tinyML® Builds

Ultra-low power machine learning at the edge success stories

Stuart Feffer – Co-founder of Reality AI,
Leading the integration with Renesas Electronics

April 19, 2023

www.tinyML.org

Thank you, **tinyML Strategic Partners**, for committing to take tinyML to the next Level, together

Executive Strategic Partners

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EDGE IMPULSE

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edgeimpulse.com

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AI research

Advancing AI research to make efficient AI ubiquitous

Power efficiency

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Personalization

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Robust learning through minimal data, unsupervised learning, on-device learning

A platform to scale AI across the industry

Perception

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Reasoning

Scene understanding, language understanding, behavior prediction

Action

Reinforcement learning for decision making

Edge cloud

Cloud

IoT/IIoT

Automotive

Mobile

Accelerate Your Edge Compute

SYNTIANT

Making Edge AI A Reality

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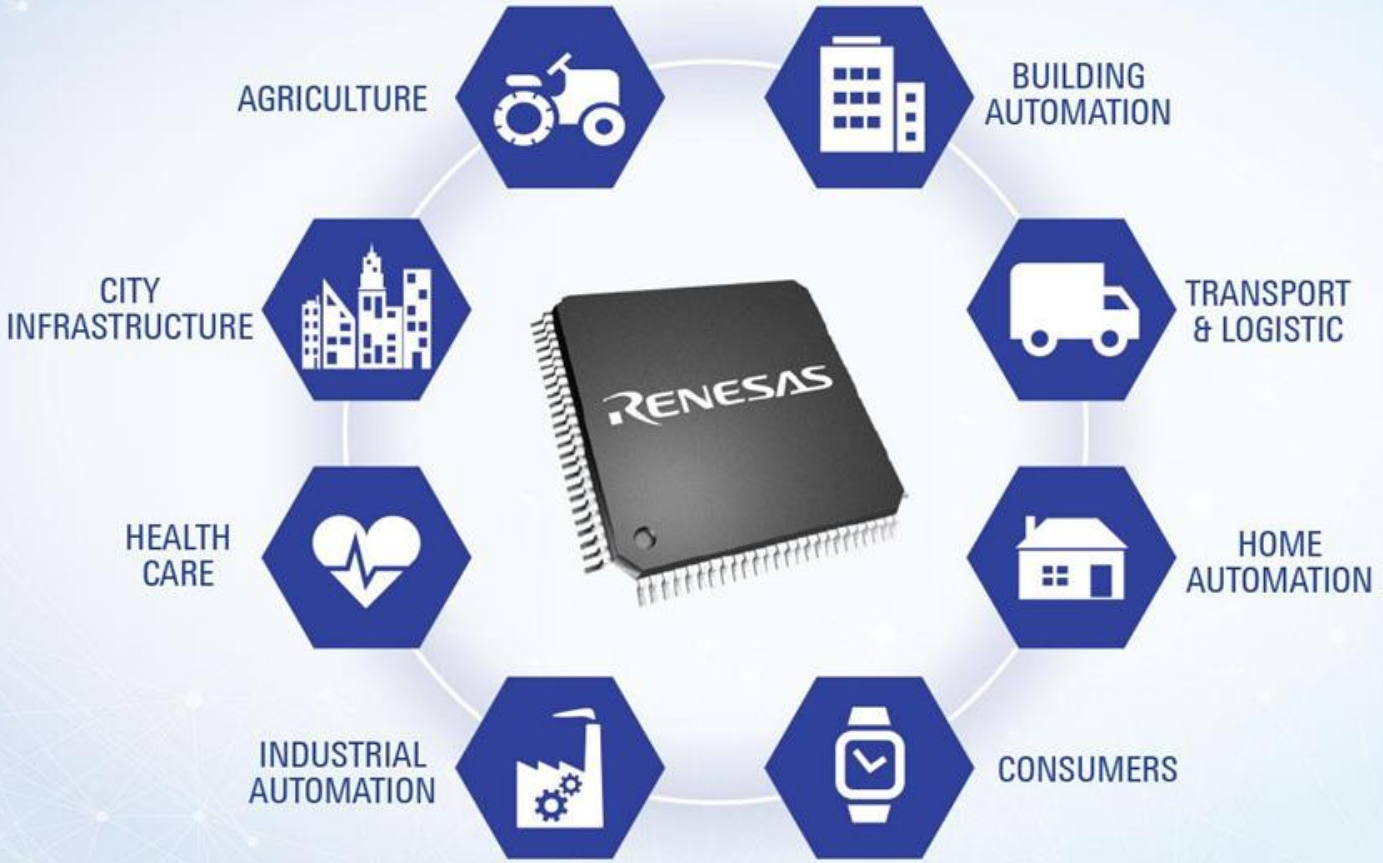
Renesas is enabling the next generation of AI-powered solutions that will revolutionize every industry sector.



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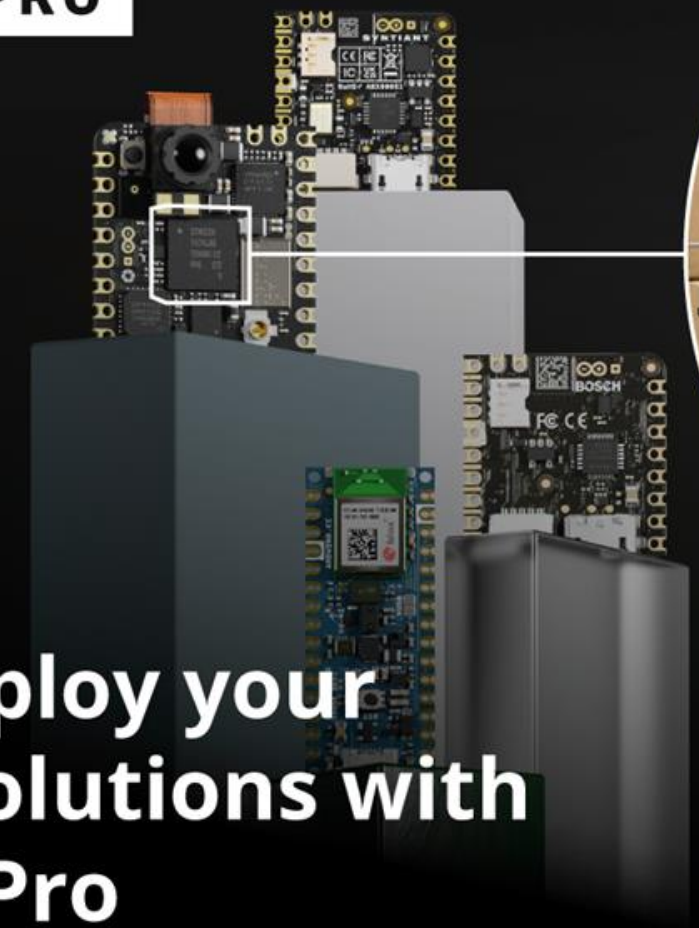

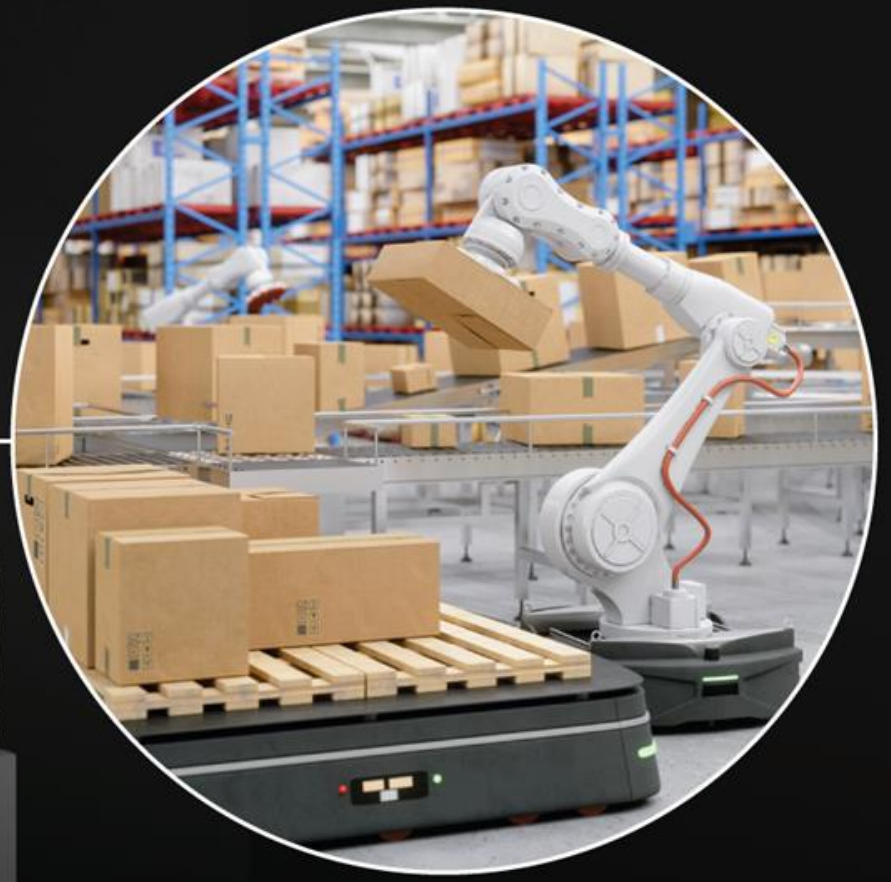

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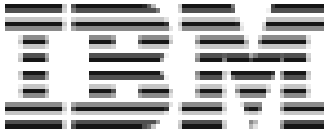

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tinyML - Enabling ultra-low Power ML at the Edge

https://www.meetup.com/tinyML-Enabling-ultra-low-Power-ML-at-the-Edge/

4k members
&
11.6k followers

The tinyML Community

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

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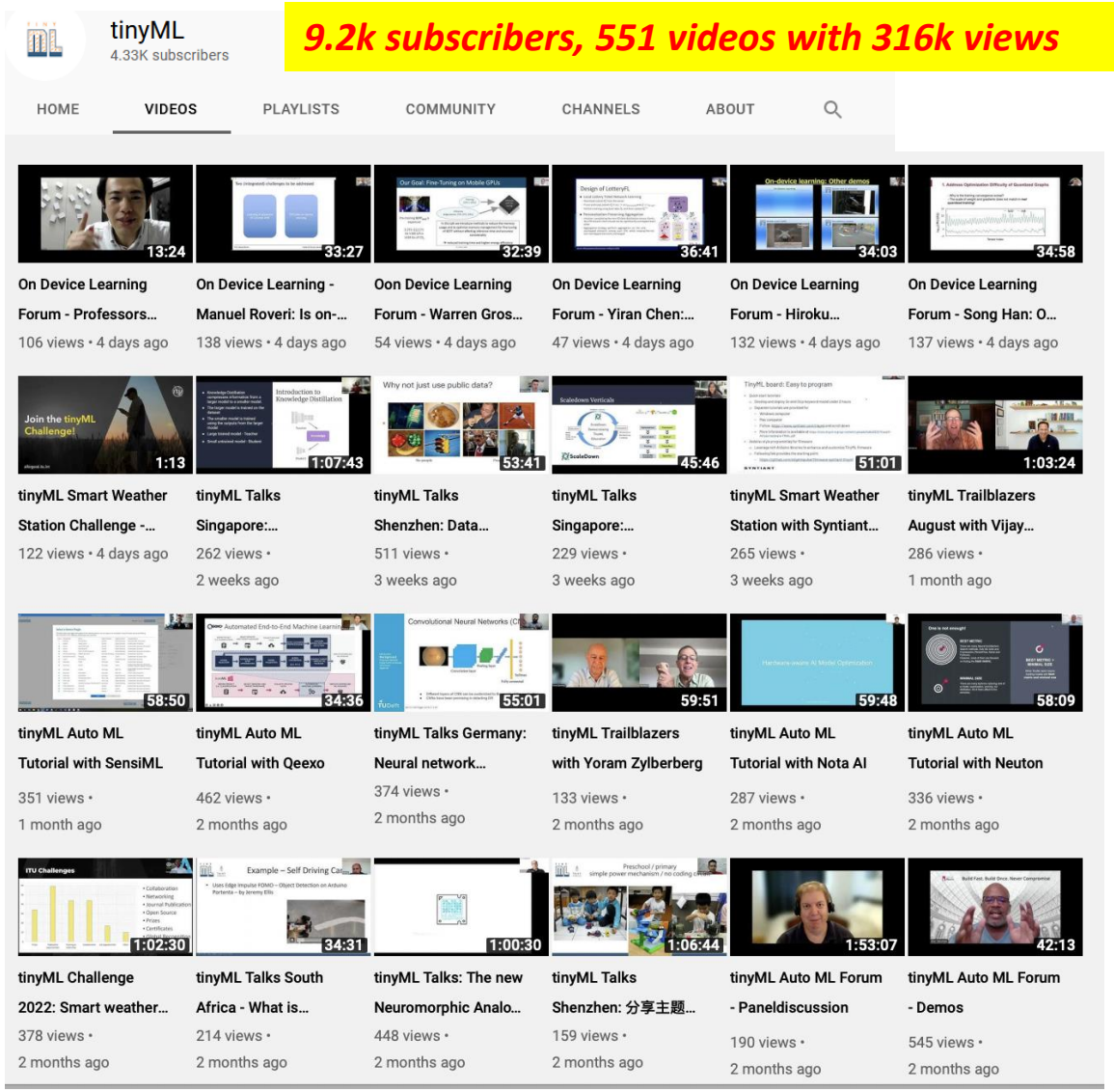

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EMEA 2023

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Reminders

Slides & Videos will be posted tomorrow

tinyml.org/forums

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Please use the Q&A window for your questions

TINY ML BUILDS

Host of the Builds Series

Venkat Rangan

Venkat Rangan is a Maker and seasoned engineer with extensive experience in IoT system design and implementation. He is the founder of tinyVision.ai Inc., a hardware and system design consulting company. Venkat previously served as a Director of Engineering at Qualcomm Inc. Venkat holds a MSEE from the University of Cincinnati and a BTech from the Indian Institute of Technology, Roorkee. He is an inventor/co-inventor on over 40 issued patents.

TINY ML BUILDS

Today's Guest

Stuart Feffer

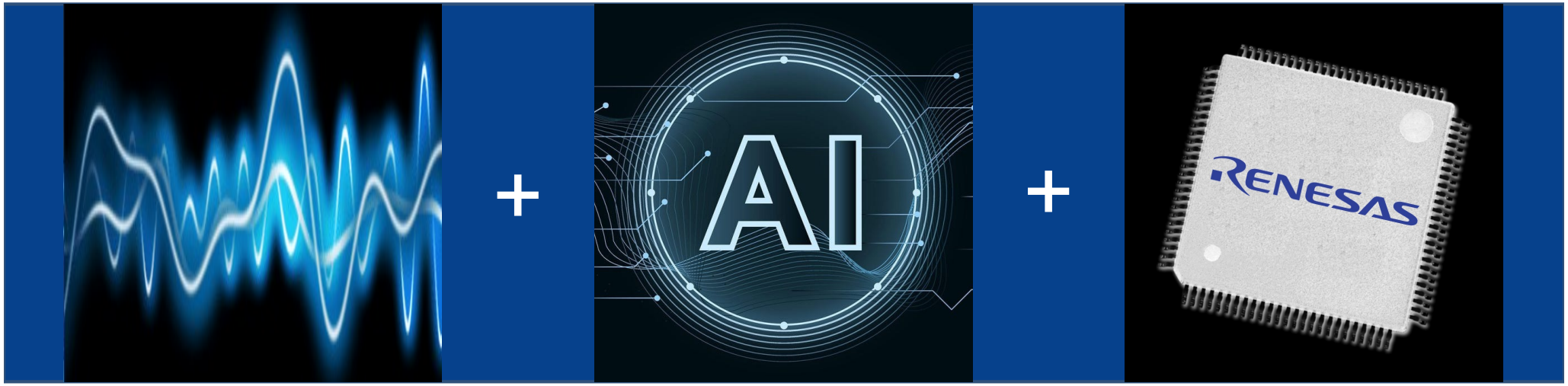
Stuart Feffer was one of the co-founders of Reality AI, and continues to run the Reality AI business for Renesas following its acquisition in 2022. Stuart holds a PhD from UC Berkeley and a BA from The University of Chicago.

Reality AI® A Renesas Company

TINYML BUILDS - WEBINAR

19 APRIL 2023
RENESAS ELECTRONICS CORPORATION

REALITY AI COMBINES ADVANCED SIGNAL PROCESSING AND MACHINE LEARNING ON MCU / MPU EDGE NODES



Advanced Signal Processing

Reality AI automatically searches a wide range of signal-processing transforms to create a custom, optimized feature transform.

Artificial Intelligence and Anomaly Detection

Reality AI automatically generates machine learning models, explanatory visualizations, and hardware design analytics.

MCU / MPU Edge Nodes

Reality AI runs on almost every MCU and MPU core available from Renesas, with new ones added constantly. Reality AI also supports Renesas Motor Control boards.

SCALABLE FROM 16-BIT TO 64-BIT CORES

Reality AI Tools® software

AI Explore™
Automated Feature Exploration and Model Generation

- AutoML (no coding)
- Explainability

BOM Optimization
Use AI to find the most cost-effective components

- Cost-optimized specifications
- Minimum sensor set

Data Readiness
Understand the state of training and testing data

- Automated
- Consistency
- Quality
- Coverage

Edge AI / TinyML
Super-compact, efficient code for the smallest MCUs

- Embedded code generation
- Ease of deployment
- MATLAB compatibility

EXAMPLE 1 – AUTOMOTIVE SWS

“See with Sound” - the Idea:

Use sound to hear safety threats that visual sensors can’t see

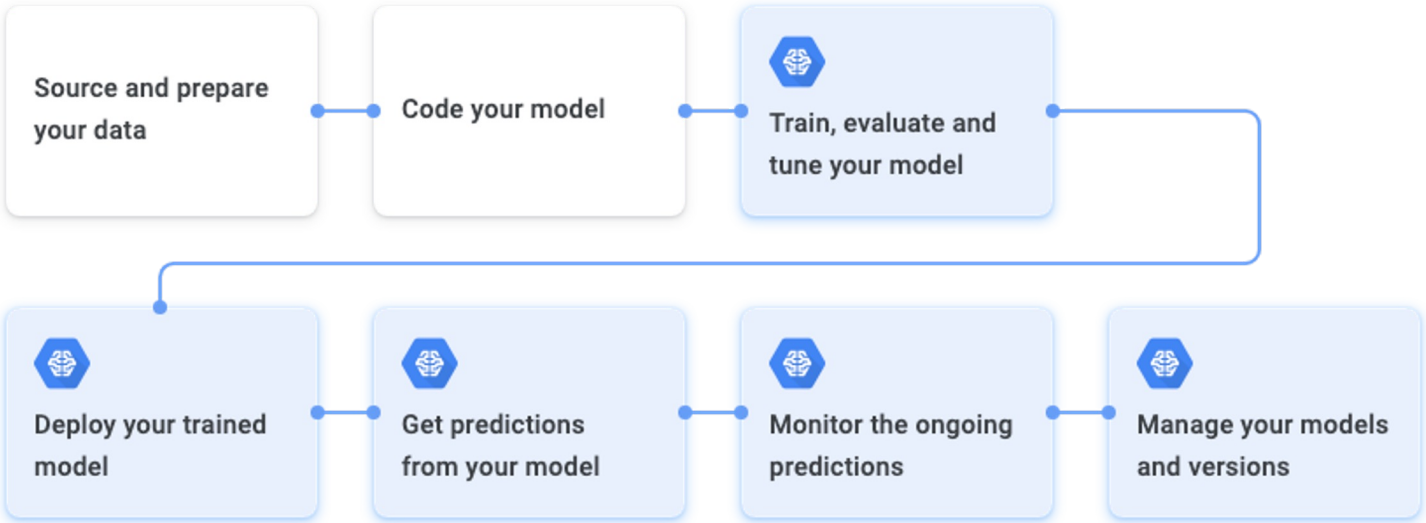
Breakdown of Technical Challenges

- Detection Algorithm
  - Noisy things (emergency vehicles)
  - Things that blend in (cars, etc.)
  - Quiet things (bicycles, joggers)
- Localization Algorithm
  - Angle of Arrival
  - Reflections and refractions
  - Distance
  - Approaching vs receding
- Hardware
  - Mic requirements
  - How many mics
  - Mic placement
  - Processor requirements
  - Component integration
- Audio processing chain

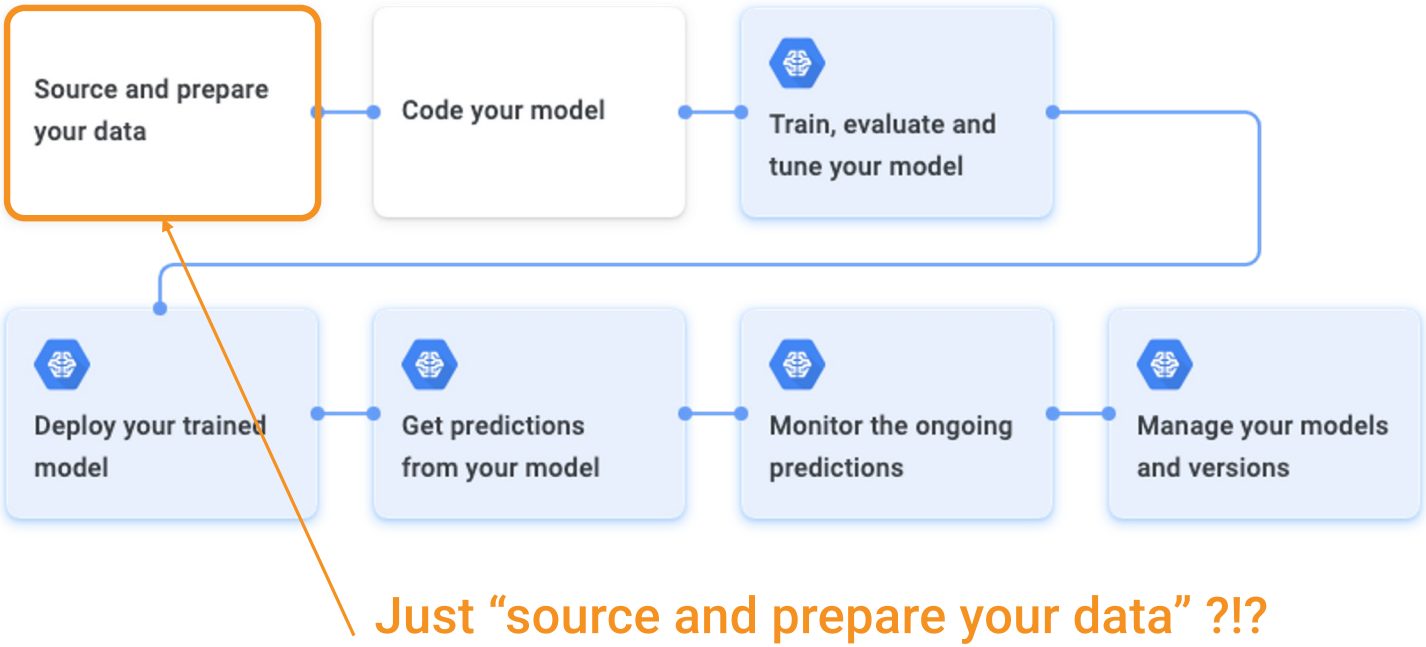
Key learnings for building with TinyML

- Iterate instrumentation with machine learning – they are intimately connected.
- Almost all the work is in hardware engineering and data collection, not ML

The Google Cloud ML Process

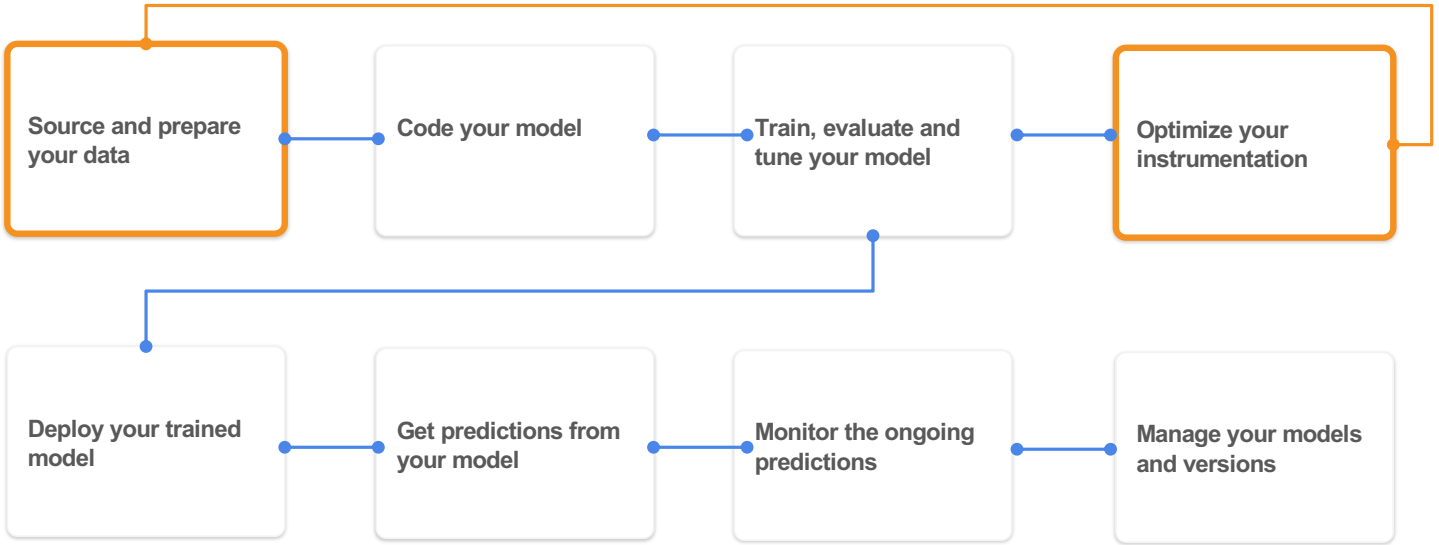


The Google Cloud ML Process



Just “source and prepare your data” ?!?
For most, that’s 2/3 of the effort and expense!

Edge AI / TinyML Process



PoCs iterate on hardware + ml together

PoC 1: Basic Feasibility

Prove that this can work at all

Simple equipment.

Quiet conditions
(but test with noise)

Try different kinds of targets.

No complications.

PoC 2: Achievable Accuracy

Prove that it can work in conditions resembling reality

Embedded, using automotive- grade for key components.

More complex conditions:

- Noise
- Reflections/Refractions

PoC 3: Product-readiness

Prove that this is ready to become a product

Integrated system using all automotive-grade components.

Mount on a moving vehicle

Test in real world conditions.

PoC 1: Basic Feasibility

Prove that this can work at all.

Simple equipment.

Quiet conditions
(but test with noise)

Try different kinds of targets.

No complications.

Targets:

- Emergency Vehicles
- Cars
- Bicycles
- Joggers

Conditions:

- Quiet park
- No reflections or refractions
- No weather or other complications

Equipment:

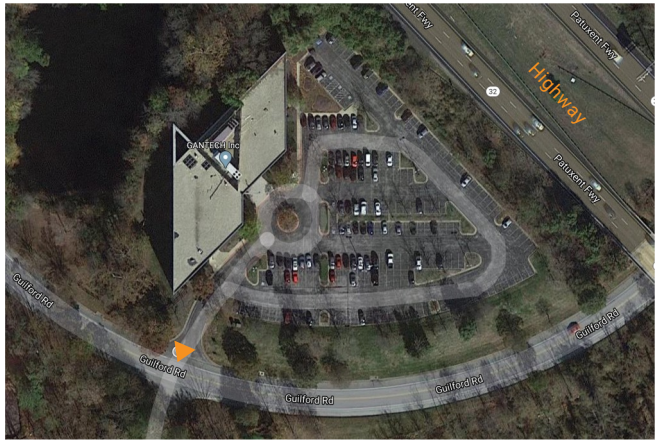
- Off the shelf audio recorder

Data Collection Plan:

- For emergency vehicles: Natural collection on streets of New York City
- For non-emergency vehicles, multiples of each type recorded at different, known speeds and distances
- Multiple repetitions of each individual vehicle at each speed, and distance

Data Collection

Data Collection - Validation w Background Noise



LOCALIZATION

Audio-based target localization is used in:

- Passive sonar on submarines
- Beamforming in smart speakers and conference equipment

For automotive, we must also contend with AoA confounds due to:

- Reflections off building walls
- Refractions around corners

Our approach combines signal processing based localization with machine learning to:

- Compute angle-of-arrival of signals
- Detect and correct for reflections / refractions

Localization methods coming soon to Reality AI Tools®

PoC 2: Achievable Accuracy

Prove that it can work in conditions resembling reality

More complex equipment.

More complex conditions:

- Noise
- Reflections/Refractions

Embedded, using automotive-grade key components.

Targets:

- Emergency Vehicles
- Cars
- Motorbikes
- Bicycles

Conditions:

- More varied noise
- Reflections or refractions
- No weather or other complications

Equipment:

- MEMS mic array

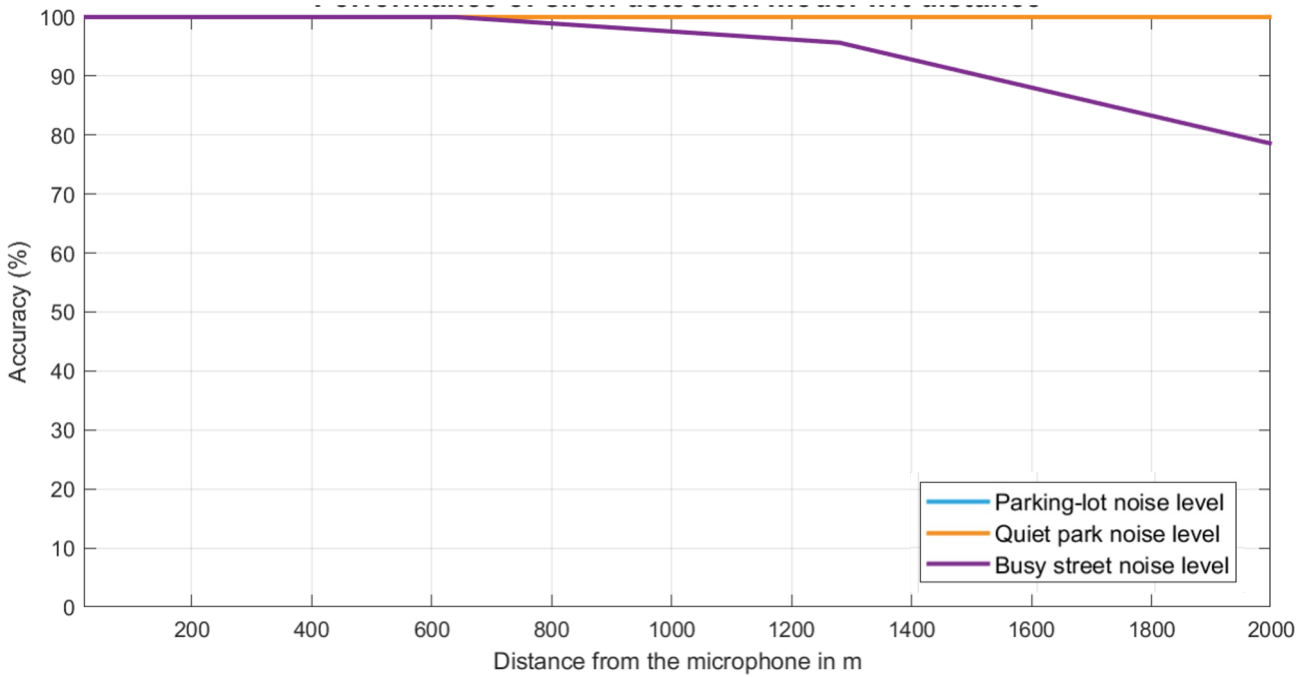
Prototype rooftop SWS array featuring automotive-grade mics from **molex** *and A2B automotive cabling solution.*

Data Collection Plan:

- Multiple vehicles of each type recorded at different, known speeds and distances, with repetitions
- Background noise collected separately, mixed in for training and testing
- Simulation of corners with reflections and refractions

PoC2 Results:

We can accurately detect and localize Emergency Vehicles > 1500m away, even in noisy environments.



PoC 3: Product-readiness

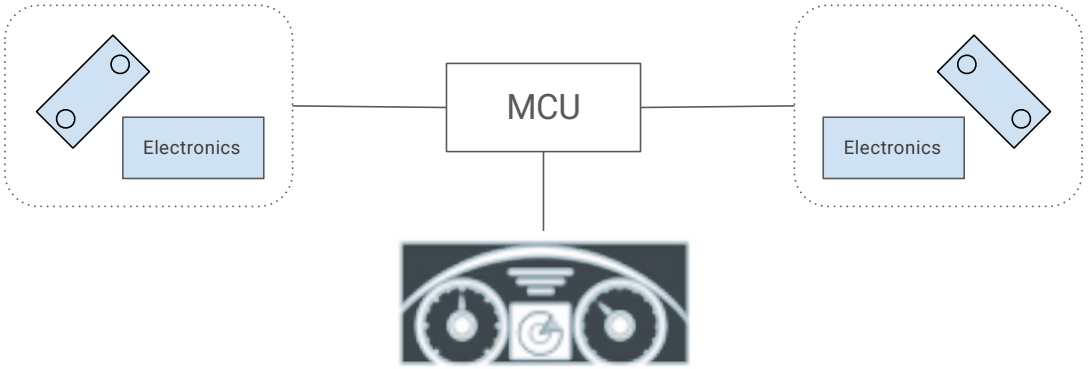
Prove that this is ready to become a product

Real, automotive-grade equipment.

Mounted on a real moving vehicle

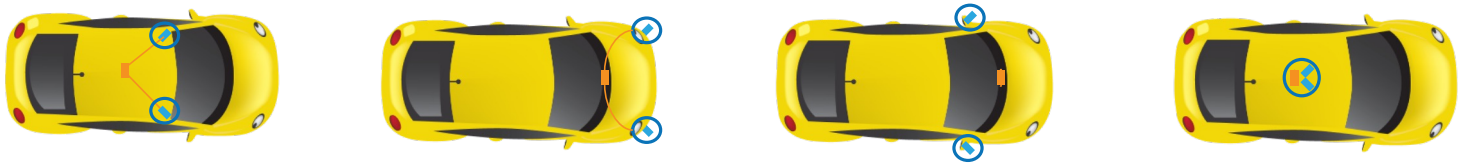
Tested in real world conditions.

PoC3 now underway



Mics and conditioning electronics mounted in different automotive components for demo by partners.

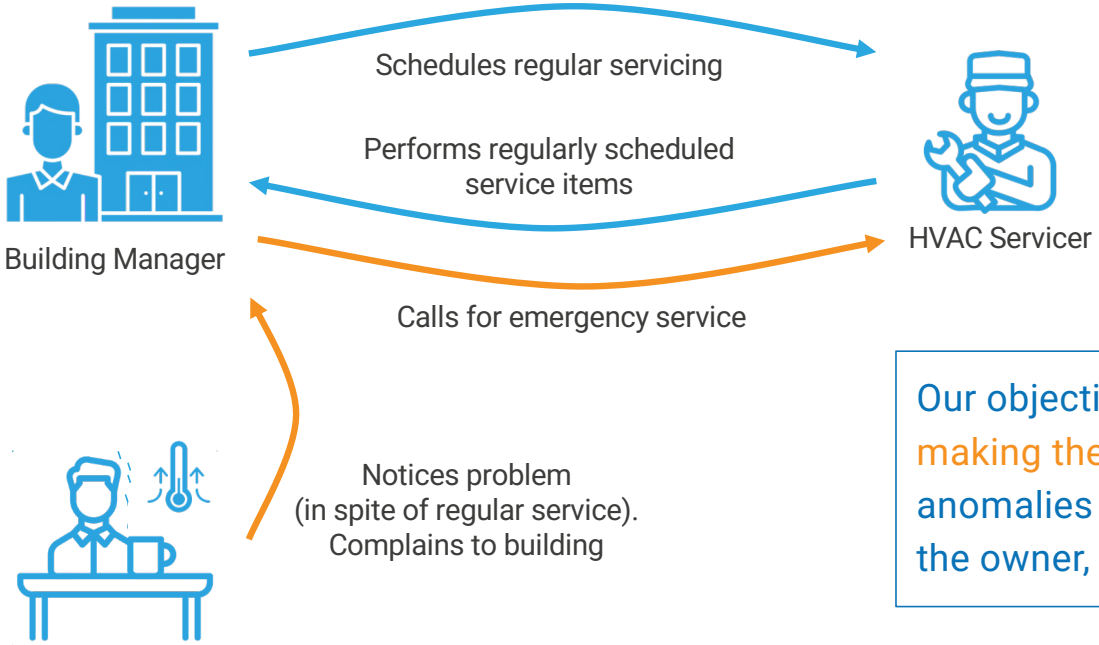
Testing in a range of configurations:



REALITYCHECK HVAC

HVAC SERVICE CAN BE MADE MUCH MORE EFFICIENT

Most HVAC servicing is done on a schedule, or in response to a problem



Our objective is to reduce emergency service calls by making the HVAC equipment self-aware, reporting anomalies and service needs in advance, directly to the owner, building manager or servicer.

NEW TECHNOLOGY CAN MAKE HVAC MORE INTELLIGENT

Using machine learning and edge processing, it is now possible to build HVAC units with the native ability to detect a wide range of faults and operating conditions.

Target Conditions for Detection and Prediction

- Blocked indoor/outdoor airflow
- Coil frosting
- Refrigerant charge issues - undercharge / overcharge
- Faulty fan
- Faulty compressor
- Failing capacitor
- Heating / cooling capacity reduction
- Filter life prediction
- Other conditions

RealityCheck HVAC

Hardware Reference Design

- Sensor Components & Mounting Locations
- Processor & Supporting Electronics
- Communications & Interfaces

Firmware

- Data Acquisition
- Signal Processing
- Output & Communications

Machine Learning

- Anomaly Detection
- Predictive Modeling
- Remaining Useful Life Prediction

plus a defined process for model training and customizing to your specific product needs

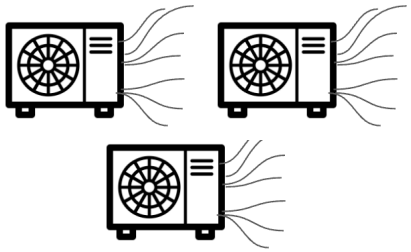
RealityCheck HVAC SOLUTION DEVELOPMENT PROCESS

Our process starts in the lab with model calibration and retraining, then moves to the field with increasing numbers of units as we develop confidence that the ML+ hardware design is performing to expectations.

Increasing confidence in model and product design performance

Pre-Start

Whiteboard / Paper Scope and Requirements Definition

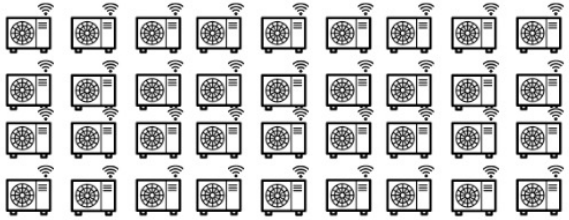


Phase I

Lab-based data collection on a few units to calibrate and retrain models for customer equipment. Typically 3-6 units.

Phase II

Field-based data collection on a more units to collect additional training data and more diverse backgrounds Typically 12-50 units.



Phase III

Field testing of prototype. Fine tuning of models and false-positive suppression. Final validation of ML models and product design prior to preparation for manufacturing. Typically 25-100 units.

DATA COLLECTION

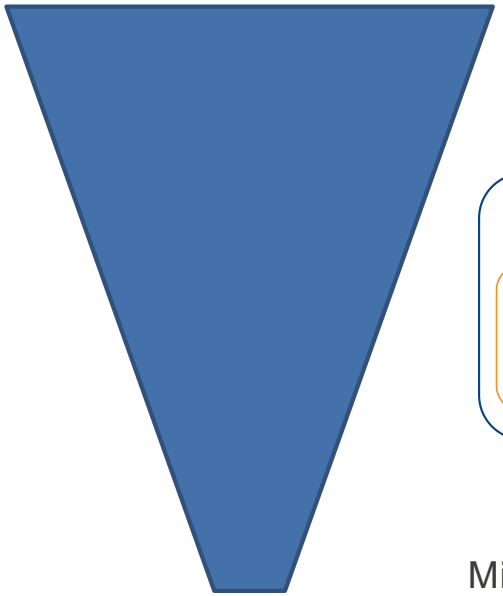
RealityCheck HVAC customers may outsource data collection to Renesas and OTS:

Optimized Thermal SYSTEMS

OTS provides prototype development and performance measurement of new technologies for HVAC systems. They operate an 8,000 sqft laboratory including multiple environmental chambers and temperature-controlled wind tunnels to enable testing for small capacity systems and components. OTS follows ASHRAE/AHRA/ANSI standards as closely as possible, where applicable, but also provide custom tests to meet specific product development needs.

SELECTING SENSORS AND MOUNTING LOCATIONS

Different types of HVAC equipment requires different instrumentation (eg residential OD/ID units, commercial units, mini-spilt systems, window units, commercial refrigeration).



Up to 130 different sensors / mounting location candidates

Reality AI Tools® software

AI Explore™
Automated Feature Exploration and Model Generation

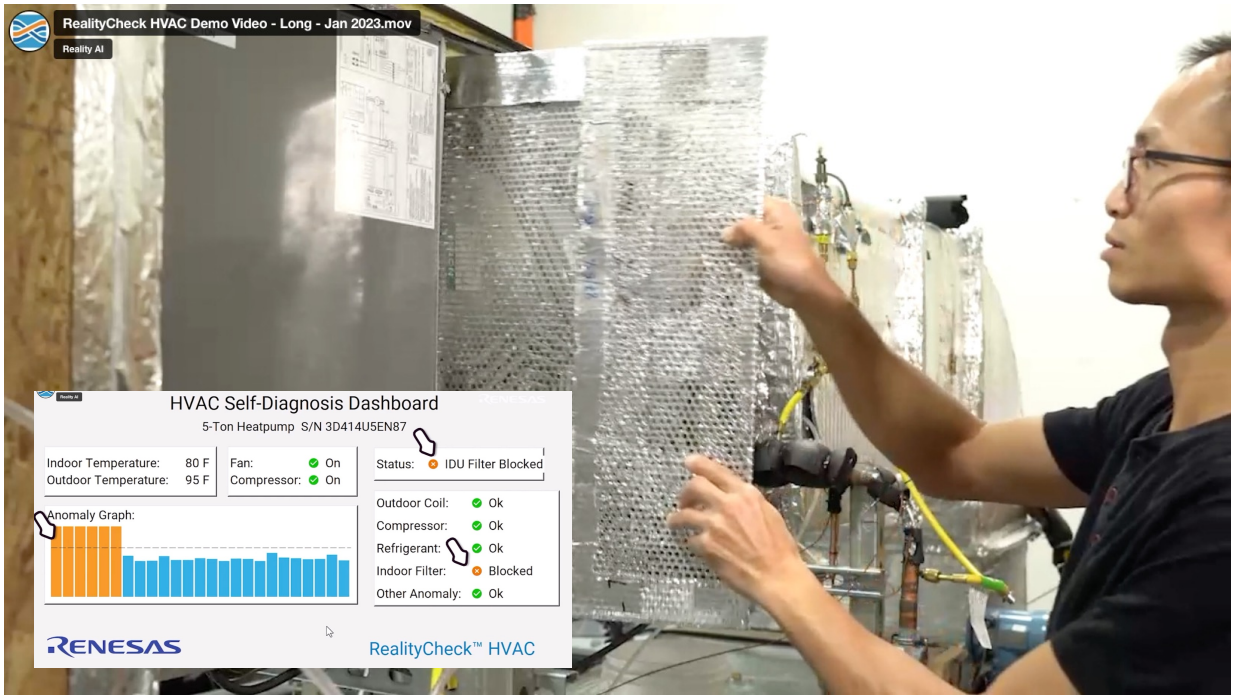
BOM Optimization
Find the most cost-effective components and mounting spots

Data Readiness
Understand the state of training and testing data

Edge AI / TinyML
Super-compact, efficient code for the smallest MCUs

Minimal, cost- and accuracy-optimized sensor set w best mounting locations

DEMONSTRATION VIDEO



Demo:

- 5-ton residential heat pump
- All instrumentation on ODU
  - Temp sensors + accelerometer
  - May replace accelerometer with RealityCheck MOTOR code running on motor control board (if available)
- Can run on any Renesas core with available capacity.
- Detecting
  - Coil blocked or frozen
  - Low refrigerant charge
  - Compressor or fan fault
  - Filter blockage / remaining useful life (on indoor unit!)
  - Uncategorized anomalies

The end

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