NEM Switch device plans and potential applications

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Business Interest Group Webinar

4 Oct 2023

i-EDGE
EDGE COMPUTING FOR EXTREME ENVIRONMENTS

Protocol

- Please feel free to interrupt and ask questions!

- This is intended to be an interactive webinar.

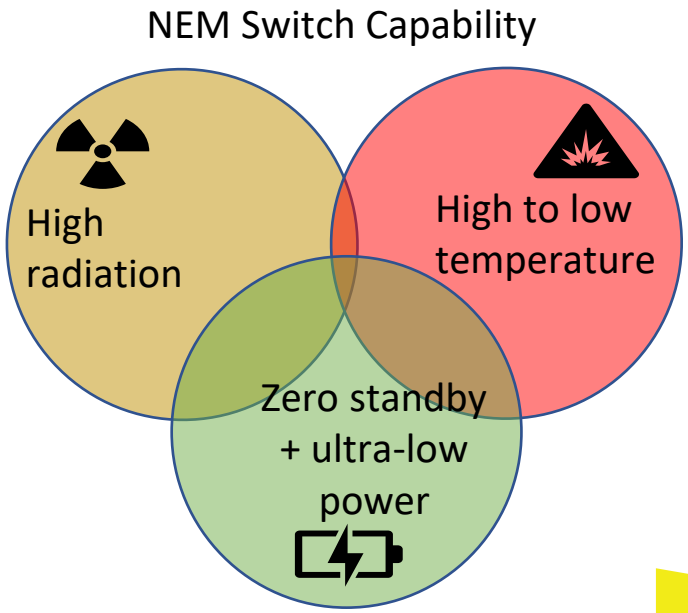
Introduction to the i-Edge Project business aims

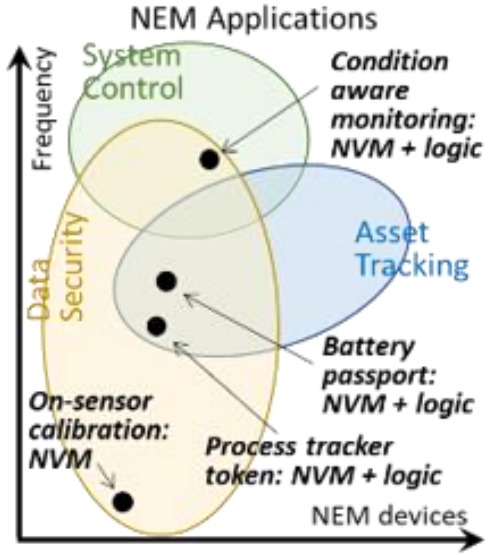
- The over-arching concept of i-Edge is to prepare a new business

- The i-EDGE project plan aims for this to be achieved by:
- 1) Taking NEM Switch technology from TRL2 to TRL6
- 2) Planning and implementing a manufacturing process.. “lab to fab”
- 3) Finding applications and developing products
- 4) Interaction with our Business Interest Group (BIG)

Finding applications to sell

- Our products must fully use NEM Switch's three advantages
- Best applications will lie in overlapping area of this Venn diagram
- This has guided our market research
- At TRL2/3, we are at Kilby and Noyce stage of IC development
  - Very low oscillator frequencies, life of 10^8 cycles
  - Low level of integration
  - We aim for own our "Moore's law effect"





NEMS platform high temperature applications

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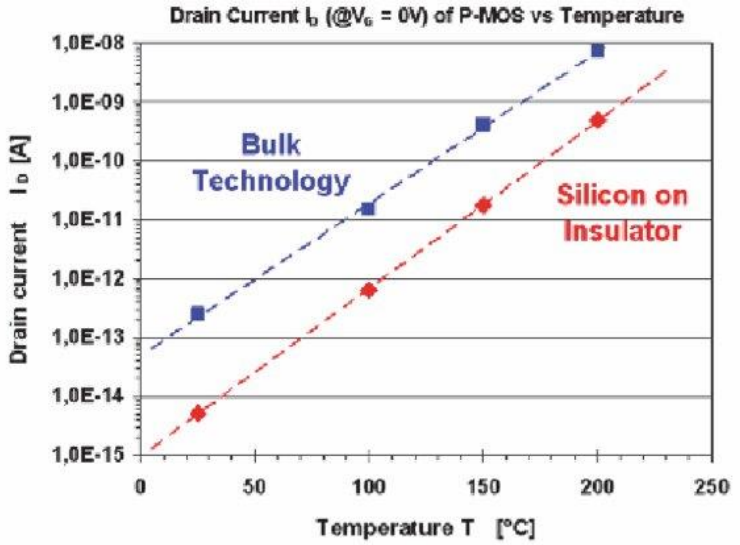
Why might NEMS temperature measurement devices win?

- As temperature increases, semiconductor drain currents increase.
- Batteries become dangerous and unusable above 150C
- Low power from unconventional source have to be used to supply power.
  - Capacitor banks
  - Mechanical energy harvesting
  - RF energy harvesting
  - Thermal energy harvesting

Drain current of a type of CMOS FET versus temperature



Potential temperature measurement applications

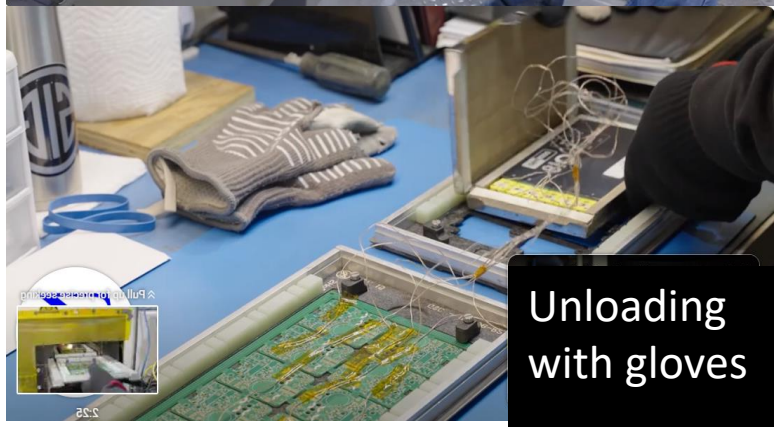
- 1) Temperature profile measurement of belt ovens
  - Where the NEM Switch temperature measurement device is transported through the oven on its belt. NEMS device is read on exit.

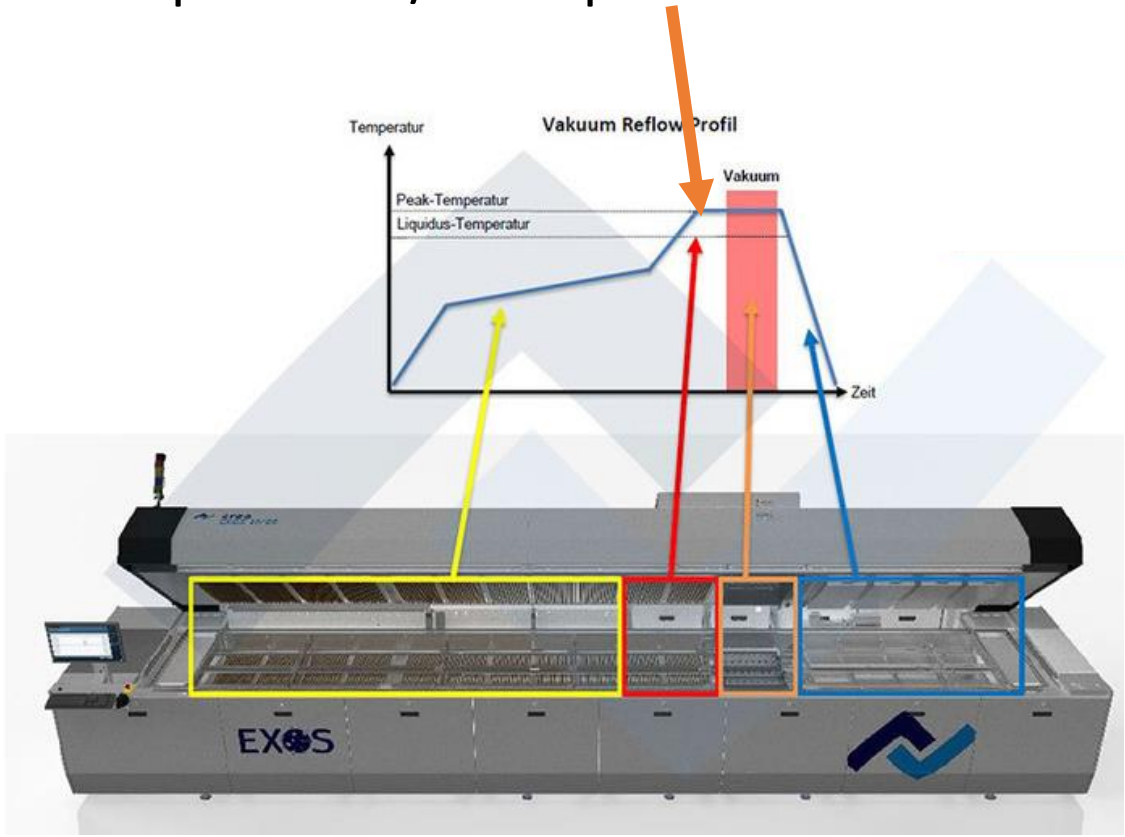
- 2) Realtime measurement batch oven measurement
  - RFID transponder used to communicate with NEMS device(s) in the oven

- 3) Rugged asset tracking
  - NEMS device compliments / integrated with CMOS to retain data or function at high temperatures.

1) Temperature profile measurement of belt ovens

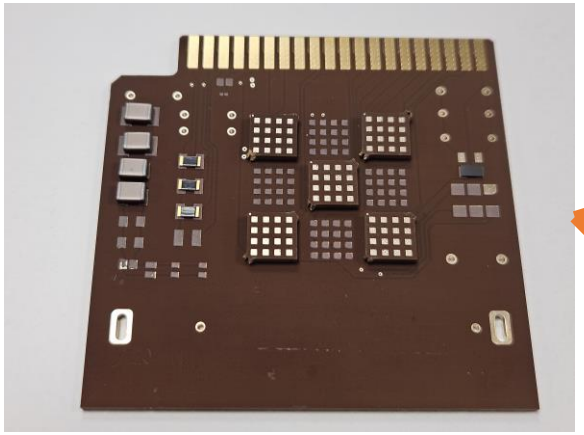
- A shielded measurement device and sample is transported through the oven on its belt.
- The device is read on exit to produce a temperature / time profile.



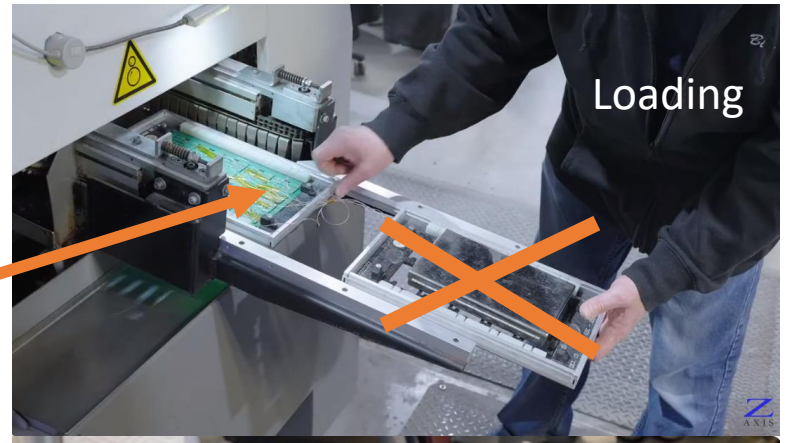


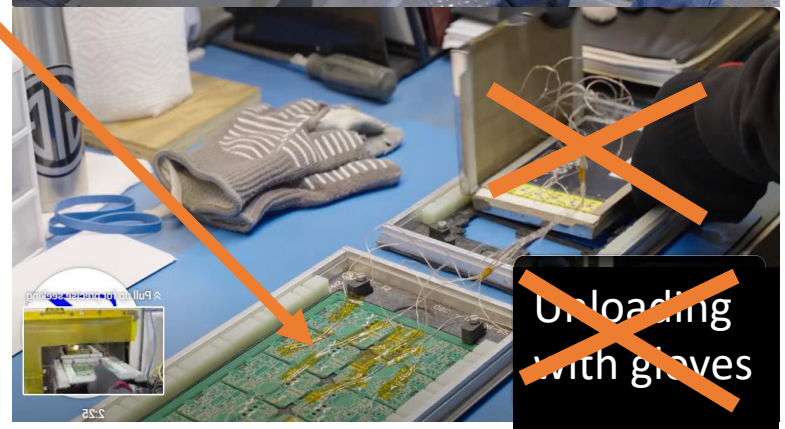
1) Temperature profile measurement of belt ovens with NEMS

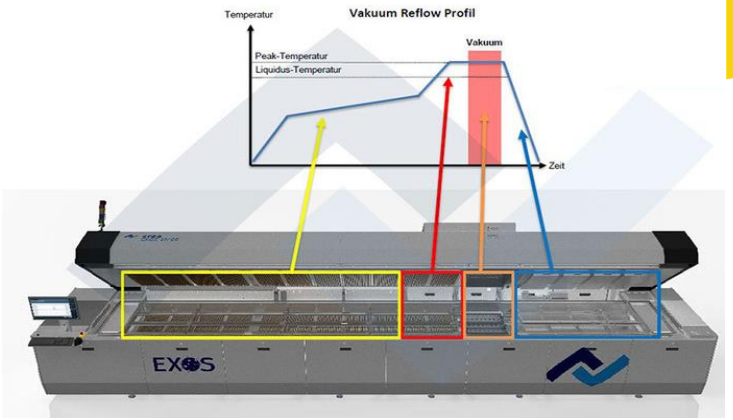
- Now no need for a high mass thermal shield
- NEMS measurement devices can be mounted on a PCB and emerge cold
  - no gloves, leads etc… allowing frequent measurement and better process control



Use a high temp NEMS replica board or mount a smaller NEMS board







Realtime batch oven measurement

- Meater – meat thermometer
  - Max temp 100C
    - (Protected by the meat)
  - Bluetooth
  - Diameter 7mm
  - Probe weight 200gms

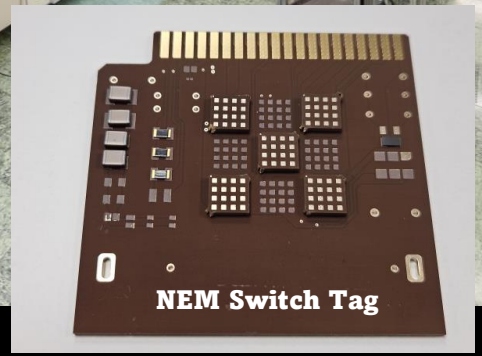
- NEMS
  - Max temp 325C – active circuitry
  - RFID
  - Probe diameter – needle, magnetic, screwed down
  - Probe weight – low (with a light flexible cable to external NEMS reader)
  - No pies destroyed by NEMS!! (no unsightly measurement holes)
  - “Goldilocks pies” – not too hot, not too cold

3) Rugged manufacturing flow asset tracking

- Many manufacturing flows contain a critical high temp step
  - eg a solder reflow, hot chemical baths, glue cures, drying

- Current RFID tag specifications
  - Operational -40°C to +85°C, *Survival -40°C to +250°C*
  - RFID

- NEM Switch tag specification
  - Operational -40 °C to 250 °C plastic case, 325 °C ceramic case
  - RFID + optional chargeable power supply
  - On board sensors – shock, humidity, temperature
  - Tracking with process monitoring



NEMS overlay complimenting CMOS at temperature

- Most activities will be at room temperature or have periods at room temperature
  - eg the case of 3) rugged asset tracking
- CMOS circuits lose all data….. but are not destroyed by temperature.
  - Ie function again when cold
- NEMS memory can retain data
- NEMS logic can collect sensor readings against time whilst at temperature
  - Eg an oven profile

- NEMS can compliment and support CMOS whilst at temperature

NEMS platform radiation applications

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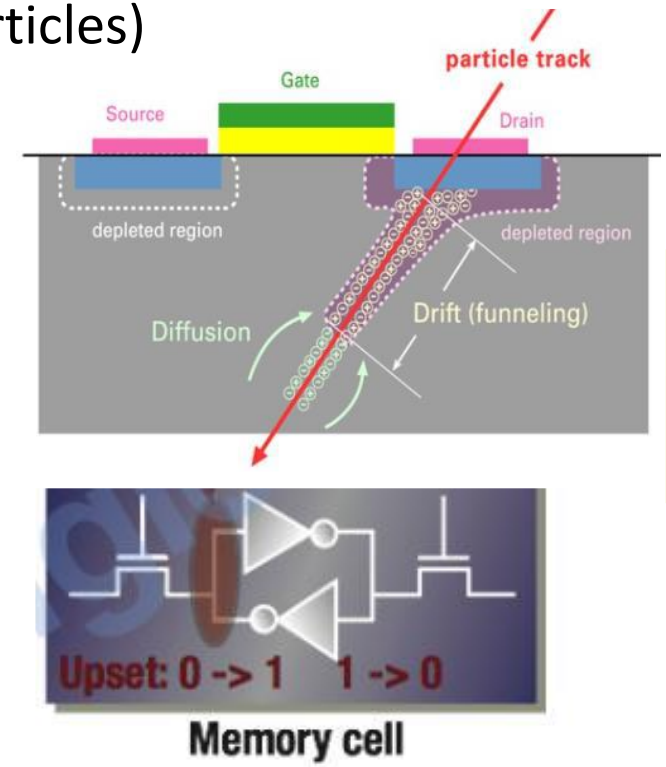
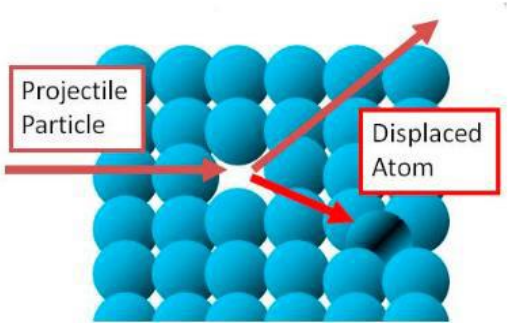
NEMS overlay complimenting CMOS in radiation?

- CMOS is instantly affected by sudden upset event from energetic particles
  - Most times, a reset or reboot restores the system (lower energy particles)
  - Sometimes, a FET is permanently damaged (higher energy)



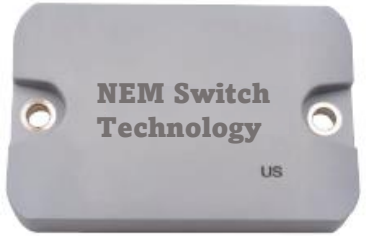
- CMOS is gradually degraded by all radiation
  - This calibrated by a Total Ion Dose



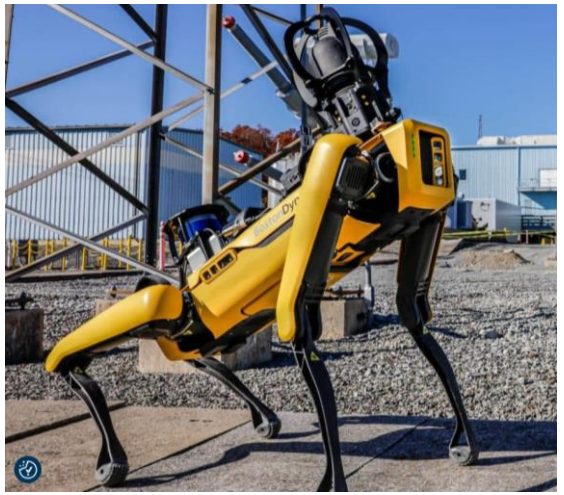
Potential radiation applications

- 1) Real time radiation level mapping
  - Bringing together multiple sensors for radiotherapy, industrial or nuclear industry

- 2) Radioactive asset tracking and monitoring



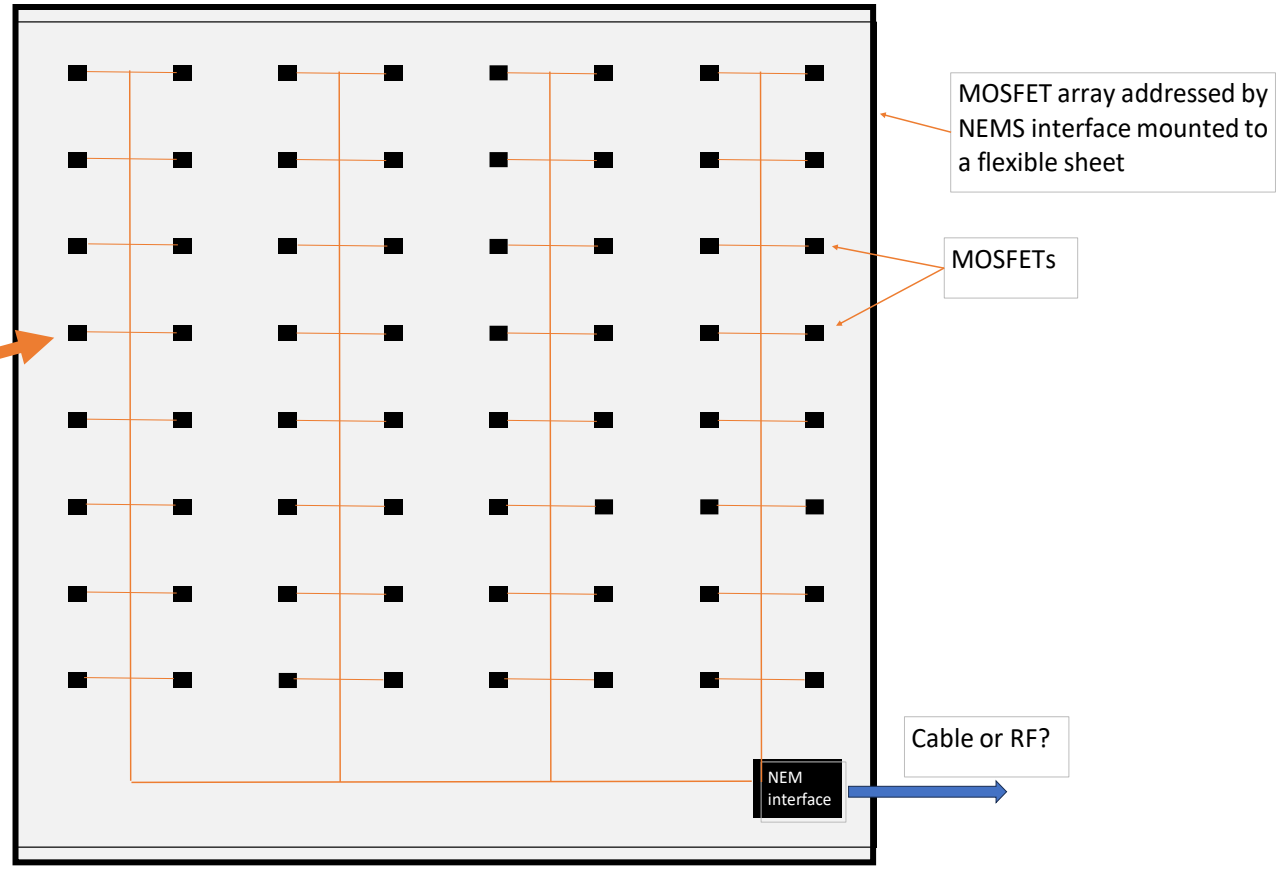
- 2) Rescue logic circuits
  - Autonomous robot or drone emergency return circuitry



1) Real time radiation level mapping

- Bringing together multiple sensors for radiotherapy, industrial or nuclear industry
  - Allows a more complete map of radiation

Replace two sensors by an array of sensors on flexible surface, read out by NEMS interface chip



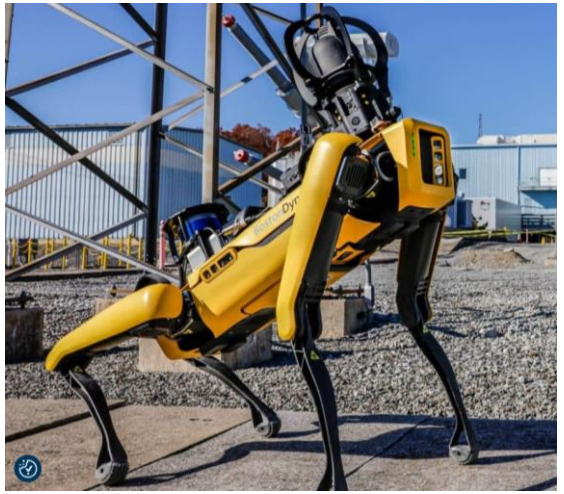
2) Rugged tracking of radiological assets

- Current specification for CMOS based RF tags
  - <100Gys, <3KGys if radiation hardened
  - RFID, long RF range on active tracking devices

- NEM Switch specification
  - >1MRad, >10KGys
  - RFID + optional chargeable power supply
  - On board sensors – shock, humidity, temperature, pH etc
  - Tracking, condition monitoring with data integrity

3) Rescue circuits

- Boot memory
- Sensor calibration data
- Power control circuits
- Autonomous robot or drone emergency return circuitry



Implementation

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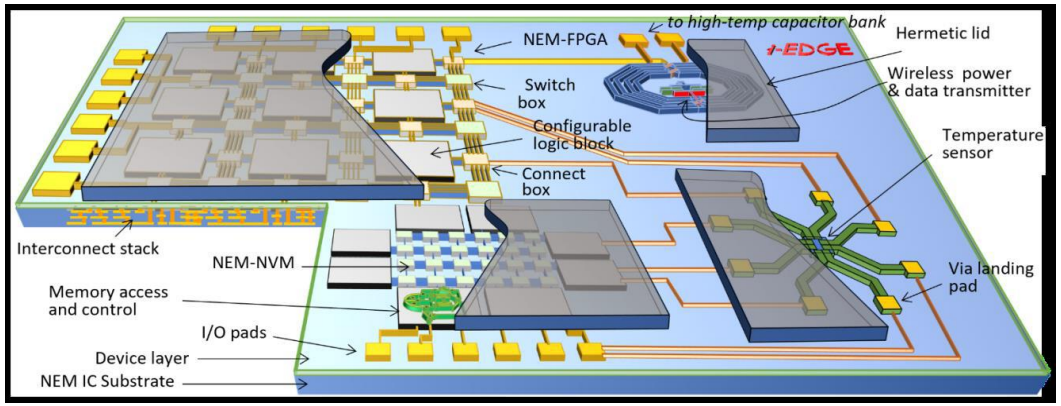
Platform device requirements

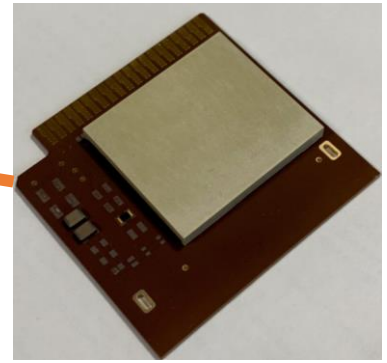
- Communication
  - Mechanical: Socket / edge connector
  - RF: RFID or Near Field
  - Use of Si diode rectification?
- Memory
- Sensors
  - Internal temperature sensor
  - External sensor port
- Compute
- Temperature
  - 250 °C polymer package
  - 325 °C ceramic package
- Radiation – TID?
- Measurement duty cycle –
  - how many times can we take a measurement / time before replacement
  - Can this product be disposable?
- Real world implementation - device design topology / packaging



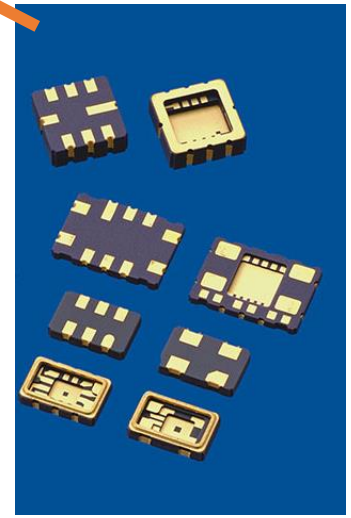
Packaging options

a) Plastic packaging

b) Plastic packaging



c) Ceramic packaging

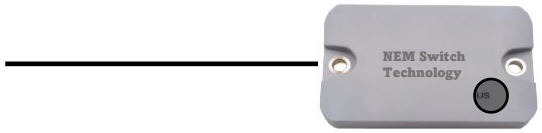


- Previous plastic packaging tests
  - Packages a) and b) survived 250C and thermal cycling -20 to 250C
  - Lower cost option

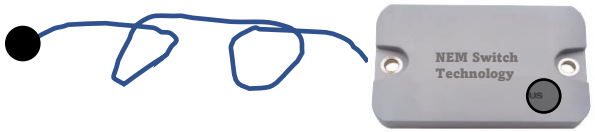
- Ceramic packaging
  - Venus lander packaging is using ceramic and surviving 465C
  - Previous evaluations have shown capability at 250C
  - 325C will be our test condition in ZeroAMP
  - Higher cost option

Packaging options – sensor configurations

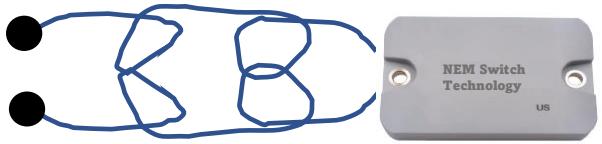
1 sensor in package sensor tag
- Temperature recorder to 250-300C (or radiation levels)



2 sensor tag: in package and rigid probe
- Probe for cooking meat



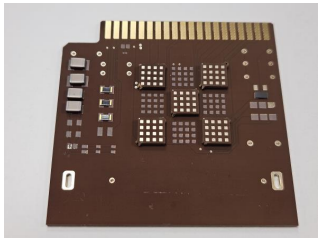
2 sensor tag: in package and end of wire sensor variants
- magnet sensor:- industrial
- needle probe: -baking cakes, bread,



2 sensor tag: both external

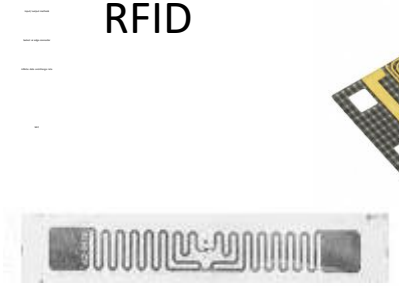
Communication and power input options

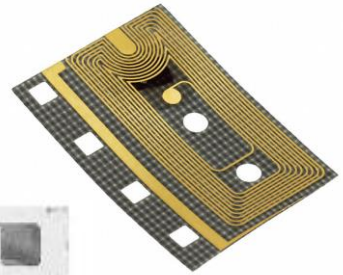
Connector

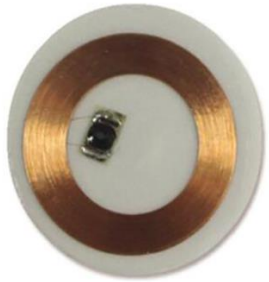


Near Field

RFID



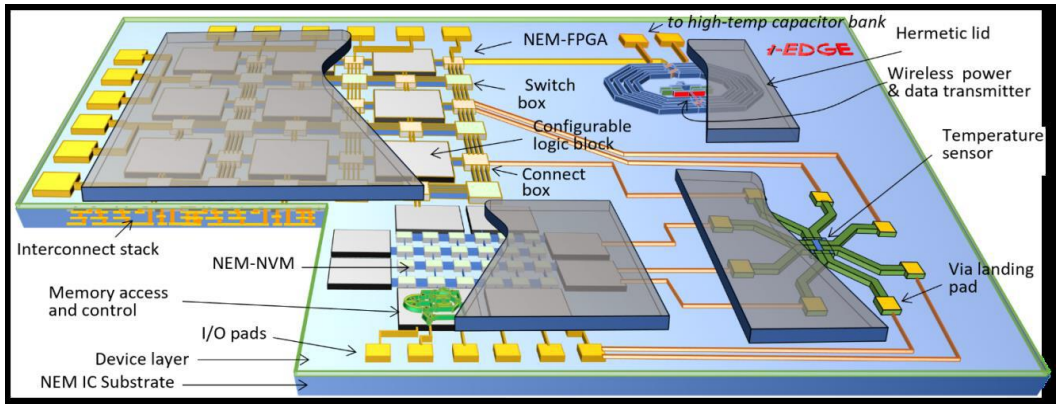




	Current	Volts	Range	Comments
Connector	1A	30V	0	Only enables post operation data down loads, most unreliable option
Near field	100uA	3.5V	1cm	More reliable than a socket, could charge a power bank, range too short for real time oven temperature readings
RFID	1uA	1V	1m	Realtime read out whilst receiving the RF field

Device(s) in our next NEM switch wafer run

- Do we develop a single multi-purpose die
  - A measurement platform?
  - Addressing many applications



- do we add standalone individual components?
  - Non-Volatile Memory (NVM)
  - Analogue to Digital Converters (ADC)
  - Power regulation

Device(s) in our next NEM switch wafer run?

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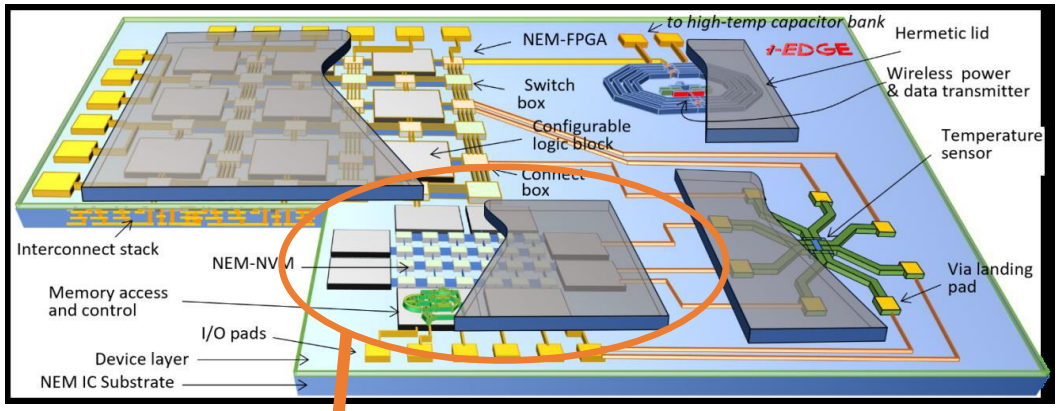

- And / or do we have standalone individual components?
  - Non-Volatile Memory (NVM)
  - Analogue to Digital Converters (ADC)
  - Power regulation

- ….Which choice makes sense in a future business plan?

END

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Registrations

- https://docs.google.com/spreadsheets/d/1WVlqTIuvFgIVCeSvtkuDaLF5Hdf-0ps3QRya3XgDHCc/edit?usp=sharing

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What to expect at the first webinar of the i-EDGE project:

1. Learn about our harsh environment low power sensor/actuator IC platform using "NEM switch technology"
   » Review our plans to package it into "i-Edge" rugged device for a broad range of applications
2. Critique our target specifications
   » Temp. (<325 °C); rad. hard (>1 MRad); device shape and size: onboard sensors, external probes
3. Influence the functional circuit blocks to be included in our next wafer run
   » RF comms, memory, computation, algorithms, sensors, interfaces, actuation
4. Find out about participating in our Business Interest Group (BIG) for:
   » Early samples, influencing platform development, regular updates

Programme of the webinar

All times are in CEST

11:00 The i-EDGE platform project and our innovative NEM switch technology
Dr. Dinesh Pamunuwa (Professor, University of Bristol)

11:20 Plans for device realisation and expected applications
Piers Tremlett (Advanced Packaging Engineer, Microchip Technology Caldicot Ltd.)

11:40 Interactive review of: presentations; platform device requirements; functionality options in (or out of) our next NEM switch wafer run

12:40 Meeting wrap up and explanation of the benefits of being a member of our BIG
Dr. Jens Bolten (i-EDGE Coordinator, workshop moderator, AMO GmbH)

13:00 End of the workshop

Discussion topics / sessions

- 1) Discussion of applications
  - Presented
  - Any further proposals by attendees?

- 2) Platform functionality segments, capability and specifications

- 3) Real world implementation - device design topology / packaging