

tinyML[®] Summit

Enabling Ultra-low Power Machine Learning at the Edge

Products and applications enabled by tinyML

March 28 – 29, 2023



www.tinyML.org

Attracting Tomorrow



A perspective on the trajectory from custom intelligent sensors to broad market adoption of smart platforms

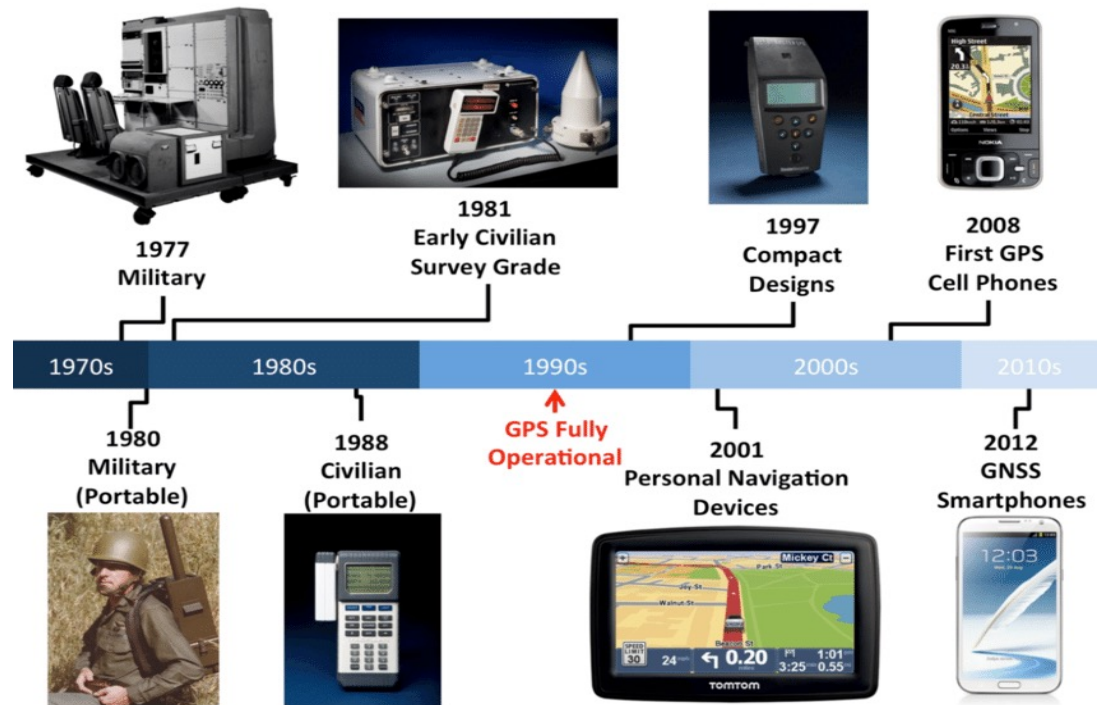
Al Heshmati



GPS – A look back at another ubiquitous technology

Started with a room full of equipment

To now embedded as a tiny block inside large SOCs that power a smart phone



Source: Tyler Reid, 2017

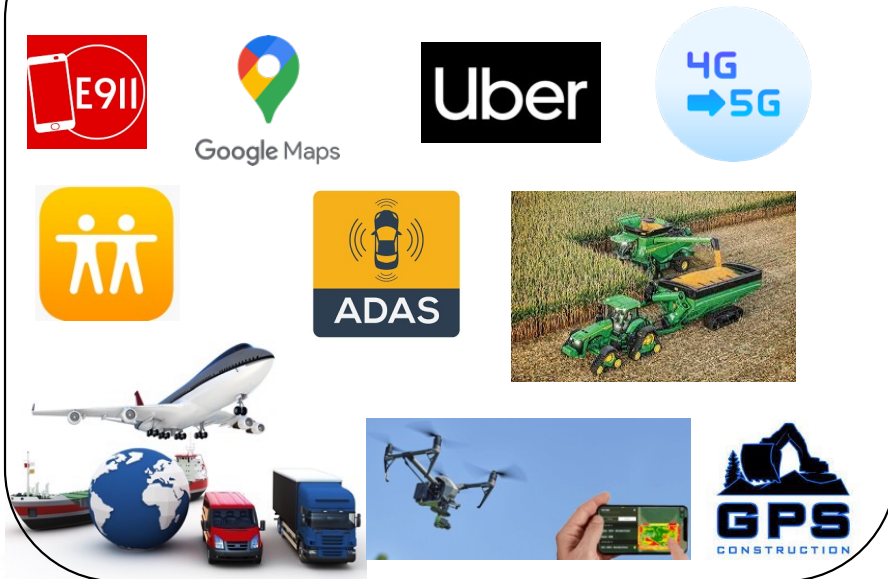
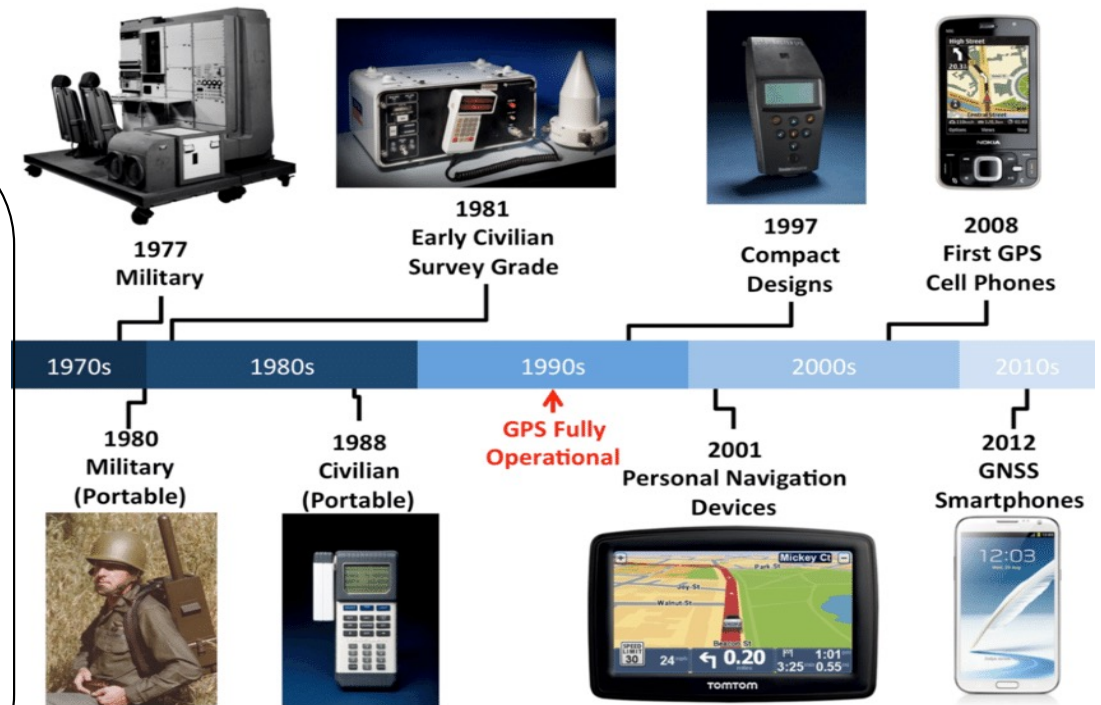


GPS – A look back at another ubiquitous technology

Started with a room full of equipment

To now embedded as a tiny block inside large SOCs that power a smart phone

Enabling life-changing functions and commerce

Source: Tyler Reid, 2017



Edge AI Use Cases are Exploding

Growth Spans Multiple Categories & Applications

Consumer

- Home Monitoring
- Home Security
- Home Automation



Wellbeing Wearables



People and Pet Tracking

Industrial & Manufacturing

- Asset Tracking
- Condition-based Monitoring
- Commercial Building Automation




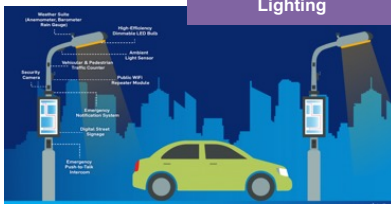





Smart Cities / Utilities

- Smart Parking
- Smart Street Lighting
- Smart Grids Smart Meters







Transportation and Logistics

- Telematics / Fleet Management Systems
- Heavy Transportation & Equipment
- User-based Insurance







Source: TinyML: The Next Big Opportunity in Tech, 2021 report by ABI Research



Consumer products have evolved, and so have the sensors

The IMU example -- decade of power, intelligence and performance

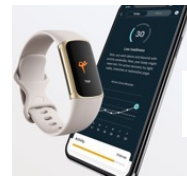


Applications are getting more intelligent

Fitness Bands – or Health Monitors



Detect Steps, calories and distance



- > 20 Exercise Modes - Auto-Exercise detection (HIIT)
- Activity Detection (Swimming, Jogging, Walking, Running etc.)
- Wrist Gestures (Bring to See, Shake, Stir, Slice, flick, clench etc.)
- Aiding PPG sensors for HRV and Heart Health Analysis (Vital Signs)
- Fall Detection, Rehabilitation, Sleep Analysis

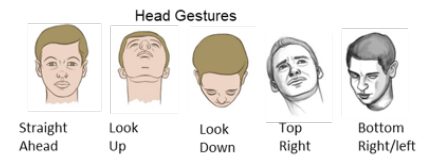
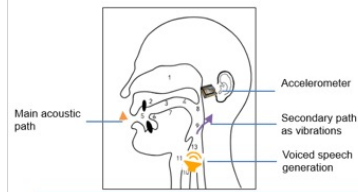
*Latest wearables include numerous ML models running on/off chip
Fall detection, sleep, rehabilitation, activity, hand gestures.*

Applications are getting more power sensitive

Hearables to TWS



3-axis accelerometer only
Tap and Shake Detection
Pedometer, HR monitoring



Latest include IMU with on-chip algorithm for capturing head orientation for Spatial Audio at <math><1\text{mA}</math>, head gesture detection and Voice Activity Detection.

Motion sensor Trends in Consumer application

Demand has driven functionality, tight integration, cost / power reduction

Applications	Then	Now	Improvement
Consumer Applications (that need 6-axis fusion)	Sensor Fusion on-chip @4.5 mA	Sensor Fusion on-chip @450 uA	10x improvement
	Sensor Fusion 2 deg/min	Sensor Fusion 0.2 deg/min	10x improvement
	Sensor Fusion for the phone only	Sensor Fusion customized for: VR, Robots, drones, TWS	Customized for each use-case
Wearables, Hearables	Pedometer @300uA	Pedometer @30uA	10x reduction
	Fixed Gestures: Tap, Freefall	Custom Gesture Suite with Machine Learning (Bring to See, Shake, Stir, Slice, flick..)	New era of customized SW 10x more features
	Accelerometer based activity classification	6-axis activity: Gyming, Swimming, Human Fall, Dance	New 6-axis wearable algorithms
SmartPhones	Wake on Motion @70uA, Pedometer, Landscape-Portrait	Wake on Motion @8uA Optical Image Stabilization	9x improvement New complex gyro SW features
TWS (hearables)	3-axis Single Tap and Shake Detect	Wake on Voice with Bone Conduction Triple Tap, Wide Area Tap, Head Gesture (nodding)	New Audio algorithm with motion

TDK's Machine Learning on a sensor chip

Attracting Tomorrow



Integration Example – Build your own ML classification model on the sensor chip



Customization

- ✓ User specific use-cases, data, features, ML models

Lower System Power

- ✓ Run optimized models on-chip for 3x lower system power than Host MCU

Time to market

- ✓ Quick POC, evaluation and test, significant reduction in development time

Enhanced Support

- ✓ Automated model generation and deployment based on user data

Ease of Use

- ✓ Single stand-alone web-based, platform independent tool

Automated Performance

- ✓ Performance reports generated on-the-fly, real-time analysis

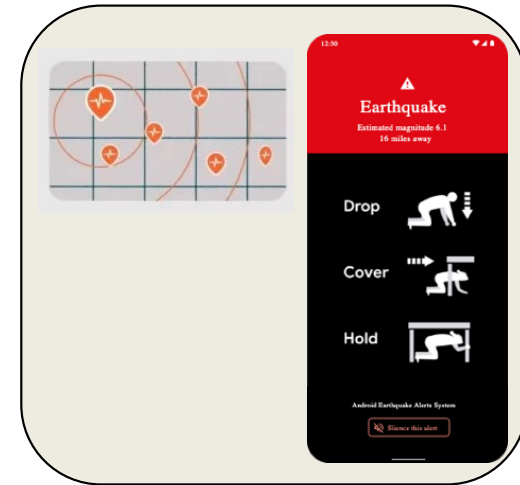


Different ways to skin the cat

Tiny is good

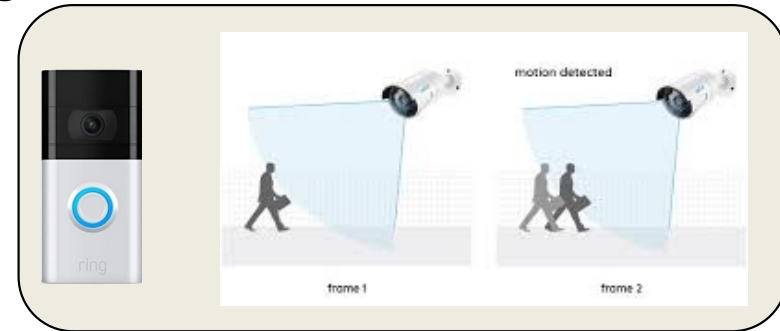
Sometimes **crowd of tinies** is even better!

Google's earthquake detection - uses the 2+ billion Android phones in use around the world as mini-seismometers to create the world's largest earthquake detection network; the phones detect the vibration and speed of shaking of an earthquake, and alert Android users in affected areas accordingly



Other times, **Be on the lookout and wake up the big brother!**

Help deliver system-level power consumption
 "Always-on" hierarchical detection



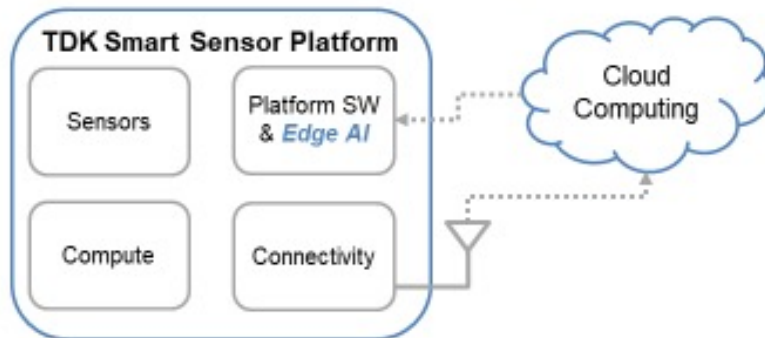
*Highly efficient tinyML solutions that integrate into larger systems
 Built with solid, easy to integrate, functional blocks*



Industrial IOT

Edge AI Challenge

TDK Smart Sensing Platform



- Enabling *AlwaysOn*, interactive apps and services
- Intelligence continues to move to the Edge, but...
- **Many verticals with differing AI requirements**
 - While we can make an IoT device spanning applications...

Industrial Sensing Applications



- **But...**
 - the diversity of applications
 - and diversity of requirements means...

There is no single AI solution covering all applications

Industrial IOT

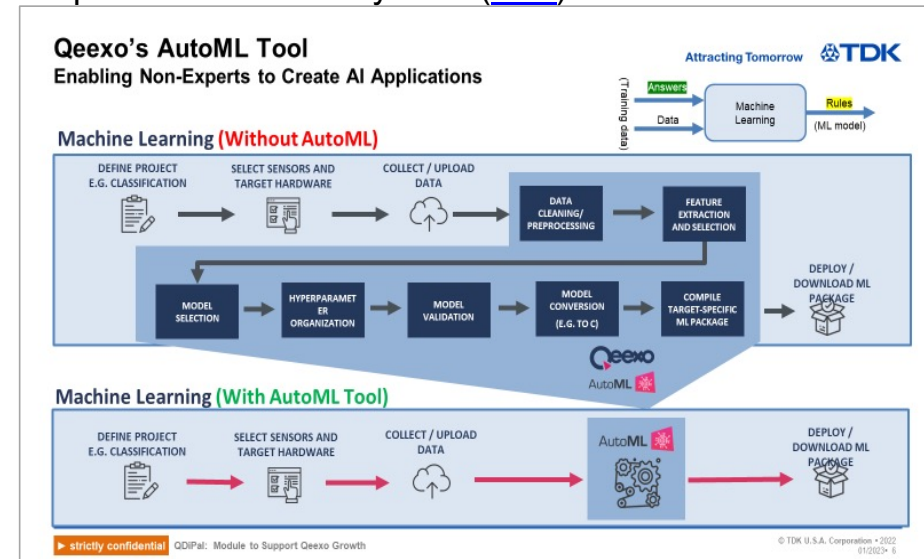
- Fragmented market with many low volume applications today
- “Killer apps” driving large volumes not yet obvious
- Knowledge gap between development community and end-applications




TDK's Focus

- Streamline end-to-end enablement of the specific domain expert
 - Focus on flexibility and TTM vs. streamlined cost for new applications
 - Reusable (HW/SW) building blocks
 - Already blessed with many many sensor and low cost silicon driven by consumer electronics
 - Facilitate Industrial digital transformation
 - Streamlined ML model generation & deployment by non-ML experts
 - Off-the-Shelf programable sensor devices
 - TDK factories as friendly beta sites


Acquisition of Qeexo by TDK ([Link](#))



I3 Micro
 Ultracompact, battery-powered wireless multi-sensor CbM module built-in edge AI and wireless mesh connectivity
[Link](#)



Smart Bug 2.0+ SIF (ML framework) dev board
 On-IMU Decision trees- 256 nodes
 On-Device BLE SoC w/ Cortex M4 app processor
[Link](#)



Evolution of Edge/Embedded Machine Learning

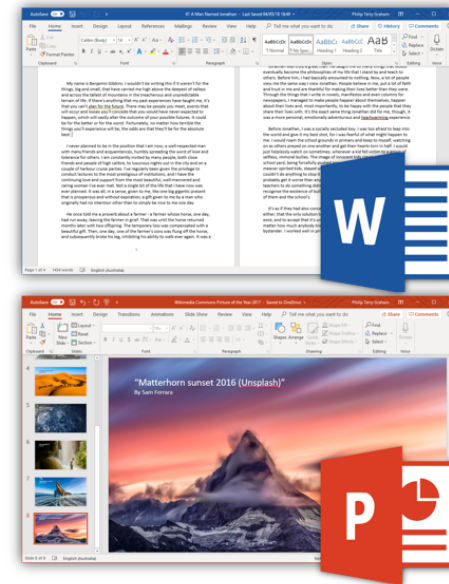
1400's (printing press era)



- Team of experts
- Weeks of work



TODAY



- One non-expert
- Hours of work

Evolution of Edge/Embedded Machine Learning

1400's (printing press era)



The right tools and easy-to-adopt building blocks are key

TODAY



- Team of experts
- Weeks of work

- One non-expert
- Hours of work



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