

tinyML[®] Foundation

Enabling Ultra-low Power Machine Learning at the Edge

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

Evgeni Gousev, Chairman of the Board, tinyML Foundation
evgeni@tinyML.org

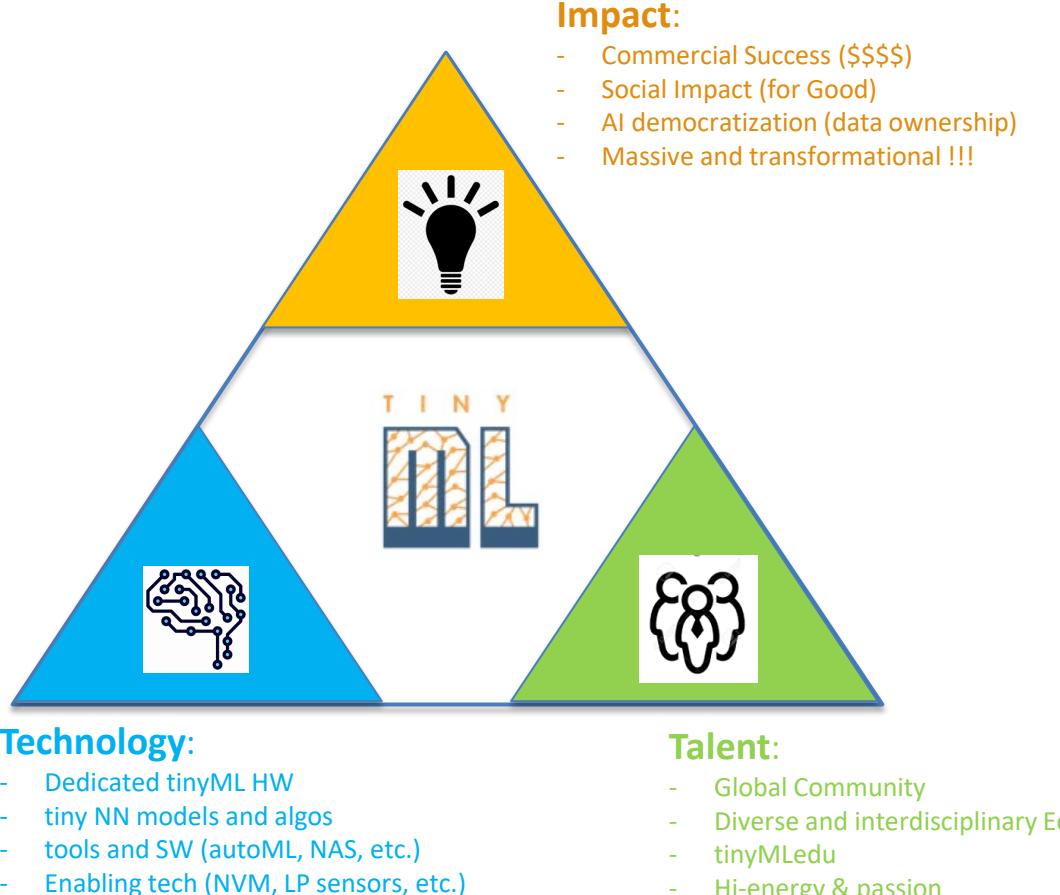


www.tinyML.org

Outline:

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

tinyML Phenomenon*:

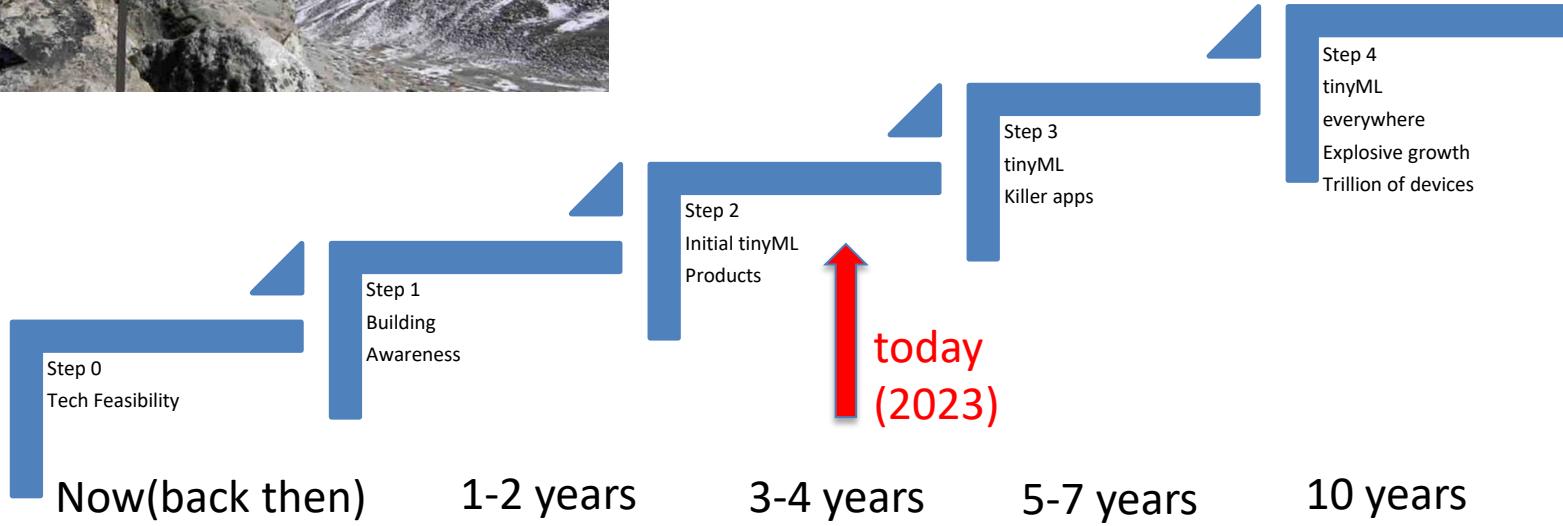


TINY
ML SUMMIT

tinyML: Happy 5th Birthday !

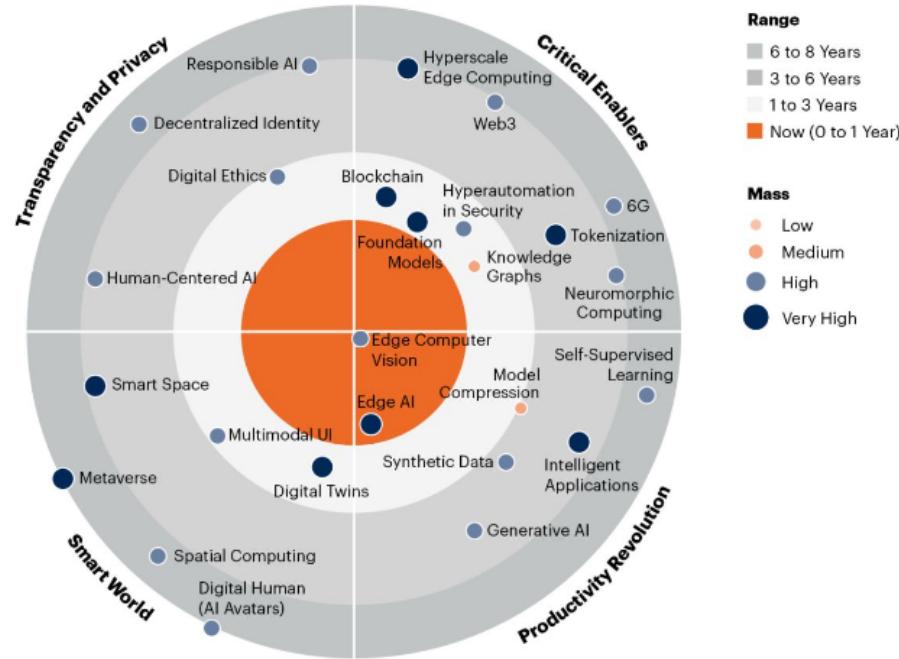


Climbing up tinyML mountain (*from 1st, 2019 Summit*)



Edge AI is happening now!

2023 Gartner Emerging Technologies and Trends Impact Radar



gartner.com



tinyML Summits are growing fast

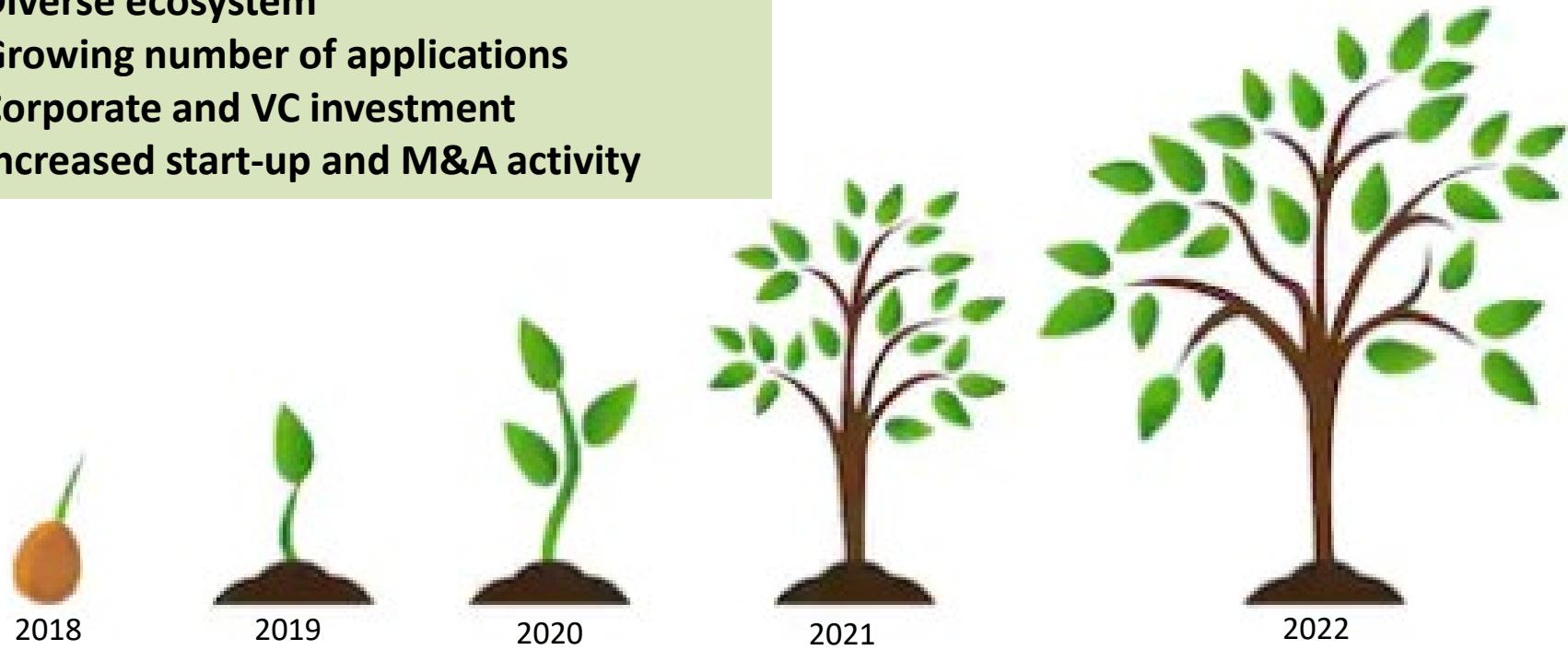
	2019 Summit (March 2019)	2020 Summit (Feb 2020)	2021 Summit (March 2021)
Attendees	160	400+	5000+
Companies	90	172	1000+
LinkedIn members	0	798	~ 2000
Meetups members	0	1140	~ 5000
YouTube subscribers	0	0	~ 4000

also started in Asia: tinyML WeChat and BiliBili



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



Interested in joining tinyML ecosystem?

www.tinyML.org



The image shows a large conference room filled with people seated at tables, facing a stage where a presentation is being given. The room has a high ceiling with recessed lighting and several chandeliers. A large projection screen is visible on the stage. In the foreground, a semi-transparent overlay contains the text "tinyML Summit 2020" and "Enabling ultra-low Power Machine Learning at the Edge". At the bottom, there are two buttons: "Register now" and "Show all information".

TINY
ML

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

**tinyML and the tinyML logo are registered trademarks of tinyML Foundation





FOUNDATION

tinyML Foundation Mission:

- 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 ($\sim 2x$ YoY)
- 10k youtube.com/tinyML subscribers, 589 videos, 345k views ($\sim 50%$ YoY)
- 3.7k members + 13k followers on LinkedIn ($\sim 2x$ 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
15,486

Groups
49

Countries
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
Deepelite



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

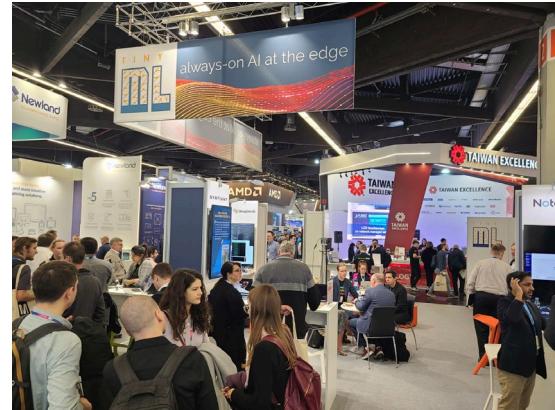
~10 Strategic Partners; Fully furnished podiums

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

A screenshot of the LinkedIn navigation bar. It includes the LinkedIn logo, a search bar with the placeholder "Search", and links for "Home", "My Network", "Jobs", "Messaging", "Notifications", "Me", and "Work".

A screenshot of the LinkedIn group header for "tinyML Foundation". It shows the group name, a "Super admin view" button, and a profile picture.

All Pages ▼ Products Content Analytics Activity 2

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](#)

A screenshot of the LinkedIn page cover for "tinyML Foundation". The cover features a dark blue background with the text "tinyML. Foundation" in large, bold, white and orange letters. Below it is the tagline "Enabling Ultra-low Power Machine Learning at the Edge". The "TINY ML" logo is visible in the bottom left corner of the cover image.

tinyML Foundation

Enabling ultra-low Power Machine Learning at the Edge
IT Services and IT Consulting - Los Altos, CA · [9,887 followers](#)

[Edit Page](#)





tinyML YouTube Channel



www.youtube.com/tinyML



tinyML
5K subscribers

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

HOME VIDEOS PLAYLISTS COMMUNITY CHANNELS ABOUT

The screenshot shows a grid of 20 video thumbnails from the tinyML YouTube channel. Each thumbnail includes the video title, view count, and upload date. The titles cover topics such as tinyML Summit 2021 sessions, tinyML Talks, and various technical presentations. The channel has 5K subscribers and 589 videos with 345k views as of July 1, 2023.

Video Title	Views	Upload Date
tinyML Summit 2021 Partner Session: Product...	146	1 month ago
tinyML Summit 2021 Partner Session: System...	121	1 month ago
Tiny Machine Learning Kit	1.4K	1 month ago
tinyML Summit 2021 Partner Session: It's an SN...	420	1 month ago
tinyML Summit 2021 Partner Session: The Pe...	104	1 month ago
tinyML Summit 2021 Partner Session: Innovati...	110	1 month ago
Deploying AI in Embedded Systems	420	1 month ago
tinyML Talks: Deploying AI to Embedded Systems	472	1 month ago
tinyML Summit 2021 Breaking News on...	160	1 month ago
tinyML Summit 2021 Partner Session: TinyML...	257	1 month ago
tinyML Summit 2021 Breaking News on...	299	1 month ago
tinyML Summit 2021 Breaking News on...	174	1 month ago
tinyML Summit 2021 Partner Session: Machine...	212	1 month ago
Example IP-Cores (Pre-Processing)	109	1 month ago
Limited Resources	55	1 month ago
tinyML Summit 2021 tiny Talks: Environmental Noi...	173	1 month ago
tinyML Summit 2021 tiny Talks: Insights from a Mult...	151	1 month ago
tinyML Summit 2021 tiny Talks: Low-power...	162	1 month ago
tinyML Summit 2021 tiny Talks: How...	129	1 month ago
tinyML Summit 2021 tiny Talks: Low-power...	168	1 month ago
tinyML Summit 2021 Partner Session: TinyML Software...	121	1 month ago
tinyML Summit 2021 Keynote: Data-Free Model...	240	1 month ago
tinyML Summit Partner Session: Pushing the AI...	82	1 month ago
tinyML Summit 2021 Partner Session: Low power...	129	1 month ago
tinyML Summit 2021 Partner Session: How...	95	1 month ago
tinyML Summit 2021 Partner Session: Low-power...	168	1 month ago
tinyML Summit 2021 Panel Discussion: tinyML...	115	1 month ago
tinyML Summit 2021 Keynote: Efficient Audio...	1.4K	1 month ago
tinyML Summit 2021 tiny Talks: An Introduction to a...	180	1 month ago
tinyML Summit 2021 tiny Talks: Low-precision...	215	1 month ago
tinyML Summit 2021 tiny Talks: Hardware Aware...	75	1 month ago
tinyML Summit 2021 tiny Talks: Neutrino: A BlackBo...	168	1 month ago
tinyML Summit 2021 tiny Talks: Market Opportunities for Edge AI	51.28	1 month ago
tinyML Summit 2021 tiny Talks: Using Neural...	56.15	1 month ago
tinyML Summit 2021 tiny Talks: Adaptive Neural...	39.48	1 month ago
tinyML Summit 2021 tiny Talks: Person Detection...	18.26	1 month ago
tinyML Summit 2021 tiny Talks: Signal Processing in...	19.03	1 month ago
tinyML Summit 2021 tiny Talks: Can we achieve more efficiency...	56.15	1 month ago
tinyML Summit 2021 tiny Talks: millijoules for...	51.28	1 month ago
tinyML Summit 2021 tiny Talks: tinyML for Edge AI	51.28	1 month ago



tinyML BiliBili Channel In Asia

主站 番剧 游戏中心 直播 会员购 漫画 赛事 月会 下载APP

为什么娱乐圈这样了?

tinyML-Asia 年度大会员
tinyML是机器学习在终端和边缘侧的微处理器设备上的技术总称，是物联网时代超低功耗边缘侧的人工智能。

主页 动态 投稿 132 频道 10 收藏 7 订阅 搜索视频、动态

代表作

2020

tinyML.Talks
Enabling Ultra-low Power Machine Learning at the Edge

软件 01:04:30

【软件】Pete Warden-开启TinyML之旅_200331
132 0

TA的视频 124

最新发布 最多播放 最多收藏

播放全部 更多 >

2021	2021	2021	2021	2021
tinyML_Summit Enabling Ultra-low Power Machine Learning at the Edge	tinyML_Summit Enabling Ultra-low Power Machine Learning at the Edge	tinyML_Summit Enabling Ultra-low Power Machine Learning at the Edge	tinyML_Summit Enabling Ultra-low Power Machine Learning at the Edge	tinyML_Summit Enabling Ultra-low Power Machine Learning at the Edge
13:03	23:20	19:31	15:15	27:34
【软件】Stuart_Feffer 【软件】-tinyML不仅仅是建模 22 4-29	【应用+视觉】Orlando_Moreira -利用椭圆 25 4-28	【算法】Moshe_Haiut -用于小型硅低功耗设备的创新型卷 16 4-28	【应用+建筑】Martin_Croome-tinyML在智 27 4-27	【系统】Mallik_Moturi-tinyML不再弱小_210323 15 4-27

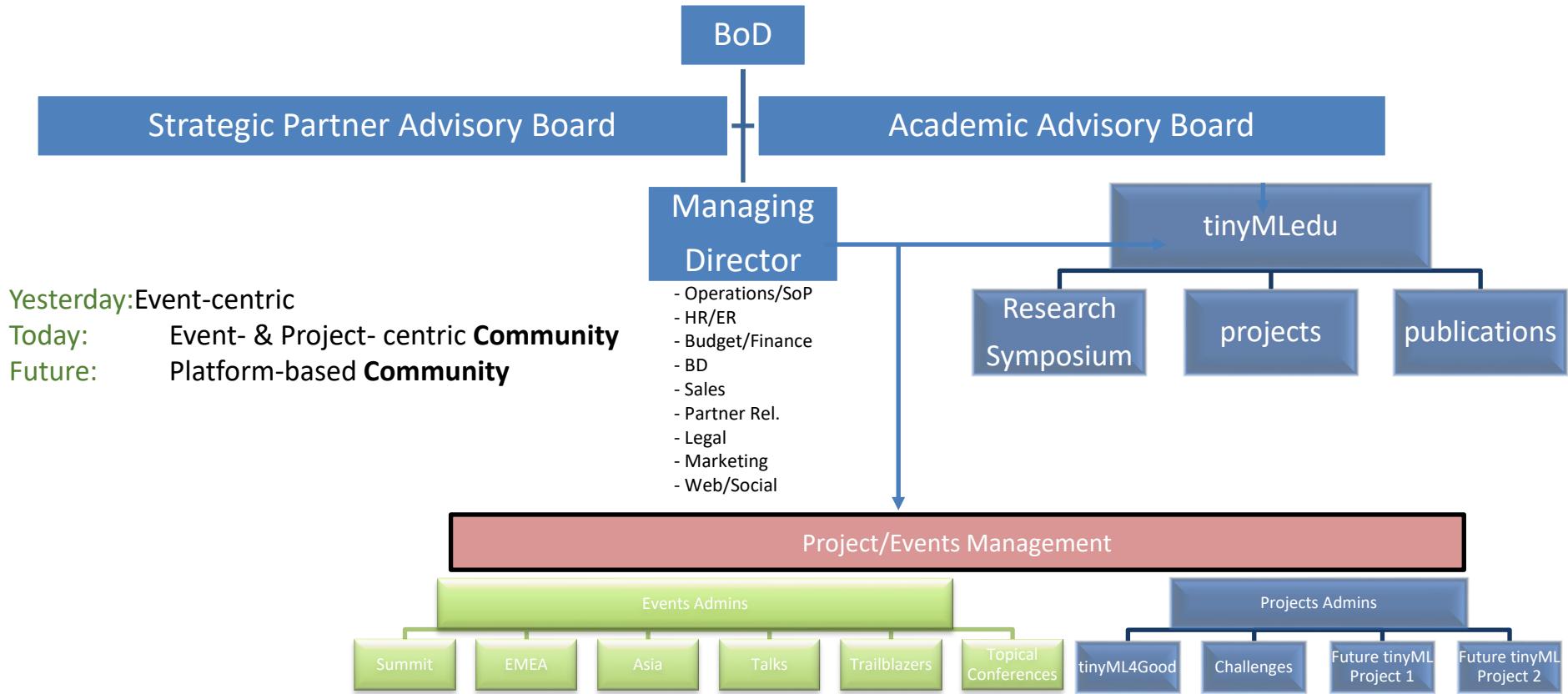


Industry Perspective and Industry-Academia Partnership

A photograph showing two hands holding puzzle pieces. The hand on the left is holding a white puzzle piece with a rounded rectangular shape and a central circular cutout. The word "Industry" is printed in black capital letters in the center of this piece. The hand on the right is holding a similar white puzzle piece, also with a rounded rectangular shape and a central circular cutout. The word "Academia" is printed in black capital letters in the center of this piece. The puzzle pieces are designed to fit together.

Academia

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



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

Data Sources:

1%

Storage and sharing



Edge ML

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

User provided: 4%

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



tiny ML

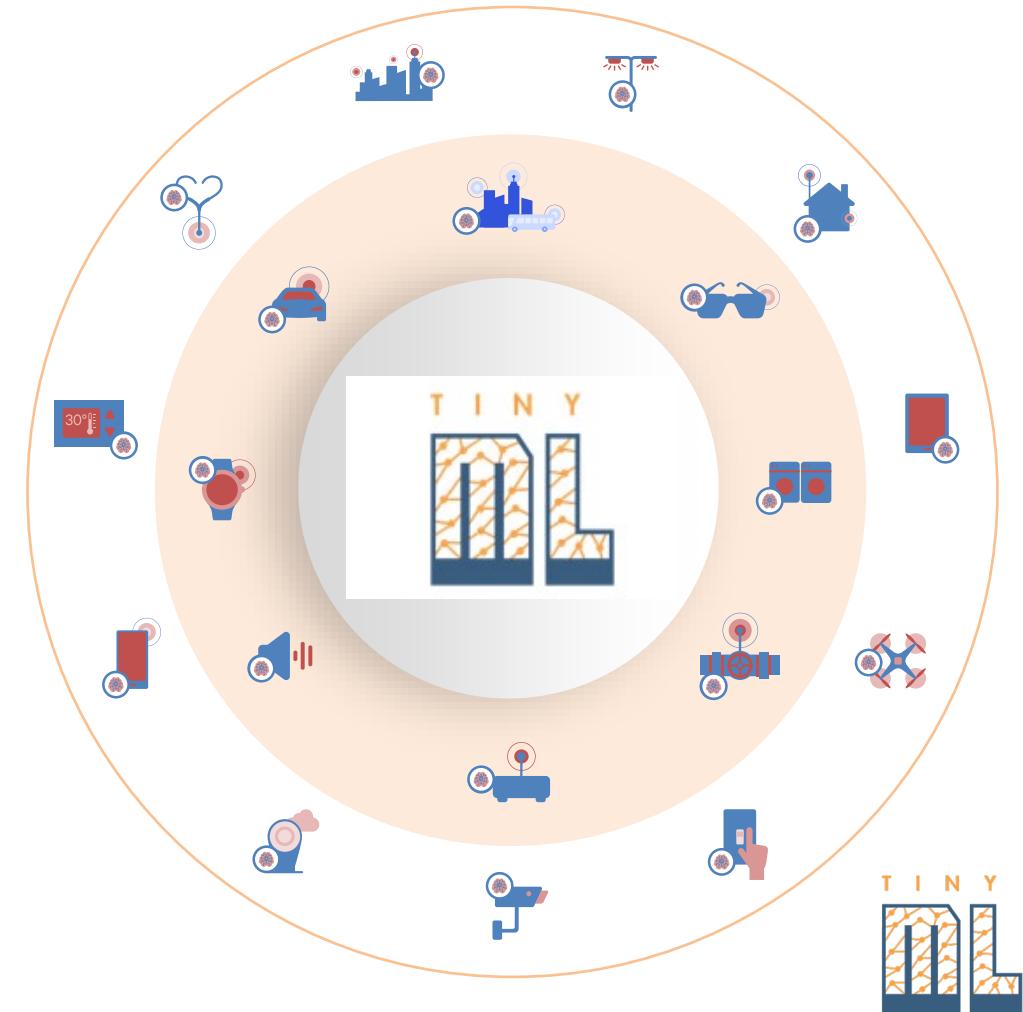
- CNN-micro
- MCU w/ HW accelerators

95%

Real-time in the physical world

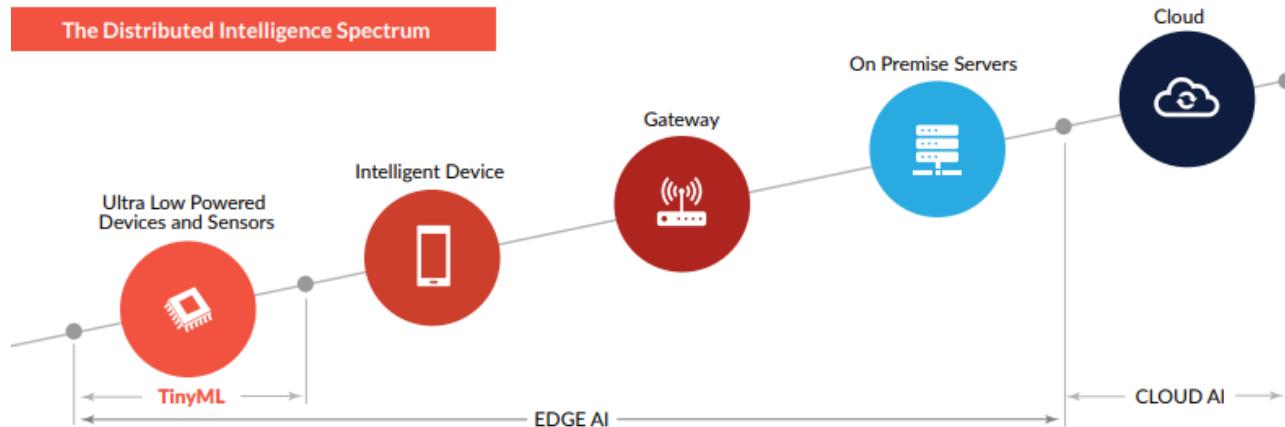


Massive tinyML
opportunities in all
verticals where
machine intelligence
meets physical world



tinyML enabled DEVICES – 2030 Forecast

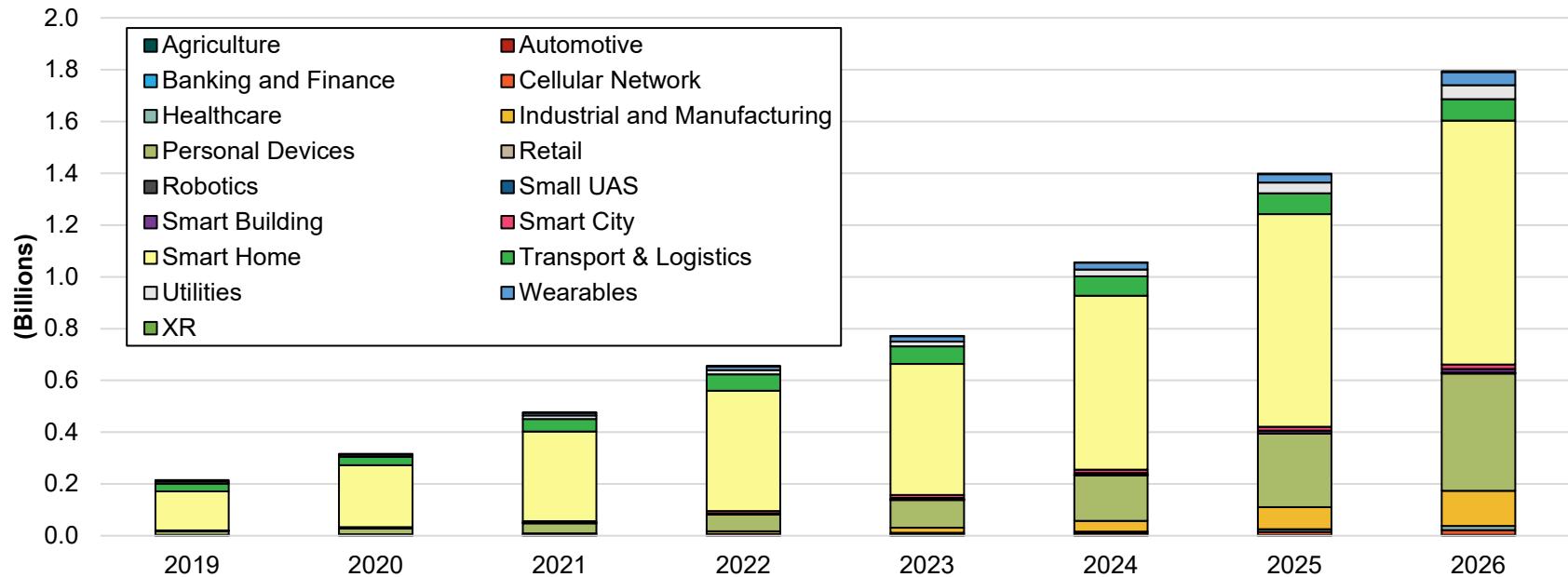
ABIresearch[®]
TRUSTED INTELLIGENCE SINCE 1990



- 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



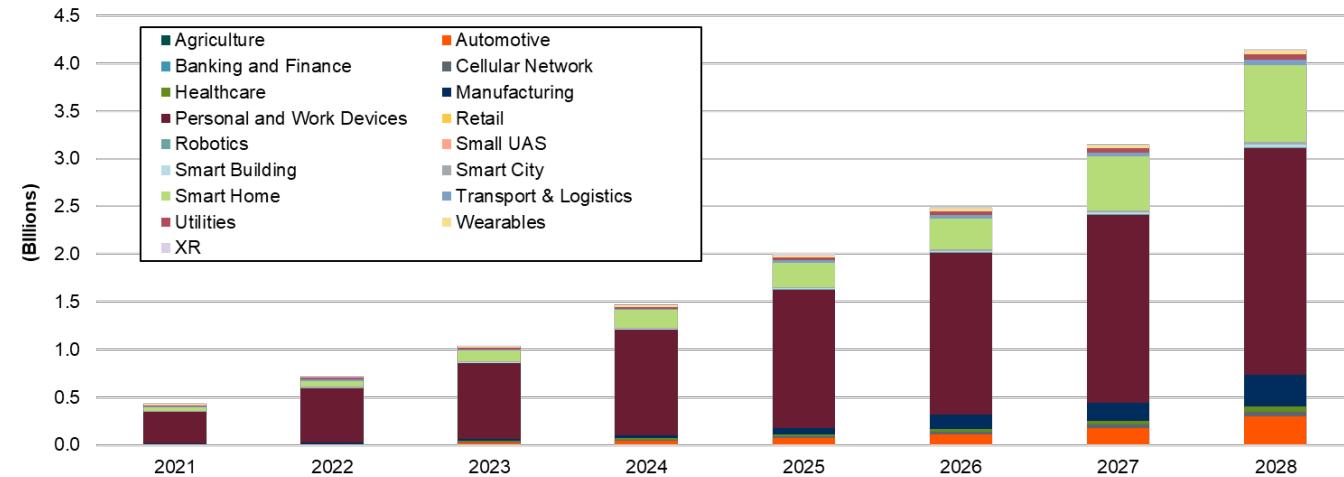
tinyML 2026 Forecast, by verticals



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

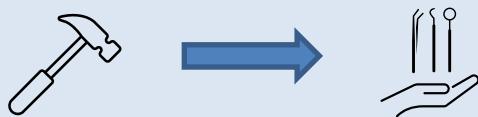
Revised 2023 forecast:
16.1B devices by 2030

- **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

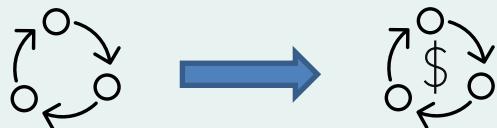
Present vs. Future



- **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.



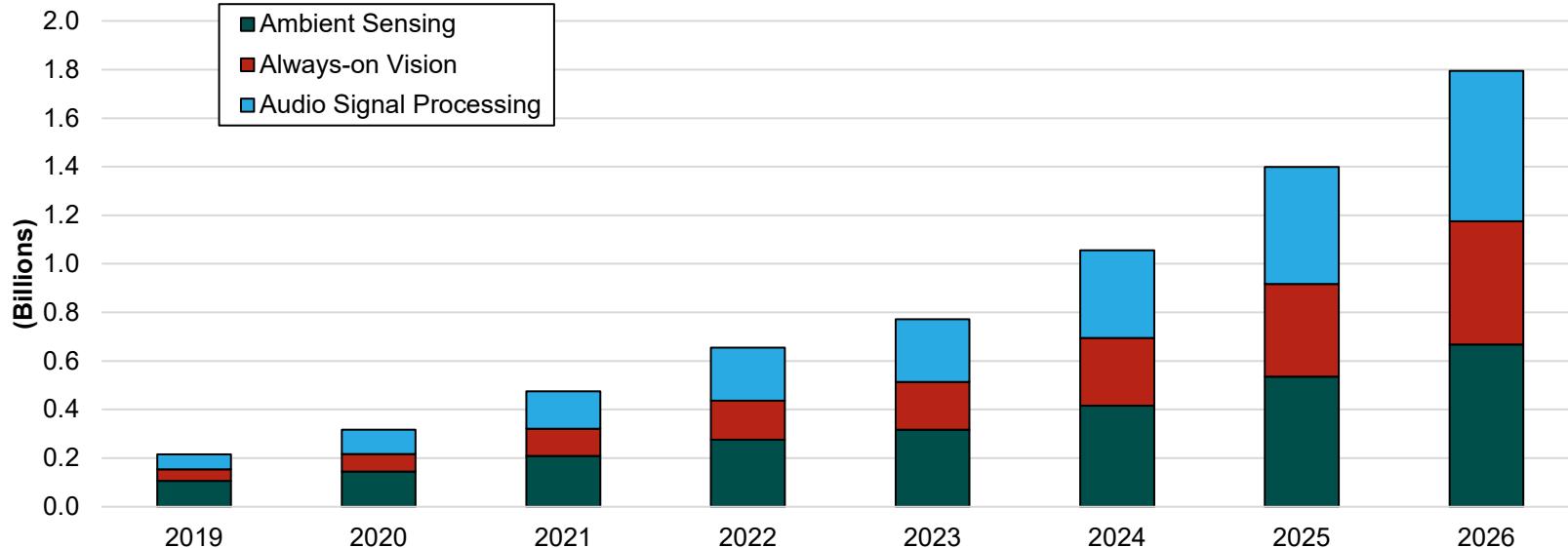
- **More to Focus on Monetization** – More edge AI chipset vendors to monetize their software capabilities, setting up potential clash with independent software vendors.



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



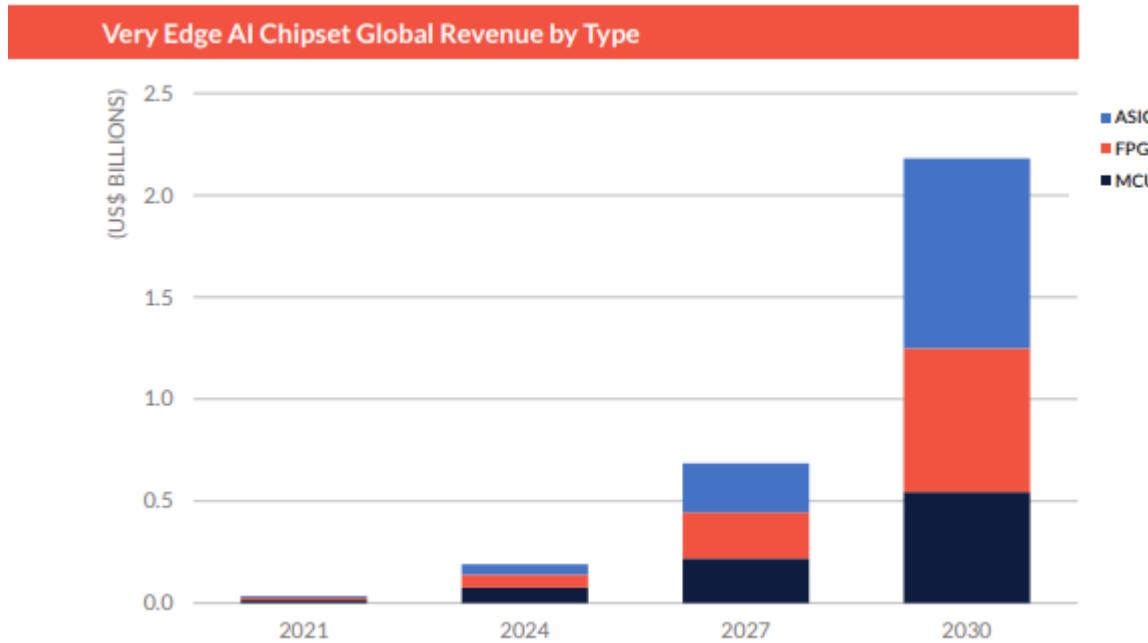
tinyML 2026 Forecast by use cases



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



tinyML 2030 Forecast by processor type

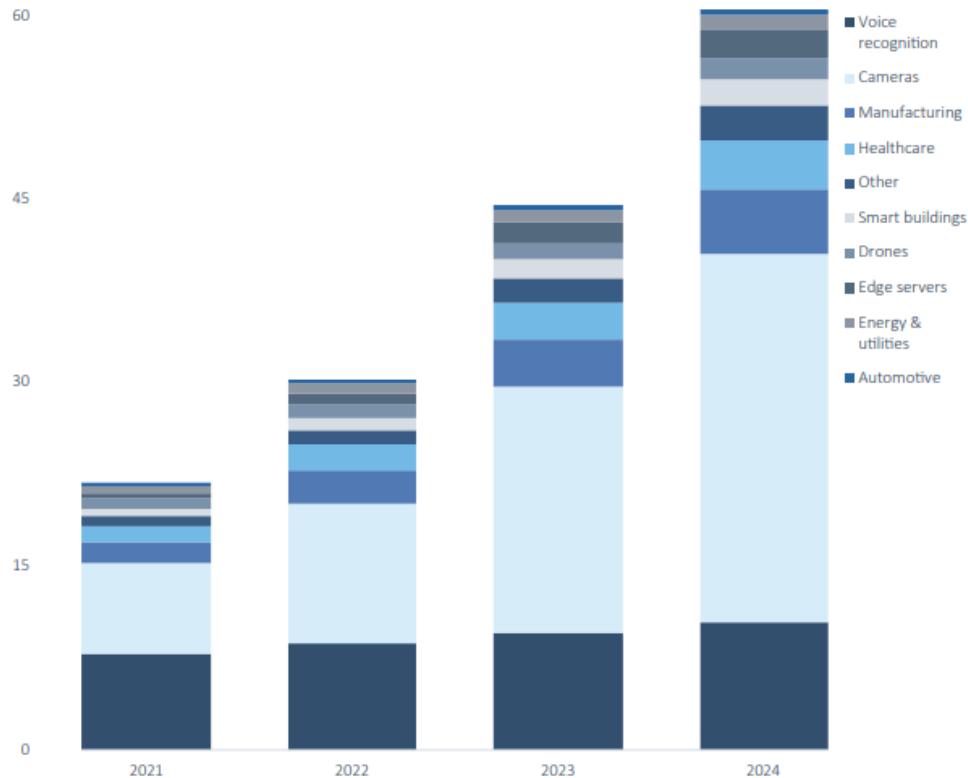


Source: Lian Jye Su, Principal Analyst, ABI Research, 2020



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

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



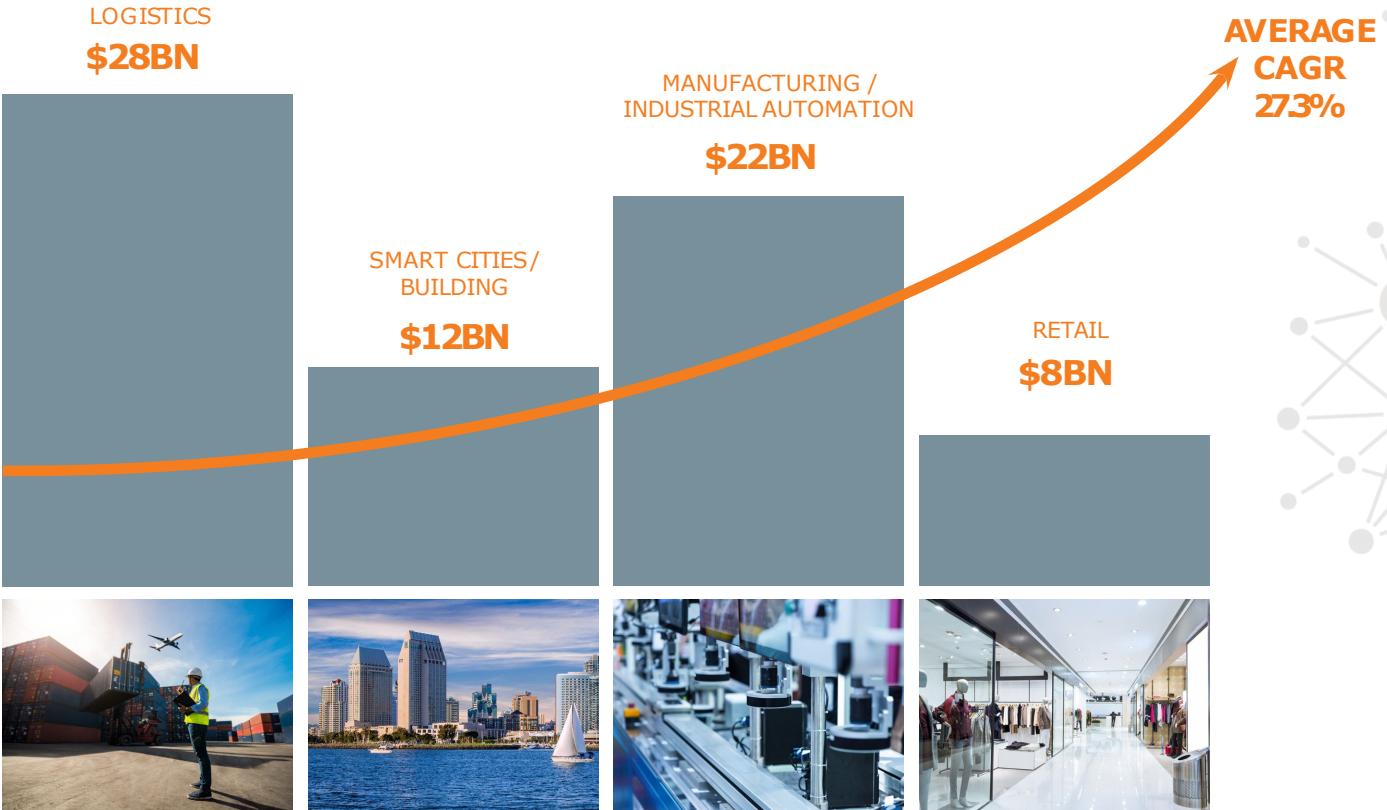
- \$60B market by 2024 (devices only)
- 41% CAGR growth

Source: PitchBook

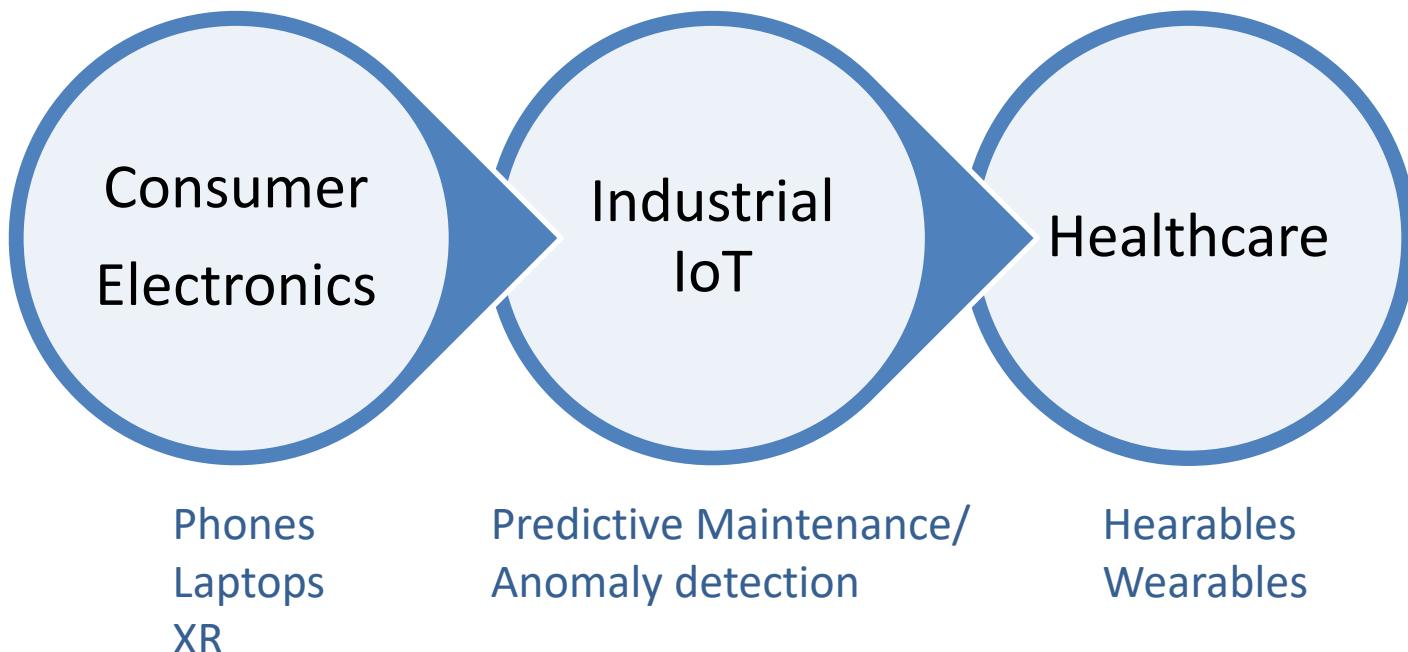
Source: Pitchbook, Emerging Tech, IoT, 2H-2020



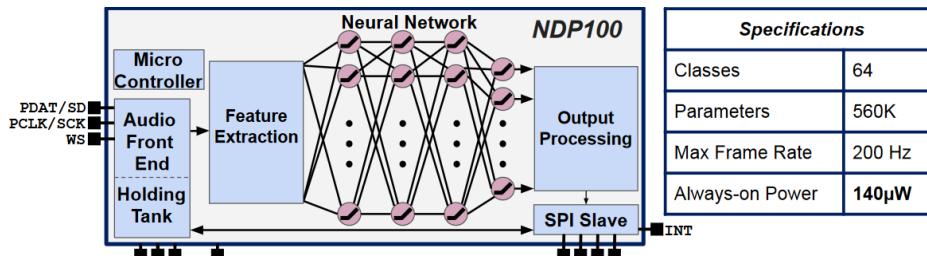
In the next 5 years tinyML can unleash over \$70BN* in economic value



Leading use cases/verticals



Example: tinyML for Always-On Voice

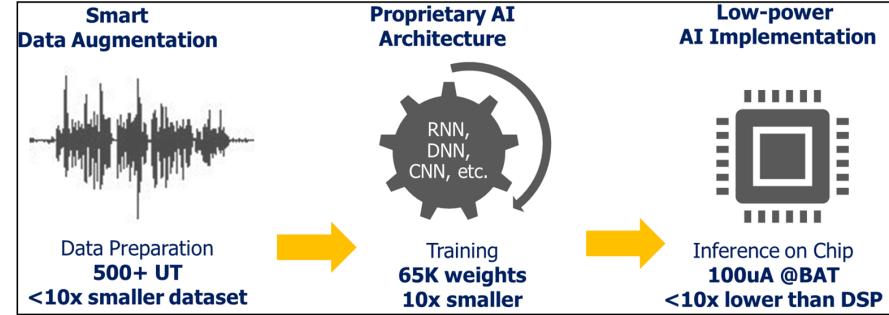


NDP100
1.4mm X 1.8mm



Courtesy: David Garrett, VP, HW

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



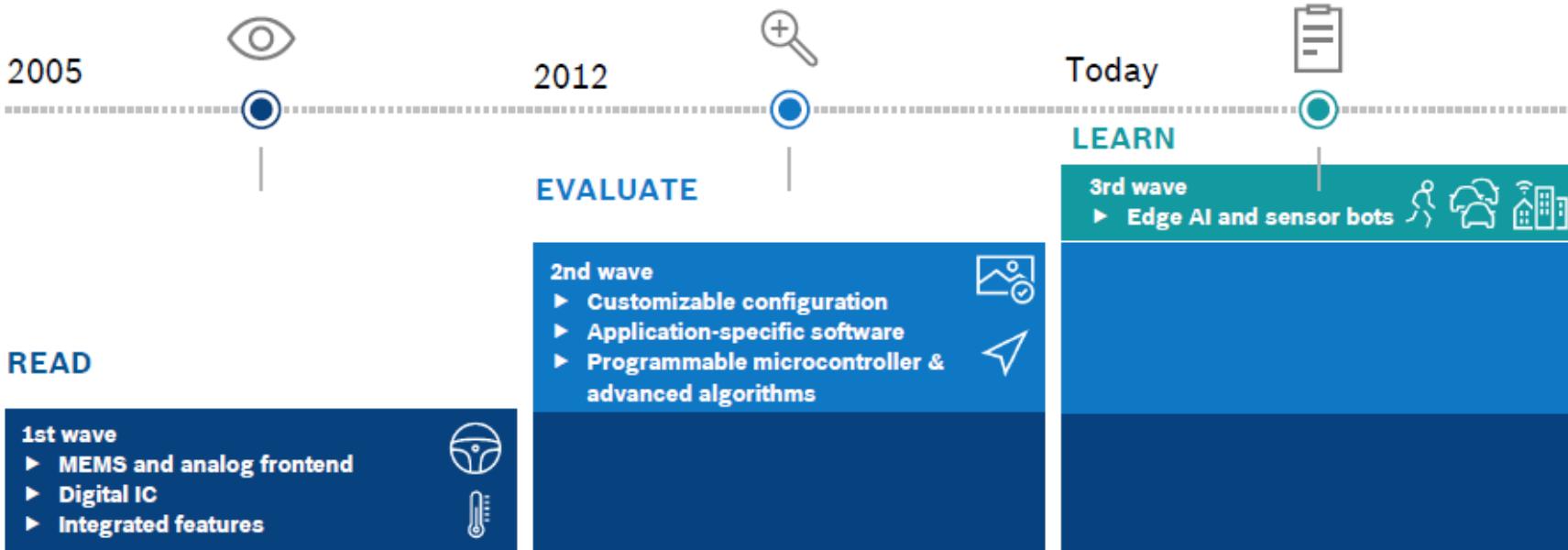
AONdevices
AI | DSP | ASIC

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

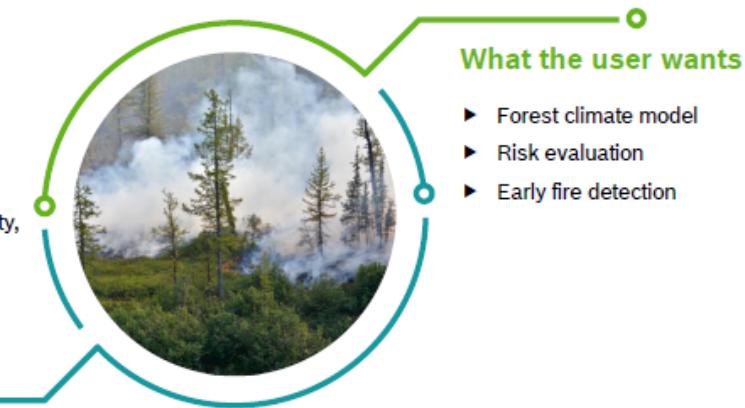


What the user wants

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

What small sensor nodes can provide

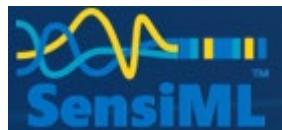
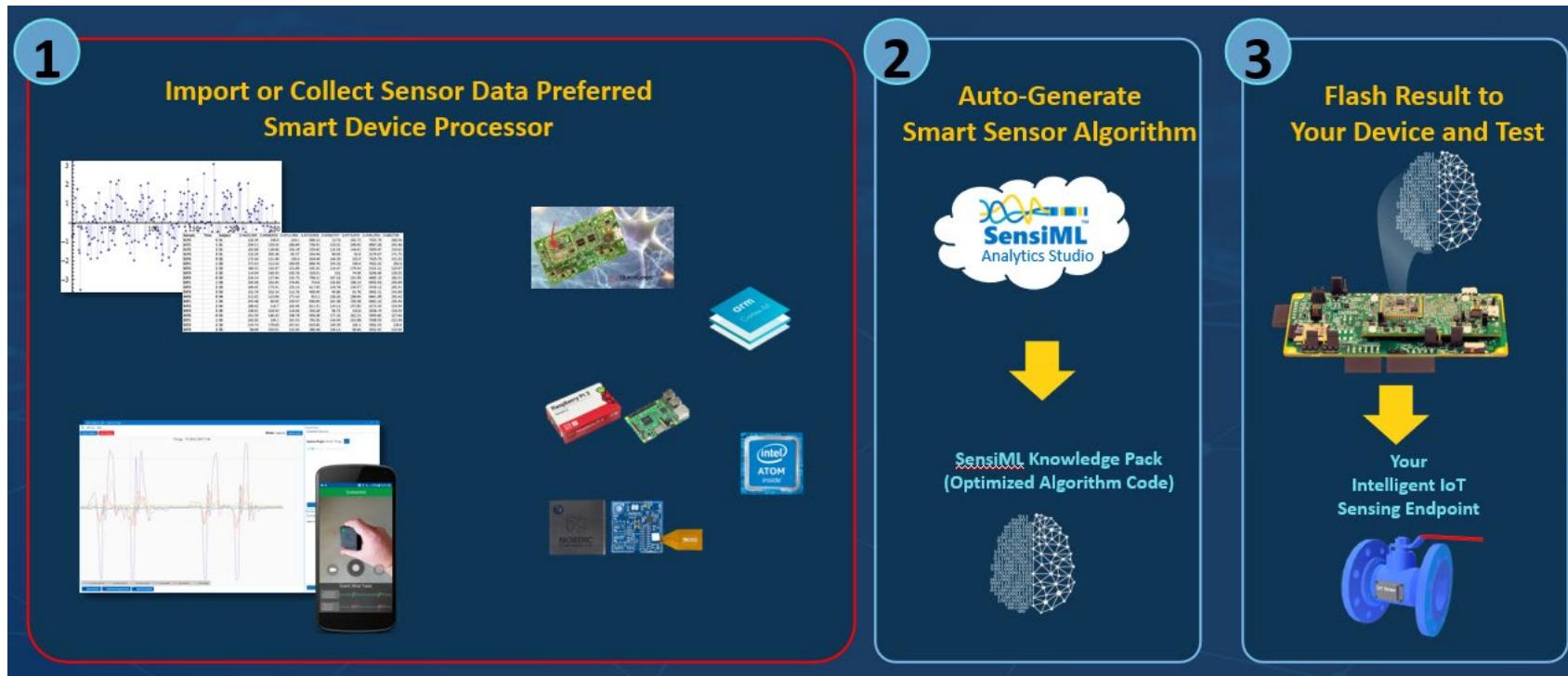
- ▶ Temperature, pressure, humidity, air flow,...
- ▶ Gas sensor signals (from air quality up to smell patterns)
- ▶ Present devices (people!)



What the user wants

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

Example: tinyML for predictive maintenance (using IMUs)



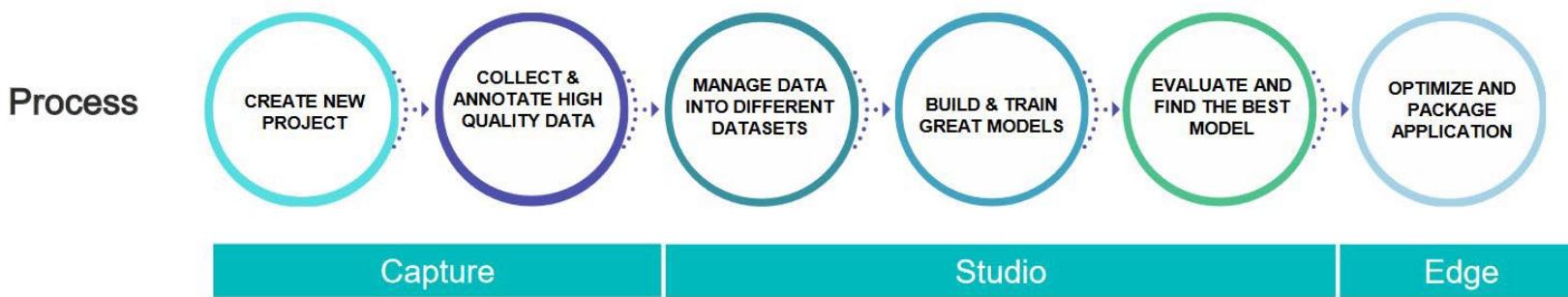
Courtesy: Chris Knorowski, CTO



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



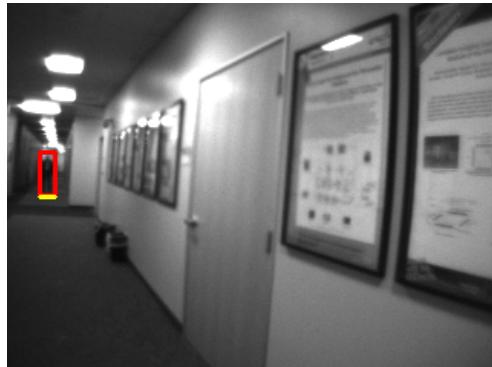
Yann LeCun (Facebook, Dec.2019): AR glasses will be the killer app of energy-efficient machine learning

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



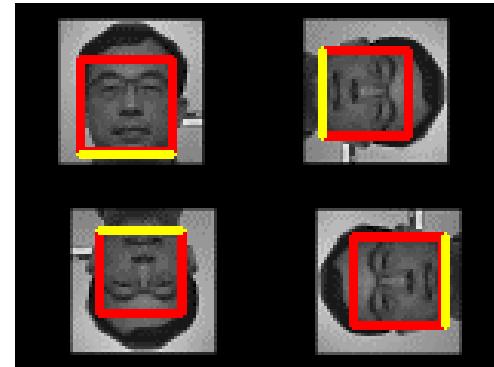
Full body



3/4 body



Change Detection



Multiple face orientation

Qualcomm

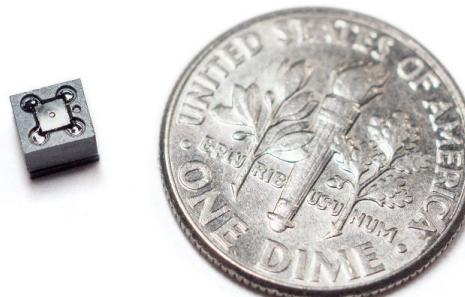
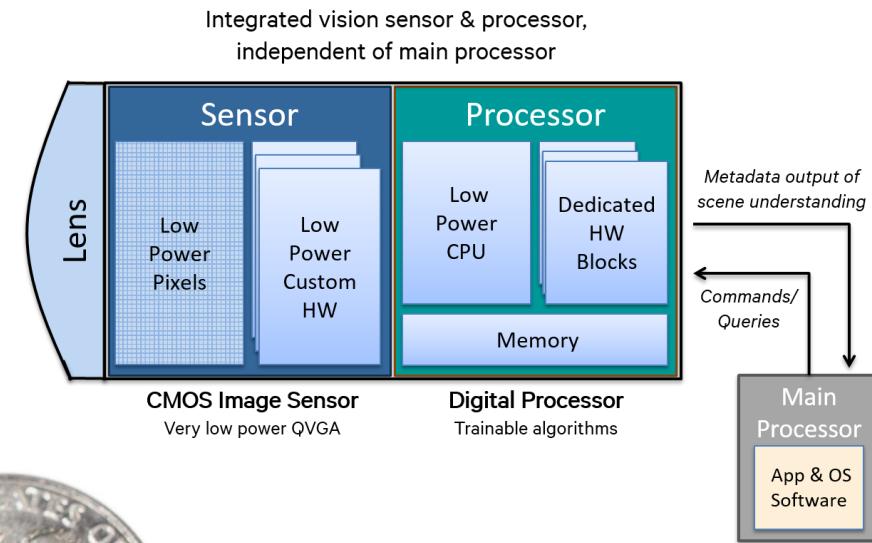
TINY
ML

tinyML for Always-On Vision

Qualcomm always-on computer vision module

Key features:

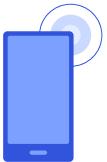
- Ultra-low power, < 1 mW (end-to-end)
- Small size
- Privacy (output is metadata)
- Configurable for different use cases
- QVGA sensor, Near-IR compatible
- Low cost



Qualcomm



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

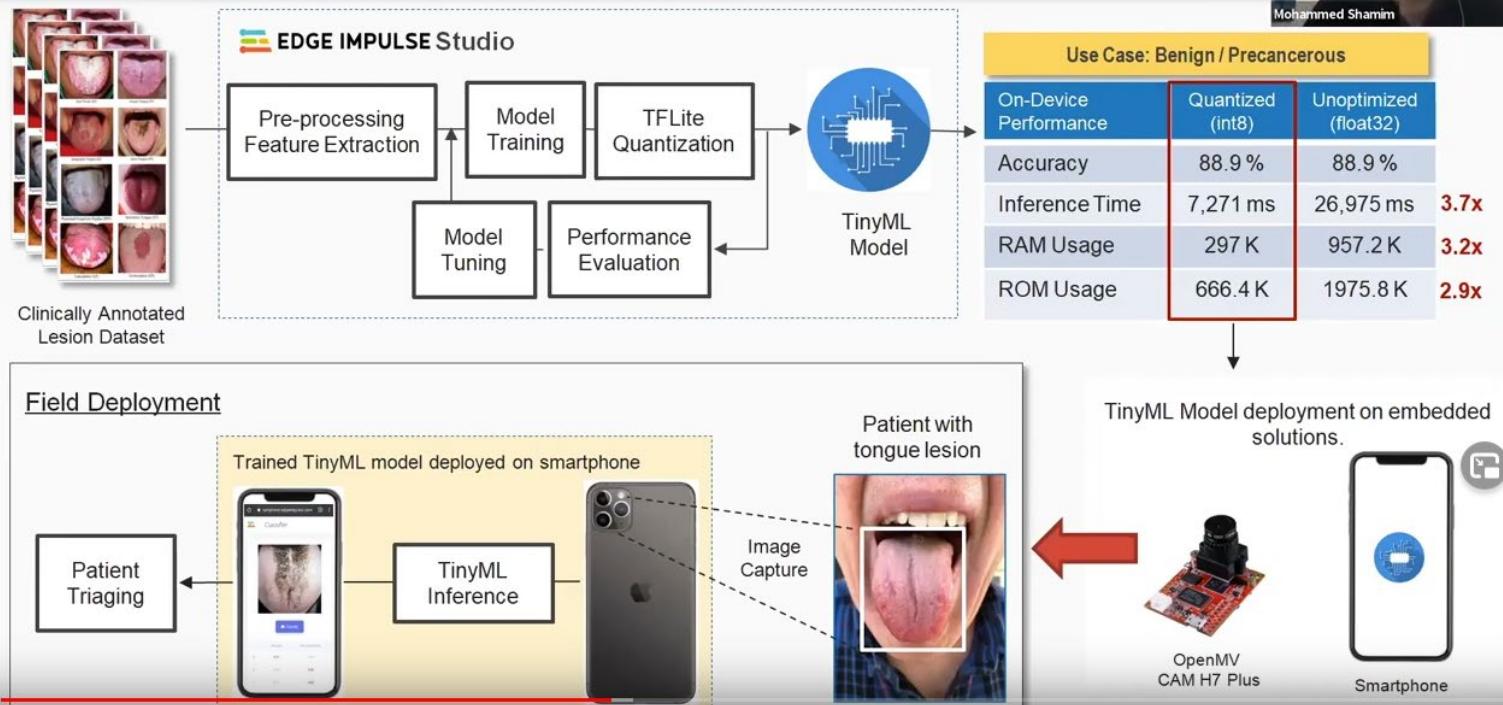


Standalone intelligent data sensor

- 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 • ④

+ 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! #culturematters #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 • ④

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

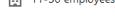


Senior Embedded System QA Engineer

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



Full-time



11-50 employees



See recent hiring trends for GrAI Matter Labs. Try Premium for free

Apply now

Save

We're Hiring TinyML Firmware Engineers

Join Our Team in Building Cutting Edge AI Solutions

SensiML

GreenWaves Technologies

1,647 followers
4mo • ④

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...



Audio Analytic
2,166 followers
5mo • ④

+ Follow

★ 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://audal/3igwDYj>



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

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

Join the PROPHESEE team !

View job

View Openings



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

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



3 connections work here



**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/1SDr6vgZOtpCtxX7s6lxzfZB_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.tinyml.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>



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



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

Vision Challenge-2021 Winners

The image shows a horizontal scrollable grid of three winning projects from the Hackster.io contest. Each project card includes a team logo, name, and a brief description.

- Team Sol:** RANKED WINNERS: 1ST PLACE. TinyML Aerial Forest Fire Detection. Image: A white drone flying over a field with a fire in the foreground.
- TheBlue Phoenix:** RANKED WINNERS: 2ND PLACE. WorkSafe: Computer Vision based multiparameter monitor with AI. Image: Three yellow and red device units labeled "WorkSafe+ Screening Device", "BLUE PHOENIX /AI", and "K-NINE".
- Huy Mai:** RANKED WINNERS: 3RD PLACE. TinySewer - Low Power Sewer Faults Detection System. Image: A 3D rendering of a sewer pipe with a small device inside.

Hackster Impact Prize

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

A project card for Dhruv Sheth's Hackster Impact Prize entry. It features a team logo, name, and a screenshot of the project interface. The project is titled "Plant Growth Estimation for High Throughput Phenotyping" and uses SONY components.

Honorable Mention

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

A project card for Bob Hammell's Honorable Mention entry. It features a team logo, name, and an image of the device. The project is titled "Flat Tire Detection Using Machine Vision".

A project card for a group of runners-up. It features a team logo, names, and an image of children. The project is titled "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*



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)



A promotional banner for the "tinyML Trailblazers" series. The background is a dark blue with a subtle geometric pattern. At the top, the words "tinyML" and "Trailblazers" are displayed in large, white and orange fonts respectively. Below them, the subtitle "Ultra-low power machine learning at the edge success stories" is written in a smaller, italicized white font. In the center, the name "Pete Warden, Google" is shown in a large orange font, with the text "Success Stories Series hosted by Chris Rowen" in a smaller orange font below it. At the bottom, the words "INSPIRE-EDUCATE-ILLUMINATE" are written in a white font. Two video feeds are visible at the bottom: on the left, a man with glasses and a dark shirt, identified as "Chris Rowen"; on the right, a man with curly hair and a blue shirt, identified as "Pete Warden".

tinyML Success Stories Series Guests



- Pete Warden, Google <https://www.youtube.com/watch?v=tIQcdhIN8q8&t=2999s>
- Kurt Busch, Syntiant co-founder and CEO, <https://www.youtube.com/watch?v=ceT8LMULiBU&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](#)
- Yoram Zylberberg, CEO, Emza Visual Sense, [tinyML Trailblazers with Yoram Zylberberg - YouTube](#)
- 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](#)
- Chris Rogers, Co-Founder and CEO, SensiML, [tinyML Trailblazers Success Stories with Chris Rogers - YouTube](#)
- Luca Verre, Co-Founder and CEO, Prophesee, [tinyML Trailblazers with Luca Verre CEO Prophesee - YouTube](#)
- Loic Lietar, Co-Founder and CEO, Greenwave Tech, [tinyML Trailblazers with Loic Lietar CEO from Greenwaves Technologies - YouTube](#)
- 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*



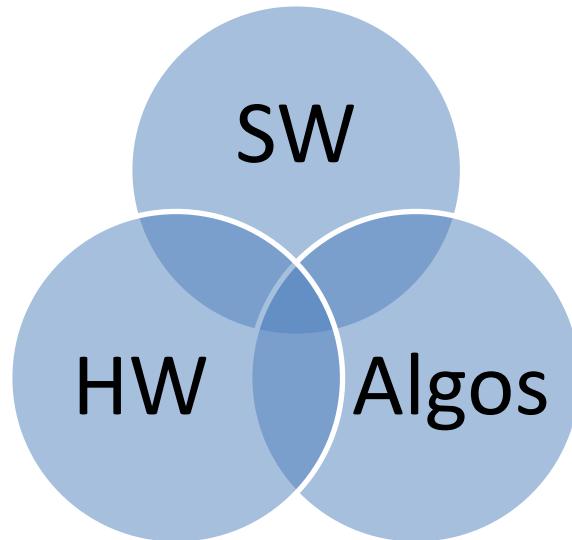
*100+ participants



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

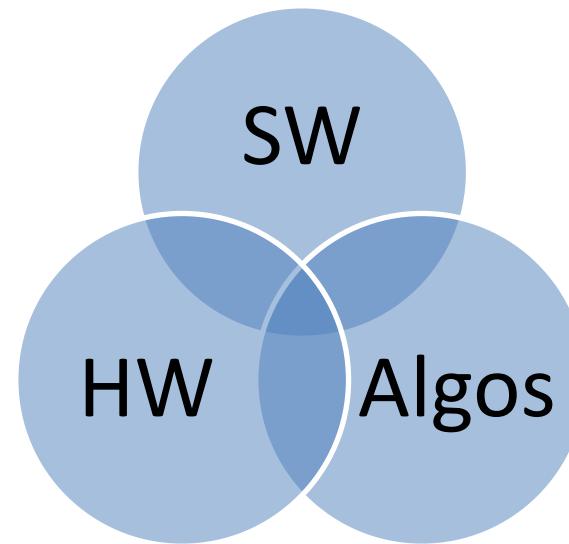


tinyML is “good enough” NOW

... 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)

The image shows the homepage of the tinyML Research Symposium 2021 website. At the top left is the TINY ML logo. To the right are navigation buttons for "Summit 2021", "Research Symposium", and "All Events". Below the navigation is a large graphic featuring a woman wearing glasses, a network of hexagons with icons like a lock, a target, and a handshake, and two small inset charts. The text "tinyML Research Symposium 2021" and "Inaugural research symposium" is overlaid on the graphic. At the bottom are "Register Now" and "Summit 2021" buttons.

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](#)

Industry peer recognition Awards



2021 Winners

SYNTIANT

 **EDGE IMPULSE**

Guangyuan HU
 PRINCETON
UNIVERSITY

2022 Winners



PROPHESEE

 **RE3XEN**
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

CARTESIA.AI

Use Case Explorer

DISMISS

Field of application

Search for use cases

Hole drilling deviation
Predict if your oil bit departed from a pre-selected trajectory

Fashion MNIST
Classify grayscale images of fashion items

MNIST
Classify black and white images of numbers

Iris plants
Classic dataset in statistics and machine learning

Bearing, belt, and EDM faults
Vibration analysis from very noisy sound files

Stator Yoke Temperature
Predict the stator temperature of an electric car with a thermal sensor

Permanent Magnet Surface Temp
Surface Temp
Predict the rotor temperature of an electric car

Stator Tooth Temperature
Predict the temperature of the stator tooth in an electric car

Stator Winding Temperature
Predict the temperature of the stator winding in an electric car

Torque
Predict the torque of an electric car

White Wine
Predict wine quality

Drive diagnosis
Detecting defects in an electric motor

Smart vacuum cleaner
Detect if your vacuum bag is empty or full (at different regimes)

Brushless wheel sk8
Brushless motor of an electric skateboard wheel

In my fan obstructed?
STM32
Detect with an accelerometer if my fan is obstructed

Smart ukulele
Smart device that can detect which note or chord is played on a ukulele

APS failures in Scania trucks
Predict failures in the Air Pressure System of Scania trucks

Cardiotocography
Measurements of fetal heart rate (FHR) and uterine contraction (UC)

Breast cancer
The data contains measurements on cells in suspicious lumps in women's breast

Is my fan obstructed?
We detect if a fan is obstructed through classification

Energy prediction
Predicting the energy consumption of energy appliances

Steel Plates Faults
Detecting faults in metal

Electric grid
Predicting if the grid will be stable given a few features

Glass tapping sound
Determine if a glass is full or empty

Occupancy detection
Predicting how many people are in a room

Lock picking
Detect if a lock is being opened with a key or using picks

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**.

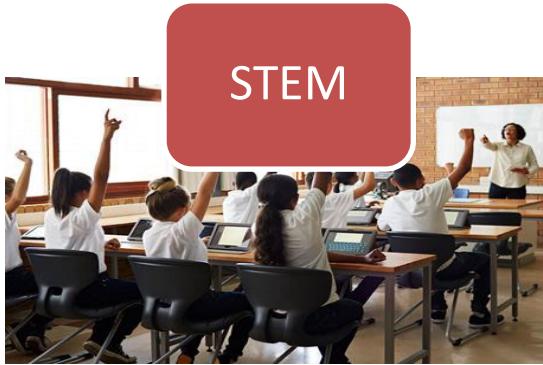
<https://www.youtube.com/watch?v=jsyHqDX5cU8&t=3s>



Healthcare



STEM



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



Earth
Climate
Conservation

Contact: 4good@tinyML.org

tinyML for Good @ GTC2021*

[REGISTER FREE](#)[SIGN OUT](#)**GTC**

KEYNOTE NOVEMBER 9 CONFERENCE & TRAININGS NOVEMBER 8-11, 2021

[Keynote](#) [Session Catalog](#) [Session Content](#) [Hands-on Training](#) [Sponsors](#) [More](#)

tinyML for Good [A31182]

The interface shows a panel discussion titled "tinyML for Good [A31182]". There are six speakers in total, each with a small video thumbnail and their name and title below it:

- KATE KAULOT, Head of Emerging Areas, NVIDIA
- EUGENI GOUSEV, Sr. Director, Qualcomm Technologies, Inc.
- FRAN BAKER, Global Social Impact and Innovation Lead, Arm
- ALEXANDER SARAVIA, Co-founder and CEO, Suplenia Tech
- CLINTON ODUOR, Co-founder, Rhinos Lab
- CHRIS ROGERS, CEO, SensiML

The NVIDIA GTC logo is visible in the bottom right corner of the video area. A progress bar at the bottom indicates the video is at 05:40 of 59:29. Control icons for volume, settings, and navigation are also present.

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.

The interface shows a Q&A section for the "tinyML for Good [A31182]" session. There are two questions listed:

- 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](#)
- How big is the tinyML market size in conservation?**
1 vote | Answered by | 0 comments
Presenter / Moderator: tinyML is revolutionizing conservation efforts by enabling real-time monitoring and analysis of wildlife populations.



*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 slide features the TinyML for Good logo on the left, which includes a globe icon and the text "tiny tech for the world's biggest challenges". The title "GOOD HEALTH & WELL-BEING" is centered above a portrait of Victor Ohuruogu, Senior Africa Regional Manager of the United Nations Foundation. The slide also lists executive sponsors: arm, EDGE IMPULSE, Qualcomm, and SYNTIANT. On the right, there is a video feed of a woman speaking, with a green waveform graphic below it. The United Nations Foundation logo is visible at the bottom right of the slide area.

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!

From Juan Diego Del... to Hosts and panelis

Thanks! Great inspiration

Fantastic workshop! Thanks a million for putting this together.

From Juan Diego Del... to Hosts and p



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

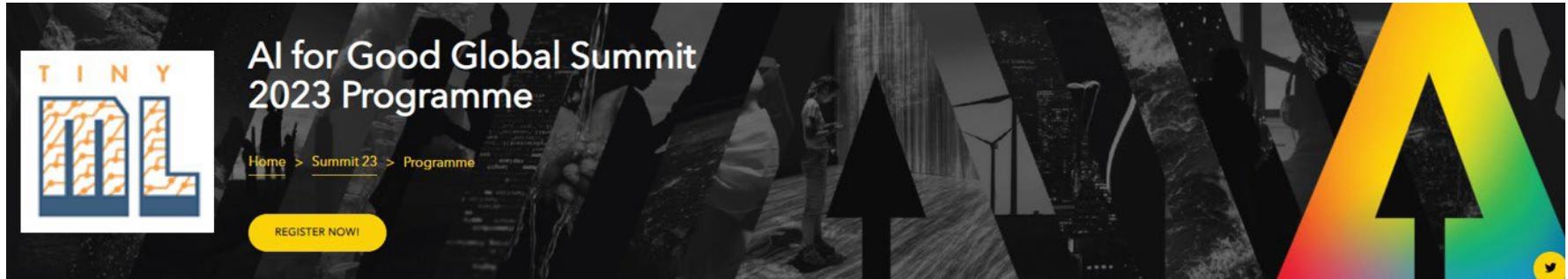
Gracias!!

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



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

Hatim Bamoumen

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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 *tinyML* **BIG** !*
TOGETHER !!!

