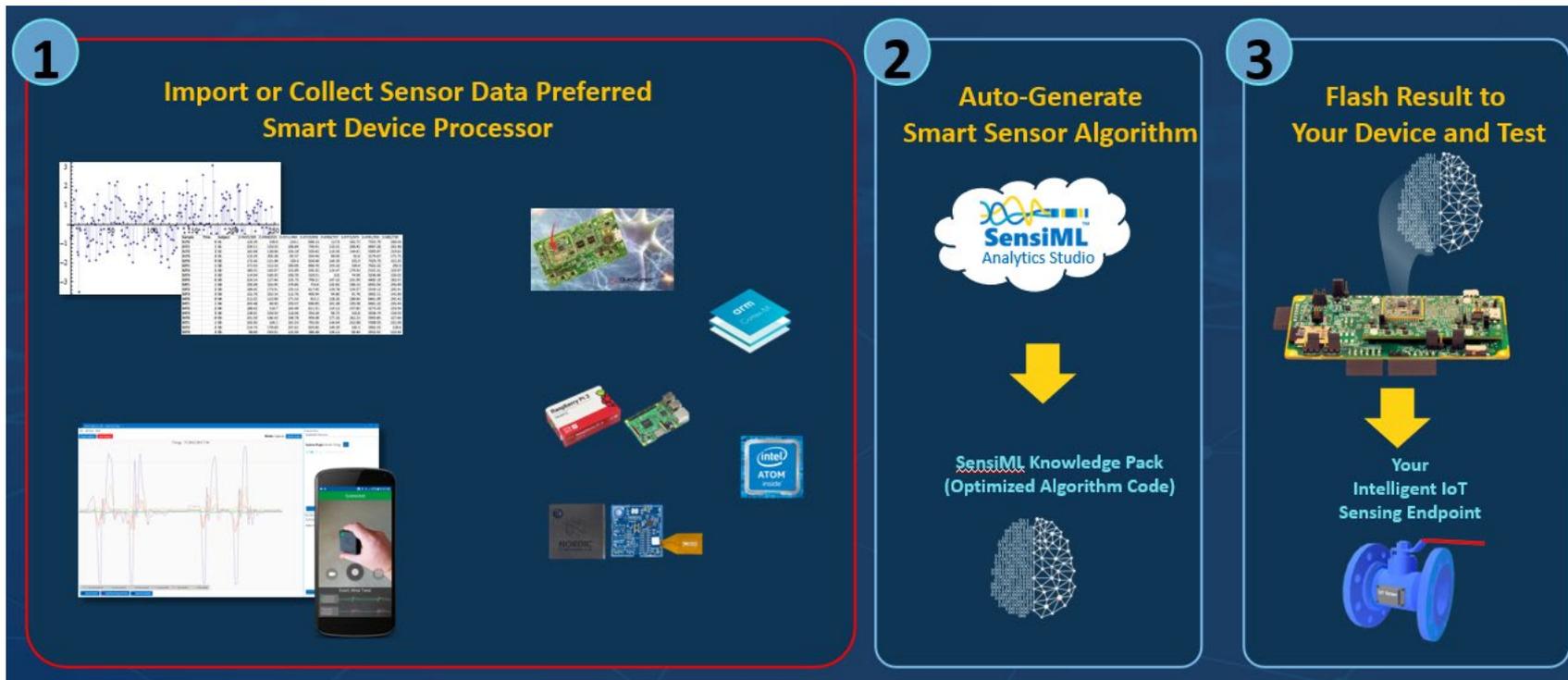


What the user wants

- ▶ Forest climate model
- ▶ Risk evaluation
- ▶ Early fire detection

Example: tinyML for predictive maintenance

(using IMUs)



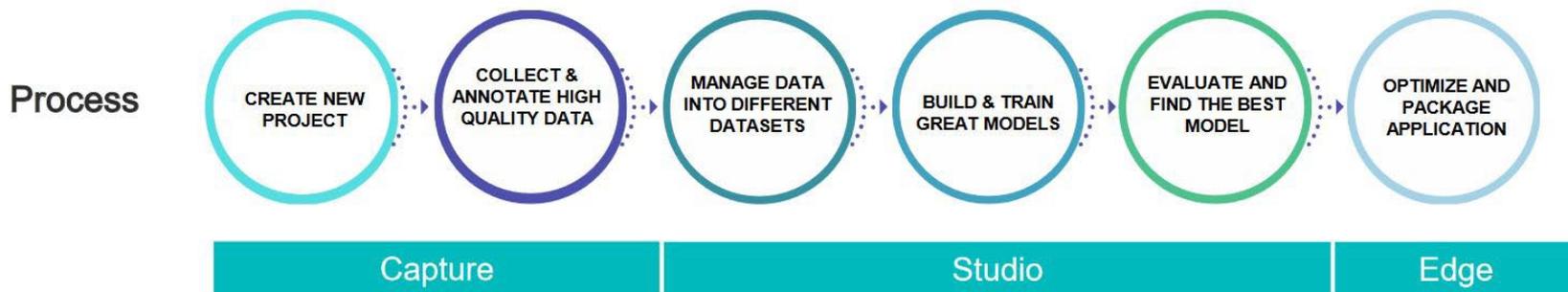
Courtesy: Chris Knorowski, CTO



Example: tinyML for Gesture Control (using Radar)



- Proof-of-concept shown at CES 2020; Working prototype of gesture-controlled in-ear headphones will be demonstrated at CES 2021
- Application running in real time on the actual radar module
- ARM M4 processor, 256KB RAM (shared with BLE, FW and other apps)
- Impossible without Edge AI/tinyML
- Just sending the data off the device would drain the battery and impossible over BLE



Example: tinyML for AR/VR applications



Yann LeCun (Facebook, Dec.2019): AR glasses will be the killer app of energy-efficient machine learning

Also watch: tinyML Talk by Hans Reyserhove (Facebook Reality Lab): Embedded Computer Vision Hardware through the Eyes of AR/VR
<https://www.youtube.com/watch?v=c4g2zwFR3ps&t=1015s>



tinyML Vision supports human detection cases



Half body



Full body



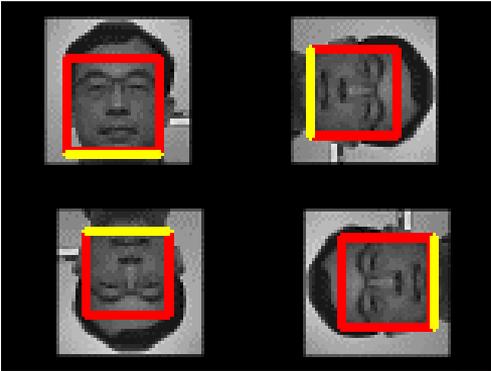
3/4 body



Change Detection



Multiple face orientation

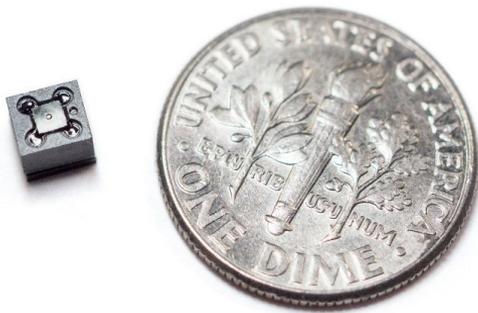
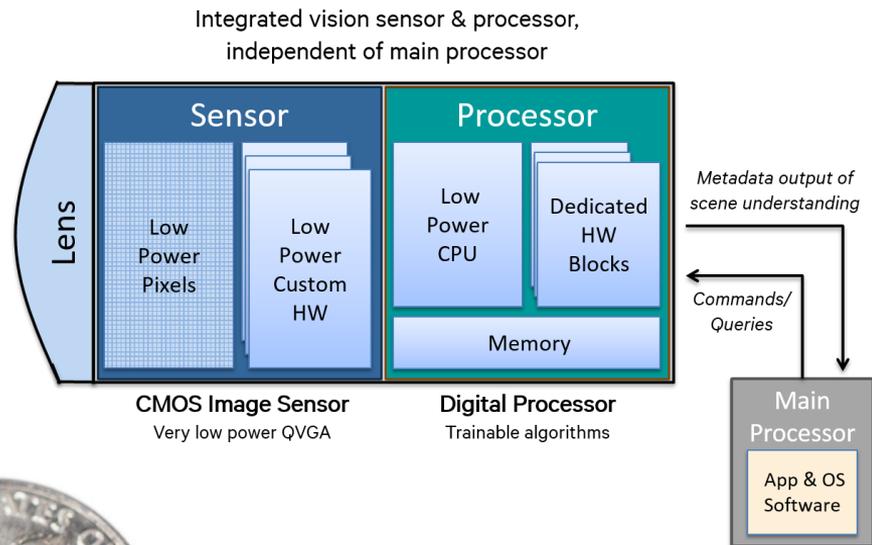


tinyML for Always-On Vision

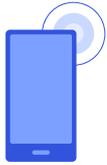
Qualcomm always-on computer vision module

Key features:

- Ultra-low power, < 1 mW (end-to-end)
- Small size
- Privacy (output is metadata)
- Configurable for different use cases
- QVGA sensor, Near-IR compatible
- Low cost



Vision will enhance many use cases across numerous verticals



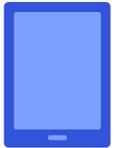
Smartphone

- Face-based auto-wake and auto-sleep
- Always-on trigger for other use cases
- Always-on trigger for iris authentication (removes multiple steps and user initiation)



Smart watch

- Face-based auto-wake and auto-sleep
- Always-on gestures



Tablets

- Simple gaze tracking for advertising attribution
- Improved landscape/portrait screen orientation



Virtual reality

- Low power gaze tracking (foveated rendering)
- Low power visual odometry for 6 DoF



'Intelligent' occupancy trigger

- Distinguish humans from other objects
- Add data layer to trigger: How many? Where?
- Trigger on particular events or objects



'Intelligent' interactivity trigger

- Face detection as a trigger for interactivity
- Smart appliance can react when a user approaches to engage it



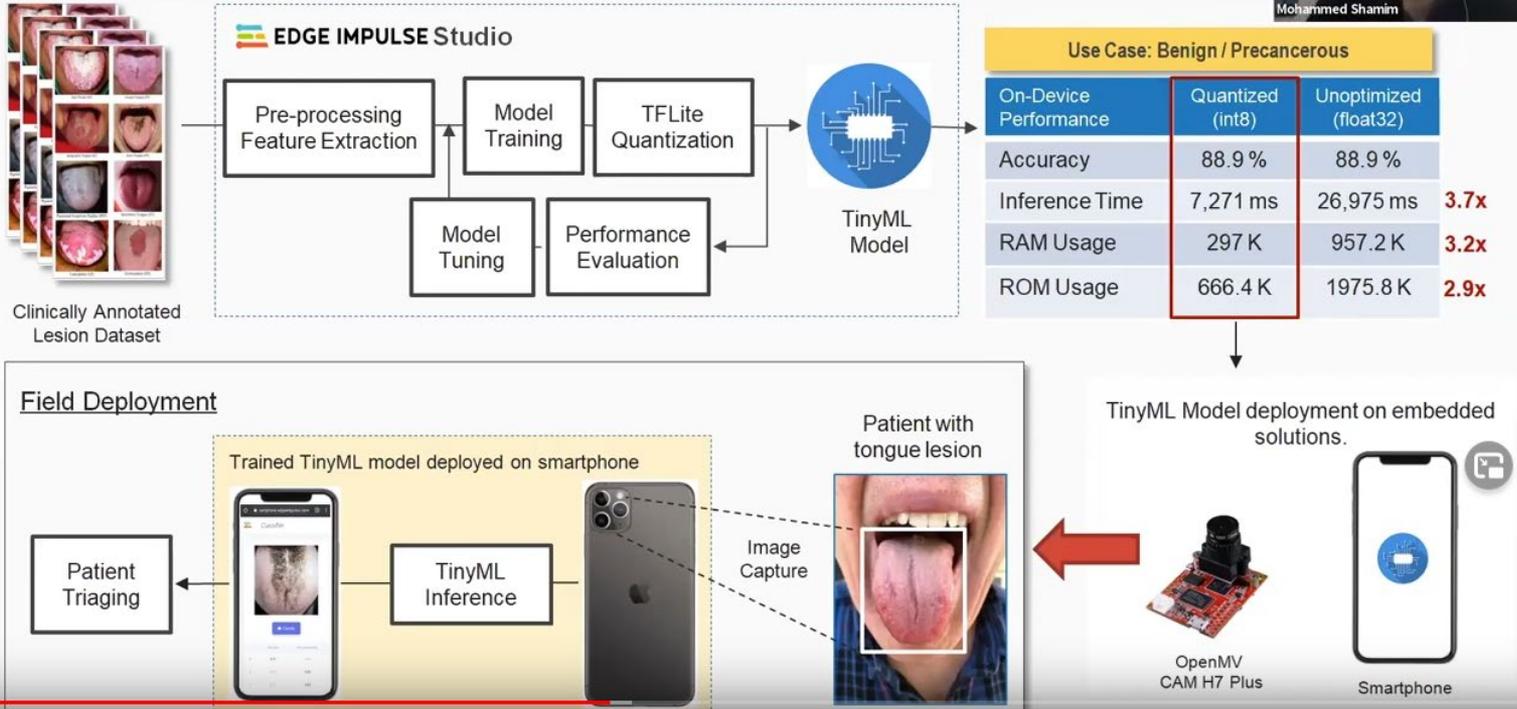
Standalone intelligent data sensor

- Heat maps of how a space is occupied
- Privacy advantages - data only, no images captured

Example: Oral cancer detection using tinyML



Automated Pre-screening Solution



Courtesy: Dr. Mohammed Zubair, King Khalid Univ, Saudi Arabia



**Call to Action
for tinyML.edu 2.0**

tinyML 2.0 Objective/”Products”

- Develop workforce for the industry (both tinyAI and bigAI)
- Educate educators
- Inspire future tinyML entrepreneurs
- Conduct research in energy efficient ML
- Promote collaborations/partnerships
- Build more awareness
- AI democratization and tinyML for Good



tinyML creates Jobs !

#hiring

Syntiant Corp.
4,336 followers
4mo • Edited •

+ Follow

We're hiring! From earbuds to automobiles, Syntiant is making #edgeAI a reality. So much so that we're looking for entrepreneurial-driven engineers to join our award-winning company. If you want to be part of a team that fosters an exciting culture of innovation, visit <https://lnkd.in/gtg4CJk> or send us your resume and cover letter to join@syntiant.com. We look forward to hearing from you! #cultrematters #culturefirst #hiring #innovation #jobs #recruitment #engineering #engineeringjobs #careers

... and more #hiring in #tinyML, this time with Cartesiam-ST
Marc Dupaquier Joel Rubino

Marc Dupaquier • 1st
Managing Director Artificial Intelligence Solutions, STMICROELECTRONICS
2mo •

We are looking for great talent to join our Edge AI Teams across the World. If you love designing new devices, if you dream big and want to make your dreams a reality, if you want to join the Global Leader of Edge AI an ...see more



Cartesiam NanoEdge AI Library
cartesiam.ai • 2 min read

**We're Hiring
TinyML Firmware Engineers**

Join Our Team in Building
Cutting Edge AI Solutions

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1,647 followers
4mo •

Audio talent is urgently needed. Greenwaves is hiring!
#hiring # #jobs #audioprocessor #audioengineer #tinyML
<https://lnkd.in/dPvRS-m>

Senior Embedded Software Engineer - Optimization of Computation of Audio Algorithm on GAP Architecture

greenwaves-technologies.com • 2 min read

As a member of the Audio team, you will contribute to port and optimize calculations an...



R&D Systems Engineer (Embedded Machine Learning Algorithm Development) San Diego and Santa Clara

San Diego

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Full time

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★EXCITING NEWS - We're recruiting! Join a dynamic team working on cutting edge AI sound recognition technology. Why not take a look at the open roles on our website? We look forward to hearing from you: <https://aud.ai/3igwDYj>



Play

Zach Shelby • 1st
Hiring! Co-founder and CEO at Edge Impulse
4mo •

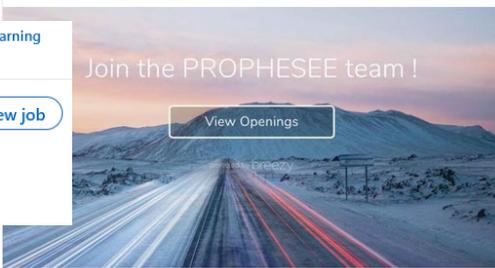
Now is your chance to join the startup democratizing machine learning for industrial, logistics and health. **Edge Impulse** is hiring full-stack developers, user success engineers and sales executives with more open positions con ...see more

Jobs at Edge Impulse

docs.edgeimpulse.com • 1 min read

Edge Impulse enables developers to create the next generation of intelligent device...

We are hiring in Grenoble and Paris.
Computer Vision and Image Processing specialists wanted!
Feel like interested? Please pay a visit to our offerings page



View job

Qeexo is hiring - come make awesome products with me! #machinelearning #qeexoautoml #tinyML

Product Manager / Senior Product Manager
Job by Qeexo
Mountain View, California, United States
Medical, Vision, Dental, 401(k)

3 connections work here



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Want to see what you'll be working on? Check out the Deeplite Neutrino Community version on [GitHub](https://github.com)!

Senior Embedded System QA Engineer

GrAI Matter Labs • Paris, Île-de-France, France 4 months ago • 14 applicants

Full-time

11-50 employees

8 connections

See recent hiring trends for GrAI Matter Labs. [Try Premium for free](#)

Apply now

Save



1. Make tinyML.edu 2.0
(HW and SW) agnostic and **modular**



for example, tinyML SW tools (e.g. tiny autoML)



State of the tinyAutoML Market 2022

June 10, 2022



Featuring:

- Edge Impulse
- Greenwaves Technologies
- Newton.ai
- Nota.ai
- SensiML
- Deeplite
- Stream Analyze
- Qualcomm AiMET
- Qeexo
- Imagimob
- OmniML

<https://www.tinyml.org/event/auto-ml-forum/>

https://docs.google.com/document/d/1SDr6vgZOtpCtxX7s6lxfzB_V6ut7YSU6iCFwWgK_A8E/edit



HW space is also very diverse:

- Greenwaves Technologies (RISC-V)
- Syntiant
- ARM
- Alif
- ST Microelectronics
- NXP
- Qualcomm
- Bosch
- Infineon
- Silicon Labs
- TDK
-





2. Real-world tinyML goes beyond
ML model training
– add **deployment**





tinyML Deployment Working Group White Paper #1

February 20, 2023

There is far more than “fit & predict” development required to deliver Tiny ML based products.

This is the first white paper in a series exploring challenges and solutions for deploying ultra-low power machine learning (ML) at the edge of the cloud. The authors are members of the [tinyML® Foundation](#) Deployment Working Group. The opinions expressed are not necessarily representative of the tinyML Foundation, its sponsors, or the authors' employers.



https://www.tinymml.org/static/98111ec2e44e63079e10872b485777a0/tinyML_Deployment_WG_White_Paper_1.pdf





3. Focus on **solutions**
not just (ML) models and tools



FOUNDATION

collaboration with



Focus on:

(i) developing new use cases/apps for tinyML vision; and (ii) promoting tinyML tech & companies in the developer community



485 participants & 52 Submissions

<https://www.hackster.io/contests/tinyml-vision>



Eyes on Edge: tinyML Vision Challenge!

with **tinyML Foundation**

Congratulations to all the winners! Check out the winning projects below.



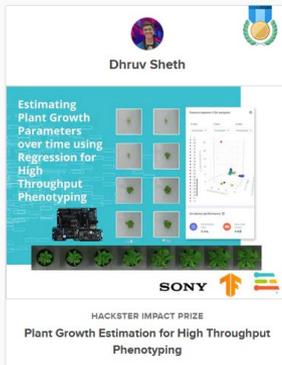
<https://www.hackster.io/contests/tinyml-vision>

Vision Challenge-2021 Winners

 Team Sol   RANKED WINNERS: 1ST PLACE TinyML Aerial Forest Fire Detection	 TheBlue Phoenix   RANKED WINNERS: 2ND PLACE WorkSafe: Computer Vision based multiparameter monitor with	 Huy Mai   RANKED WINNERS: 3RD PLACE TinySewer - Low Power Sewer Faults Detection System
--	---	---

Hackster Impact Prize

The winner was awarded a \$250 Gift card + Video interview + More (\$530 value)



Dhruv Sheth

HACKSTER IMPACT PRIZE
Plant Growth Estimation for High Throughput Phenotyping

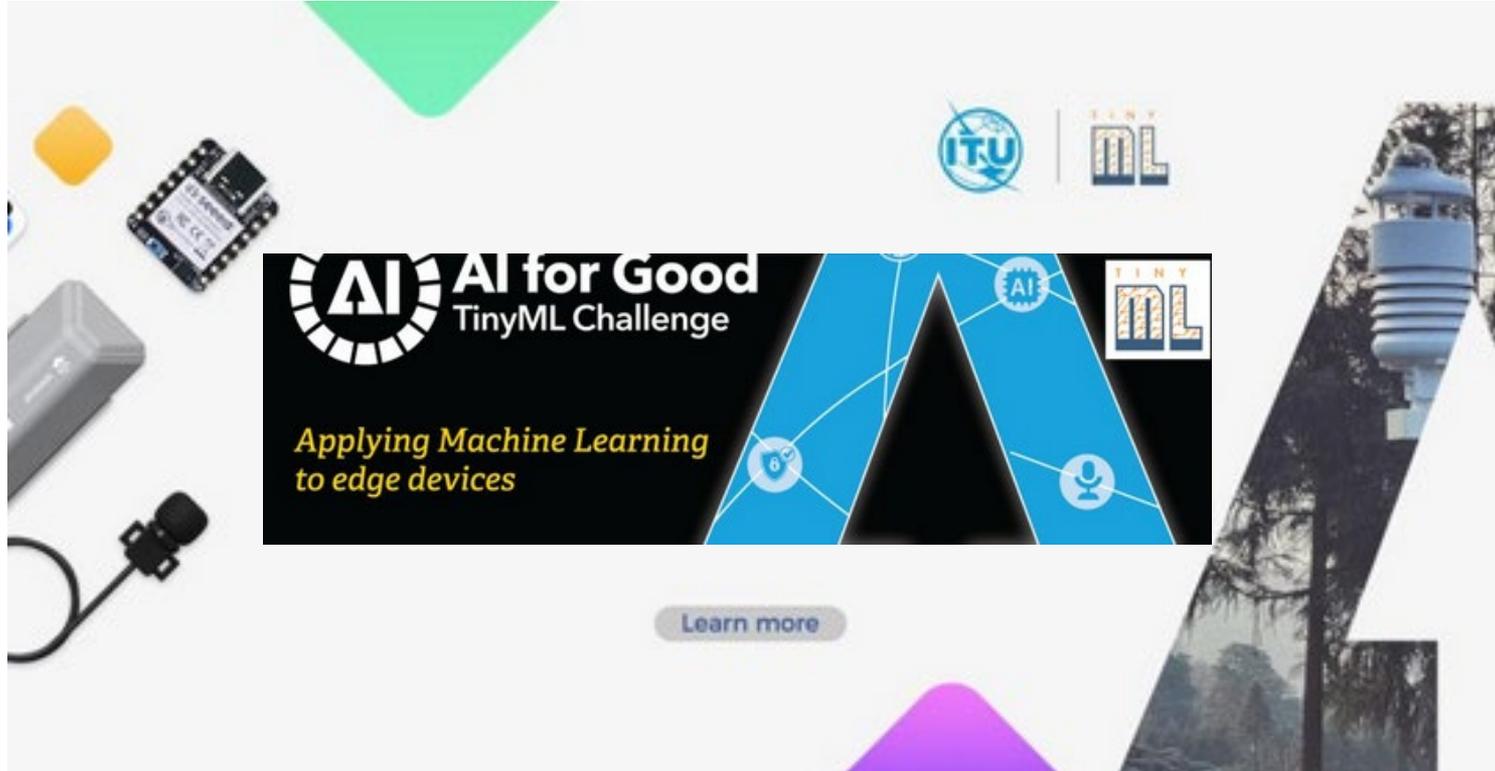
Honorable Mention

Each runner up was awarded a \$500 Gift Card (\$500 value)

 Bob Hammell   HONORABLE MENTION Flat Tire Detection Using Machine Vision	 Ariela, Anna, Audrey, Nathan, Tianlang, Haoming, Eric, Edward, Tera   HONORABLE MENTION Smart Bird Feeder
---	--



Smart Weather Station Challenge-2022: *collaboration with UN/ITU*



<https://challenge.aiforgood.itu.int/match/matchitem/71>



tinyML Challenge-2023 on pedestrian detection: *collaboration with City of San Jose*



Search



Picture in picture

tinyML **Foundation**
Enabling Ultra-low Power Machine Learning at the Edge

**Pedestrian Detection
Hackathon Kickoff**

April 25, 2023

**TINY
ML**
www.tinyML.org

0:08 / 46:08

tinyML Pedestrian Hackathon Kickoff 2023 - Pedestrian Detection

<https://www.youtube.com/watch?v=J1NYQaQe7M8&t=2s>



tinyML BUILDS Series



- 1 hour on-line LIVE and interactive interviews with tinyML “Builders”
- Have you wondered what goes into building a REAL WORLD tinyML device/product? In this series, we discuss the details of how product developers and engineers built their tinyML devices, from early development phases to commercialization. The discussion is a deep dive into engineering and tech that these teams have developed and lessons learned.
- Started in April 2023
- Hosted by Venkat Rangan, Founder and President of tinyVision.ai



tinyML Success Stories Series

- Inspiration and educational series
- 1 hour on-line LIVE and interactive interviews with tinyML “movers and shakers”
- Recent M&A stories, VC views, new products, breakthrough research in the academia
- Started in December 2021
- Hosted by renowned entrepreneur Chris Rowen (CISCO)



tinyML® Trailblazers
Ultra-low power machine learning at the edge success stories

Pete Warden, Google
Success Stories Series hosted by Chris Rowen

INSPIRE-EDUCATE-ILLUMINATE

Chris Rowen

Pete Warden

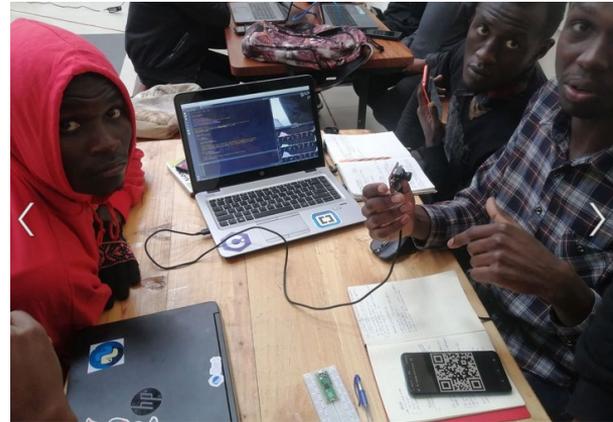
tinyML Success Stories Series Guests



- Pete Warden, Google <https://www.youtube.com/watch?v=tlQcdhIN8q8&t=2999s>
- Kurt Busch, Syntiant co-founder and CEO, <https://www.youtube.com/watch?v=ceT8LMUIiBU&t=112s>
- Joel Rubino, Cartesiam.ai co-founder and CEO, <https://www.youtube.com/watch?v=NkT7rMiTQRk>
- Marian Verhelst, Prof at KU-Leuven and tinyML BoD, <https://www.youtube.com/watch?v=COMoXOSQALY>
- Eric Pan, Founder and CEO, Seeed Studio, <https://www.youtube.com/watch?v=DRfv-Rwy3lw&t=1715s>
- Thierry Moreau, OctoML Co-Founder, <https://www.youtube.com/watch?v=GaLJ47bmQ1I&t=129s>
- Mouna Elkhatib, Founder and CEO, AONDevices, [tinyML Trailblazers Success Stories with Mouna Elkhatib - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20Success%20Stories%20with%20Mouna%20Elkhatib)
- Yoram Zylberberg, CEO, Emza Visual Sense, [tinyML Trailblazers with Yoram Zylberberg - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20with%20Yoram%20Zylberberg)
- Vijay Janapa Reddi, Prof. at Harvard University, <https://www.youtube.com/watch?v=wk7bQvzR5Ik&t=18s>
- Zach Shelby, CEO and Co-Founder, Edge Impulse, <https://www.youtube.com/watch?v=15GdPnoQhB8>
- Massimo Banzi, Co-Founder and CTO, Arduino, [tinyML Trailblazers Success Stories with Massimo Banzi - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20Success%20Stories%20with%20Massimo%20Banzi)
- Chris Rogers, Co-Founder and CEO, SensiML, [tinyML Trailblazers Success Stories with Chris Rogers - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20Success%20Stories%20with%20Chris%20Rogers)
- Luca Verre, Co-Founder and CEO, Prophesee, [tinyML Trailblazers with Luca Verre CEO Prophesee - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20with%20Luca%20Verre%20CEO%20Prophesee)
- Loic Lietar, Co-Founder and CEO, Greenwave Tech, [tinyML Trailblazers with Loic Lietar CEO from Greenwaves Technologies - YouTube](https://www.youtube.com/watch?v=tinyML%20Trailblazers%20with%20Loic%20Lietar%20CEO%20from%20Greenwaves%20Technologies)
- Sang Won Lee, Co-Founder and CEO, Qeexo, <https://www.youtube.com/watch?v=NpO45JPVFlo>
- Kishore Manghnani, Co-Founder and CEO, Shoreline IoT



tinyML Kenya Developer Day, July 2022*



*100+ participants

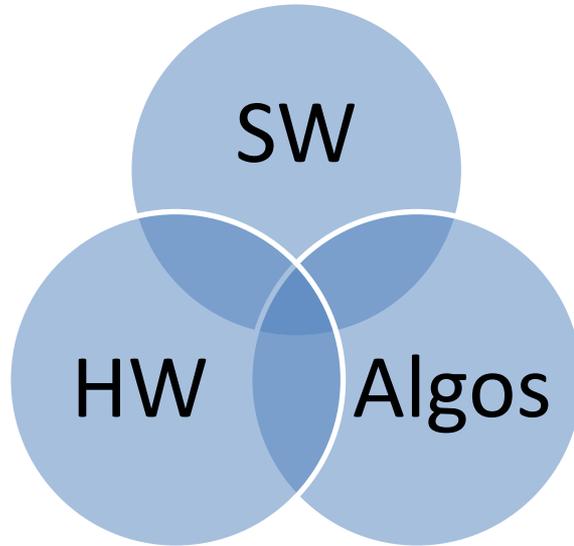




**4. Encourage & embrace holistic,
systems/project based
multi-disciplinary approach**

How is tinyML Implemented ?

- Key:**
- Holistic HW-SYS(algorithms/networks)-SW co-design
 - Extreme optimization and innovation in all three areas

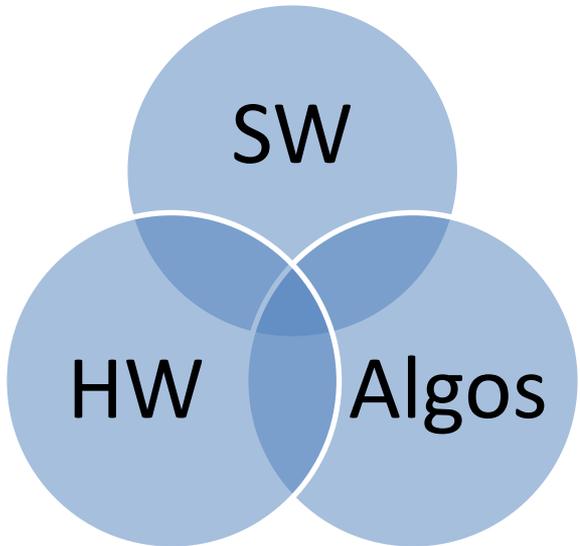


tinyML is “good enough” **NOW**

... *and more enhancements coming in the near future*

\$\$\$ *More tinyML apps and value creation*

\$ *initial tinyML applications*



HW accelerators (digital)

- *Compute in memory*
- *Analog compute*
- *Neuromorphic*

Quantization, compression
Smaller models (100s kB)

- *Novel algos/networks*
- *10s kB models*

Enabling technologies: ULP sensors, novel memories, 3D, energy scavenging, ULP radio





5. tinyML = embedded + ML





6. Conduct basic research

Inaugural tinyML Research Symposium (March 26, 2021)



TINY ML

Summit 2021 Research Symposium All Events

MACHINE LEARNING

tinyML Research Symposium 2021

Inaugural research symposium

Register Now Summit 2021

Committee



Boris MURMANN
Program Chair
Stanford University



Vijay JANAPA REDDI
Program Chair
Harvard University

Publications



Ultra-low power machine learning at the edge

Proceedings Research Symposium

Proceedings of tinyML Research Symposium

[Research Symposium 2021](#)

[Research Symposium 2022](#)

[Research Symposium 2023](#)

www.proceedings.tinyML.org

Industry peer recognition Awards



2021 Winners

SYNTIANT

 **EDGE IMPULSE**

Guangyuan HU



**PRINCETON
UNIVERSITY**

2022 Winners



REXEN
technology

Andrea BEJARNO-CARBO





7. More attention to **data** engineering



EMEA 2023

Summit 2023

Research Symposium 2023

tinyML Sponsors

All Events



tinyML Datasets & Benchmarking Working Group

<https://www.tinyml.org/event/tinyml-dataset-benchmarking-working-group/>





- 8. Promote tinyML impact and applications/use cases (e.g. tinyML application zoo)**
- share known use cases
 - inspire student to think out of the box
 - don't be shy to talk about positive impact

Plentiful tinyML use case: some more examples

CARTESIAM.AI Presented by **NanoEdge™ AI Studio**

Use Case Explorer

Browse use cases and check how NanoEdge™ AI Studio performs. For each use case, find the data and parameters used, as well as video demos and/or tutorials. DISMISS

Field of application Search for use cases

 <p>Hole drilling deviation Predict if your drill bit departed from a pre-selected trajectory</p>	 <p>Fashion MNIST Classify grayscale images of fashion items</p>	 <p>MNIST Classify black and white images of numbers</p>	 <p>Iris plants Classic dataset in statistics and machine learning</p>	 <p>Bearing, belt, and EDM faults Vibration analysis from very noisy sound files</p>	 <p>Stator Yoke Temperature Predict the stator temperature of an electric car with a thermal sensor</p>	 <p>Permanent Magnet Surface Temp Predict the outer temperature of an electric car</p>	 <p>Stator Tooth Temperature Predict the temperature of the stator tooth in an electric car</p>	 <p>Stator Winding Temperature Predict the temperature of the stator winding in an electric car</p>
 <p>Torque Predict the torque of an electric car</p>	 <p>White Wine Predict wine quality</p>	 <p>Drive diagnosis Detecting defects in an electric motor</p>	 <p>Smart vacuum cleaner Detect if your vacuum bag is empty or full (at different regimes)</p>	 <p>Brushless wheel s&B Brushless motor of an electric skateboard wheel</p>	 <p>Is my fan obstructed? STM32 Detect with an accelerometer if my fan is obstructed</p>	 <p>Smart ukulele Smart device that can detect which note or chord is played on a ukulele</p>	 <p>APS failures in Scania trucks Predict failures in the Air Pressure System of Scania trucks</p>	 <p>Cardiotoxicography Measurements of heart rate rate (HR) and uterine contraction (UC)</p>
 <p>Breast cancer The data contains measurements on cells in suspicious lumps in women's breast</p>	 <p>Is my fan obstructed? We detect if a fan is obstructed through classification</p>	 <p>Energy prediction Predicting the energy consumption of energy appliances</p>	 <p>Steel Plates Faults Detecting faults in metal</p>	 <p>Electric grid Predicting if the grid will be stable given a few features</p>	 <p>Glass tapping sound Determine if a glass is full or empty</p>	 <p>Occupancy detection Predicting how many people are in a room</p>	 <p>Lock picking Detect if a lock is being open with a key or using picks</p>	

Try NanoEdge™ AI Studio for free now!

[DOWNLOAD NANOEDGE™ AI STUDIO](#)



Courtesy:



Social impact: tinyML/tinyAI for Good



<https://www.un.org/development/desa/disabilities/envision2030.html>

tinyML/tinyAI will make significant contribution to major SDG goals:

- Good Health and Well-being
- Clean Water and Sanitation
- Affordable and Clean Energy
- Decent Work and Economic Growth
- Industry, Innovation and Infrastructure
- Sustainable Cities and Communities
- Responsible Consumption and Production
- Climate Action
- Life on Land
- Partnerships to achieve the Goal

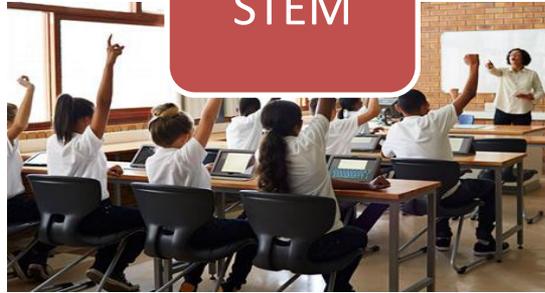
😊 Strong differentiation and significant impact potential: unlike cloud based AI, tinyML is **ultimately connected to LIFE** via sensors and actuators in most/all verticals: environmental, smart agriculture, food, wellness/health, climate, education, etc.

😊 Prof. Song Han at MIT has developed an AutoML approach, “Once-for-All”, allows to **reduce carbon footprint by 1/1000th** while designing a network wrt the conventional ML and **improve inference time(energy) by about 2x**.

<https://www.youtube.com/watch?v=jsyHqDX5cU8&t=3s>



STEM



Kate Kallot
NVIDIA
Head of Emerging Areas,
tinyML for Good Leader

Healthcare



Earth
Climate
Conservation

Contact: 4good@tinyML.org

tinyML for Good @ GTC2021*

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tinyML for Good [A31182]



KATE KALIDT
Head of Emerging Areas, NVIDIA

EVGENI GOUSEV
Sr. Director, Qualcomm Technologies, Inc

FRAN BAKER
Global, Social Impact and Innovation Lead, Arm

ALEXANDER SARAWIA
Co-founder and CEO, Sunplena Tech

CLINTON ODUOR
Co-Founder, Rhions Lab

CHRIS ROGERS
CEO, SensiML

NVIDIA GTC

Attendee >

tinyML for Good [A31182]

All questions (8) ▾ Top voted ▾

How mature is the tinyML technology stack?

3 votes
Answered by |
0 comments >

Presenter / Moderator

tinyML tech stack is getting quite mature, both in the HW and SW areas.

See full answer
View all answers >

Attendee

How big is the tinyML market size in conservation?

1 vote
Answered by |
0 comments >

Presenter / Moderator

tinyML is not tiny. It has a big impact on healthcare, education, conservation and climate change. In this panel discussion, our tinyML experts will share the tinyML for Good applications, opportunities, and how tinyML drives AI innovation in the emerging markets.

**210k attendees registered at GTC2021*



Inspirational tinyML for Good Workshop, Nov.17, 2021*

Very well presented on all fronts! Thanks everyone for the "education" and for sparking the urge to focus more on TinyML.

Get Inspired, Make Great Things Happen!

Thoroughly enjoyed thanks!

The screenshot shows a presentation slide with a dark blue header. On the left, there is a vertical sidebar with the 'tinyML For Good' logo and the text 'tiny tech for the world's biggest challenges' above a landscape image. The main header contains the 'EXECUTIVE SPONSORS' logos: arm, EDGE IMPULSE, Qualcomm, and SYNTIANT. The slide title is 'GOOD HEALTH & WELL-BEING'. Below the title is a video frame showing a man, Victor Ohuruogu, speaking at a microphone. To the right of the video is the United Nations Foundation logo. Below the video, the name and title of the speaker are listed: 'Victor Ohuruogu, Senior Africa Regional Manager, United Nations Foundation'. A QR code is located in the bottom left corner of the slide.

Fantastic work Barke. Am glad that we can move forward the conversation and potential project with the Zanzibar Fisheries and Marine Resources Research Institute where you are also involved.

Massive inspiration and very helpful for useful idea generation, thank you!

Fantastic workshop! Thanks a million for putting this together.

From Juan Diego Del... to Hosts and panels

Thanks! Great inspiration

From Juan Diego Del... to Hosts and panels



From Juan Diego Del... to Hosts and panelists:

Gracias!!

Thank you for this meeting and all local projects, many ideas to develop

Evgeni, thank you so much for including me today! I am even more inspired than ever to do something meaningful with you and TinyML



*600 registered attendants

tinyML at AI for Good Global Summit 2023 (UN/ITU)



Geneva, Switzerland, July 6-7, 2023



How TinyML Can be Leveraged to Solve Environmental Problems: A Survey

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TinyML: Applied AI for Development

Marco Zennaro (ICTP/UNESCO), Brian Plancher (Harvard University), Vijay Janapa Reddi (Harvard University)

Abstract

Artificial intelligence (AI) will likely be an instrumental part of progress towards the United Nations' Sustainable Development Goals (SDGs). However, its adoption and impact are limited by the immense power consumption, strong connectivity requirements and high costs of cloud-based deployments. TinyML is a new technology that allows machine learning (ML) models to run on low-cost, low-power microcontrollers, circumventing many of these issues. We believe that TinyML has a significant role to play in achieving the SDGs and facilitating scientific research in areas such as environmental monitoring, physics of complex systems and energy management. To broaden access and participation and increase the impact of this new technology, we present an initiative that is creating and supporting a global network of academic institutions working on TinyML in developing countries. We suggest the development of additional open educational resources, South-South academic collaboration and pilot projects of at-scale TinyML solutions aimed at addressing the SDGs.



*Let's make **tiny**ML **BIG** !*
TOGETHER !!!

