

ENTS: Experiences in Co-Designed Environmental Sensing

2026 SenSys

Successful Wireless Sensor Networks (WSNs)



ZebraNet

Successful Wireless Sensor Networks (WSNs)

Collaboration with biologists



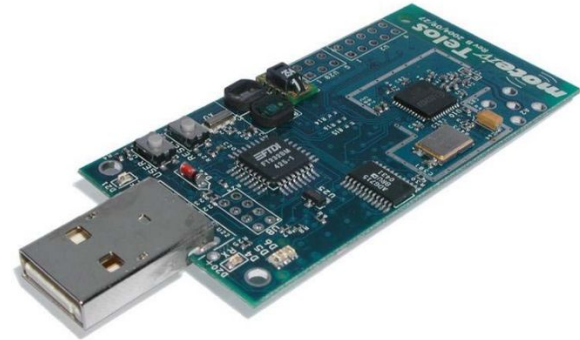
ZebraNet

Successful Wireless Sensor Networks (WSNs)

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ZebraNet



Telos

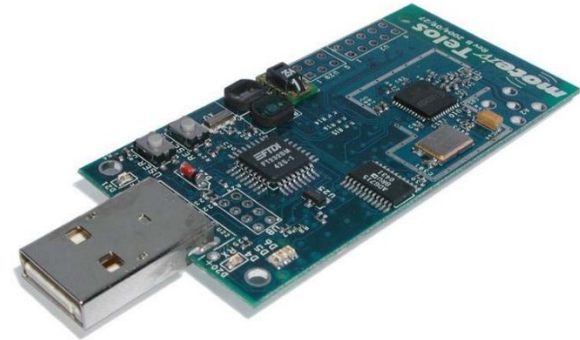
Successful Wireless Sensor Networks (WSNs)

Collaboration with biologists



ZebraNet

Easy to use, *extensible*



Telos

Other WSNs

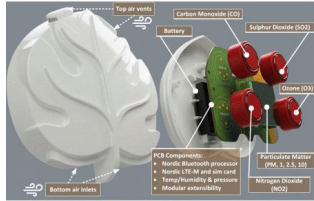


Pible

Other WSNs



Pible

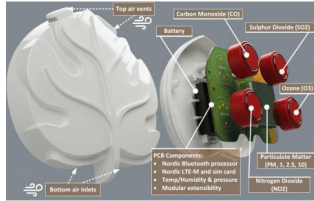


Eclipse

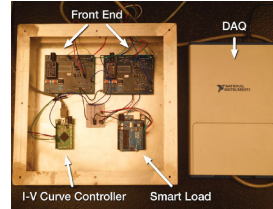
Other WSNs



Pible



Eclipse

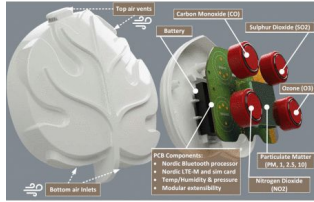


Ekho

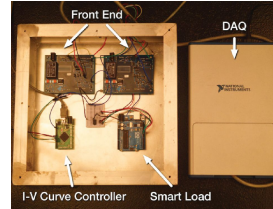
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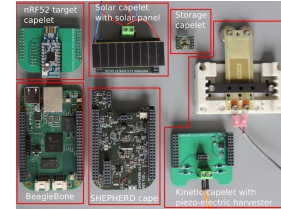
Pible



Eclipse



Ekho

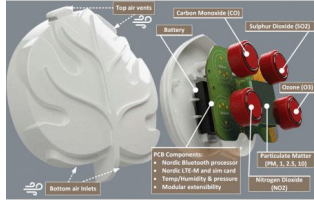


Shepherd

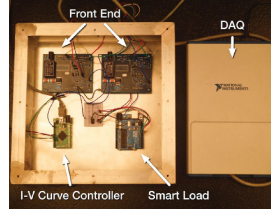
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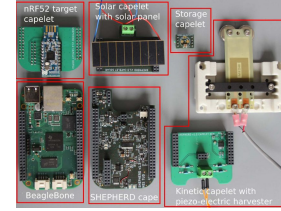
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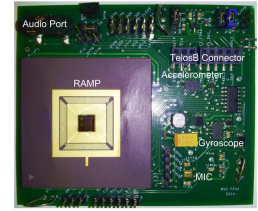
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Ekho



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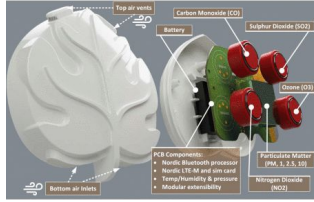


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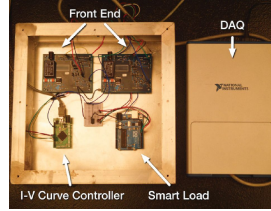
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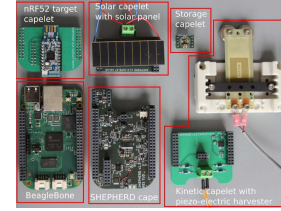
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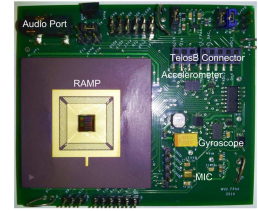
Eclipse



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Shepherd



RAMP

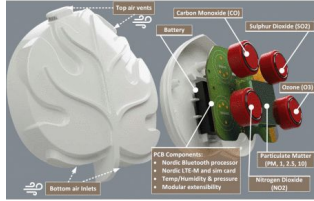


Signpost

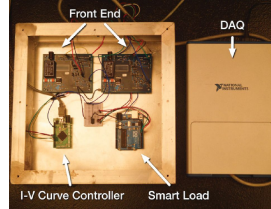
Other WSNs



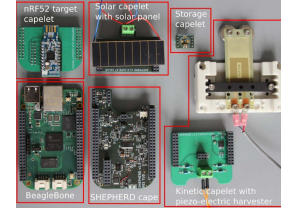
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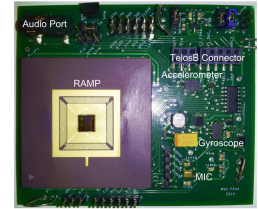
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Ekho



Shepherd



RAMP



Signpost

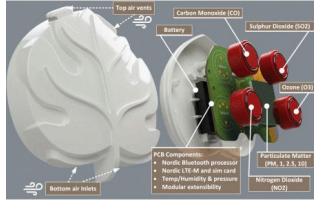


Firestorm

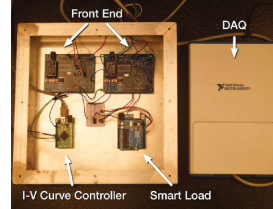
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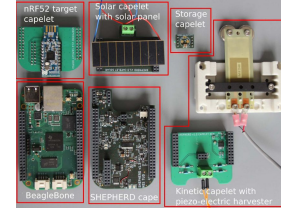
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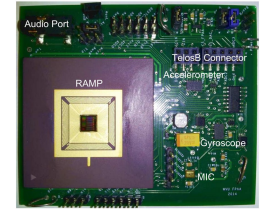
Eclipse



Ekho



Shepherd



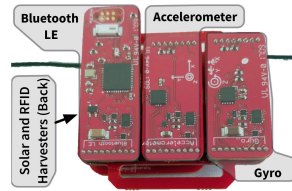
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Signpost



Firestorm

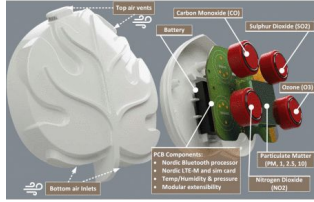


Flicker

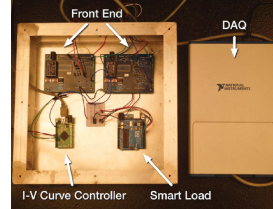
Other WSNs



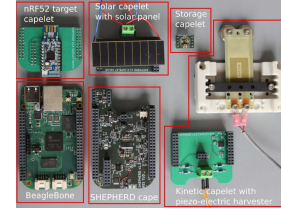
Pible



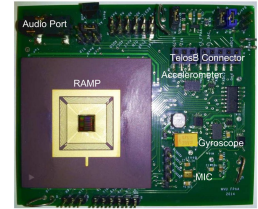
Eclipse



Ekho



Shepherd



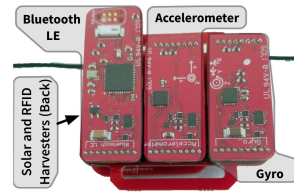
RAMP



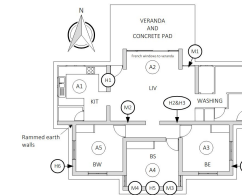
Signpost



Firestorm



Flicker

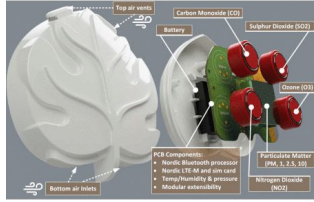


BuildSense

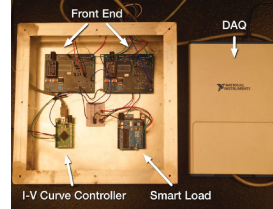
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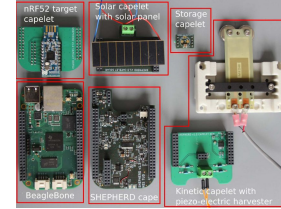
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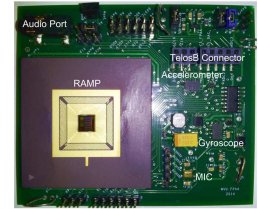
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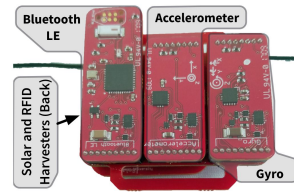
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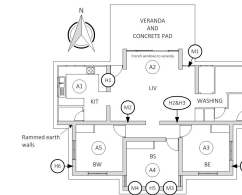
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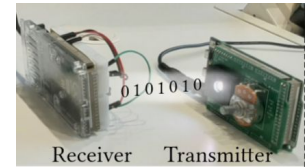
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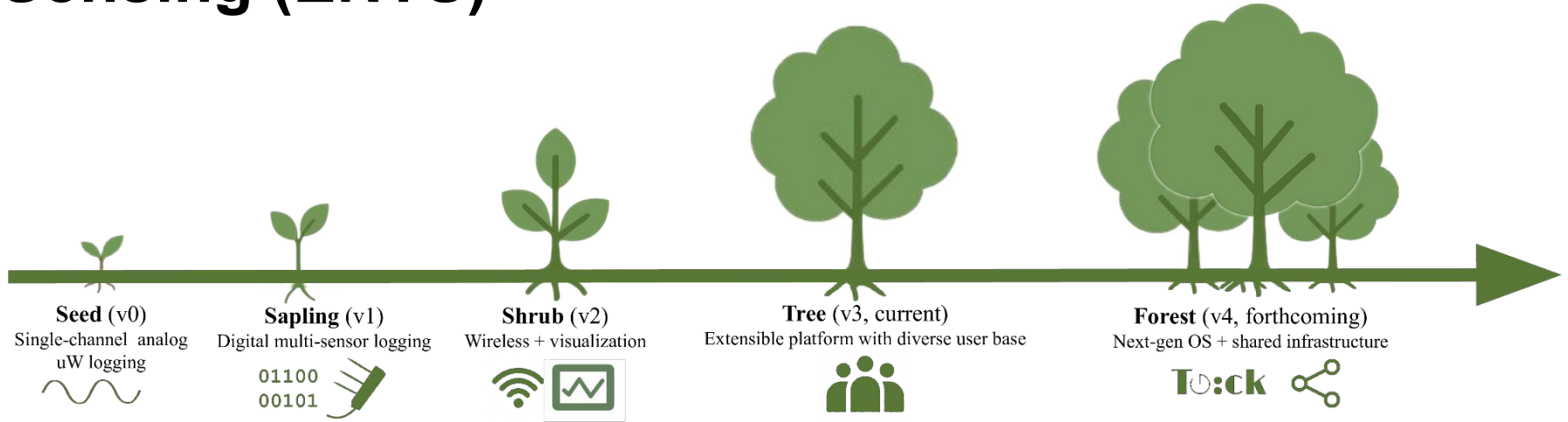


BuildSense

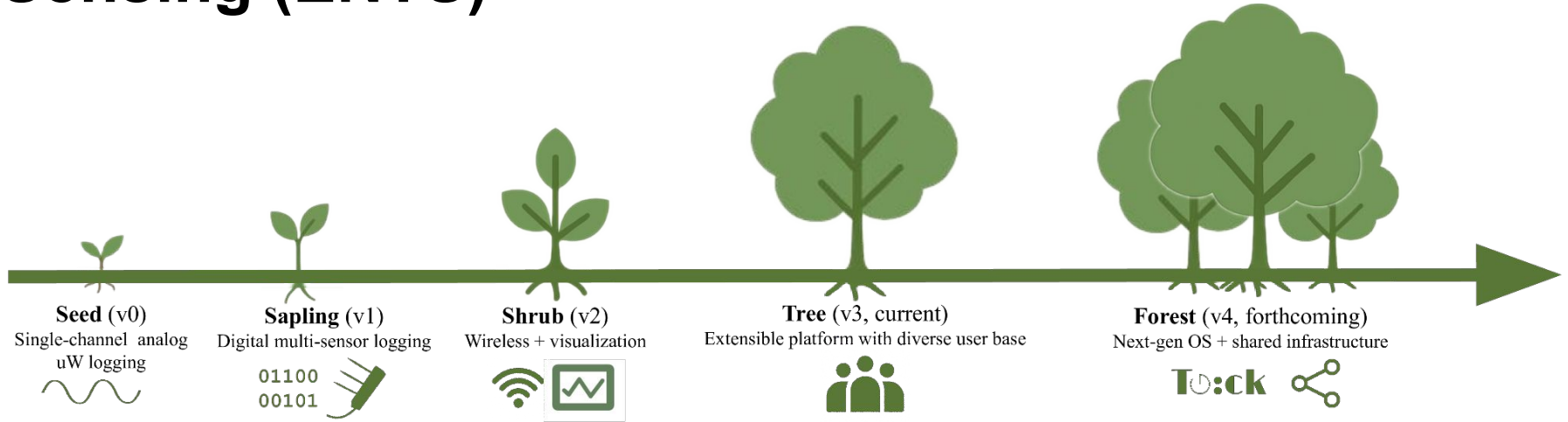


T-light

Environmental NeTworked Sensing (ENTS)



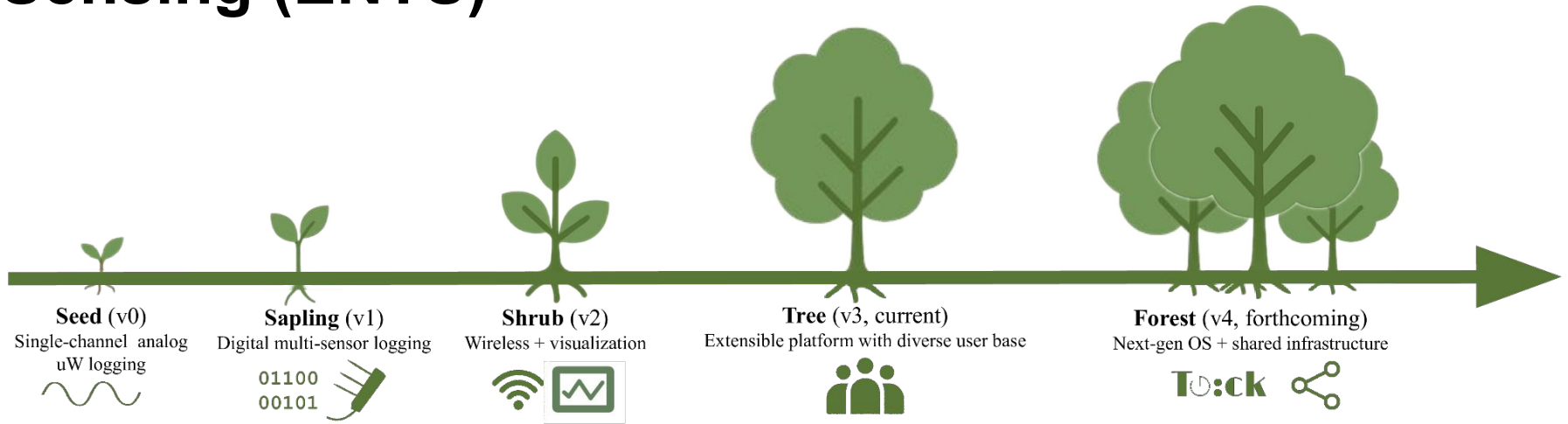
Environmental NeTworked Sensing (ENTS)



Design principles:

1 Design for breadth

Environmental NeTworked Sensing (ENTS)

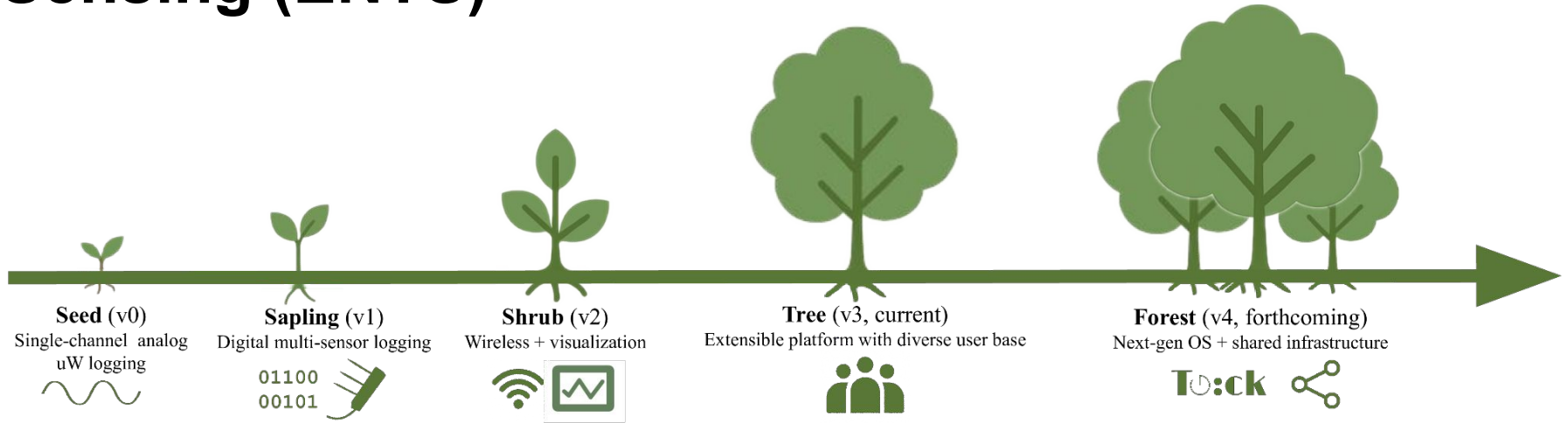


Design principles:

1 Design for breadth

2 Extensibility

Environmental NeTworked Sensing (ENTS)



Design principles:

1 Design for breadth

2 Extensibility

3 Co-design and outreach

Applications



Large scale dataset collection of SMFCs

4 universities, 72 cells, year long experiment



Applications



Large scale dataset collection of SMFCs

4 universities, 72 cells, multiple months of data

Biomimetic leaf wetness sensor

Researching disease mitigation in agriculture



Applications



Large scale dataset collection of SMFCs

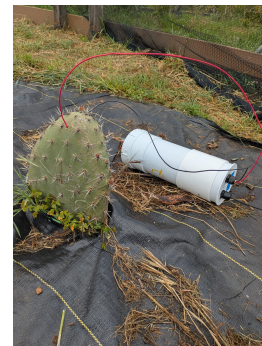
4 universities, 72 cells, multiple months of data

Biomimetic leaf wetness sensor

Researching disease mitigation in agriculture

Power output from prickly pear cacti

Enabled field deployments with wireless data collection



Applications



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Demonstration irrigation site

Application showcasing extensibility



Applications



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Application showcasing extensibility

Open Source Community

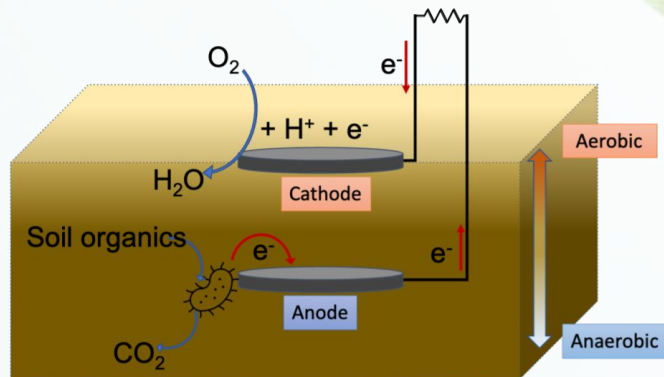
Facilitate continued growth of the platform



Metric	Hardware	Firmware	Visualization
Internal Contributors	6	7	10
External Contributors	0	2	5
Commits	404	1259	1158
Forks	0	4	18



Use case: μW level power measurements



Power generation from soil

Seed (v0)

Sapling (v1)

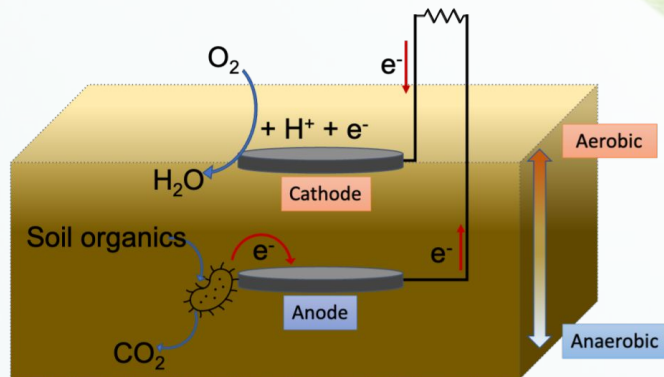
Shrub (v2)

Tree (v3)

Forest (v4)



Use case: μW level power measurements



Keithley DAQ6510

Power generation from soil

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Sapling (v1)

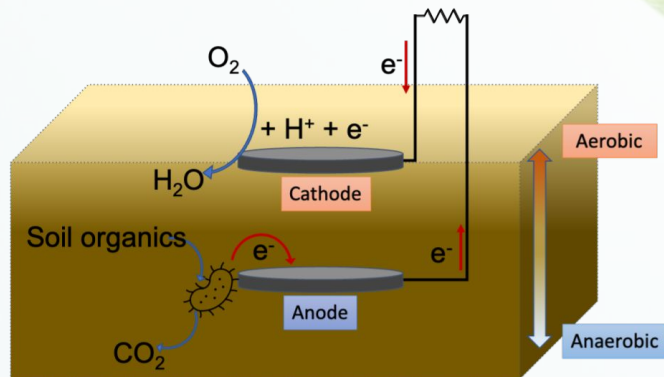
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Use case: μW level power measurements



Power generation from soil



Keithley DAQ6510



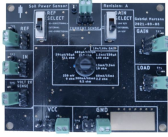
Seed (v0)

Sapling (v1)

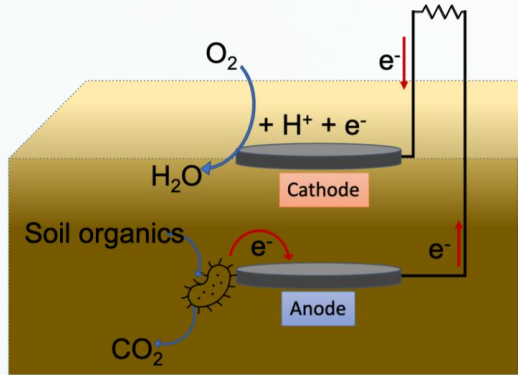
Shrub (v2)

Tree (v3)

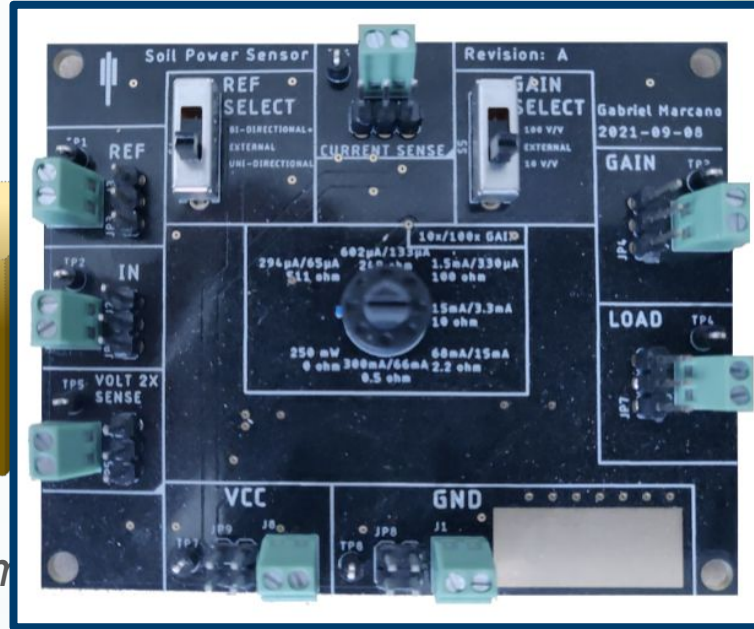
Forest (v4)



Use case: μW level power measurements



Power generation from



Seed (v0)

Sapling (v1)

Shrub (v2)

Tree (v3)

Forest (v4)



Use case: μW level power measurements

Takeaway: Start by being good at one thing

Power generation from soil

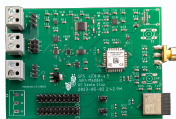
Seed (v0)

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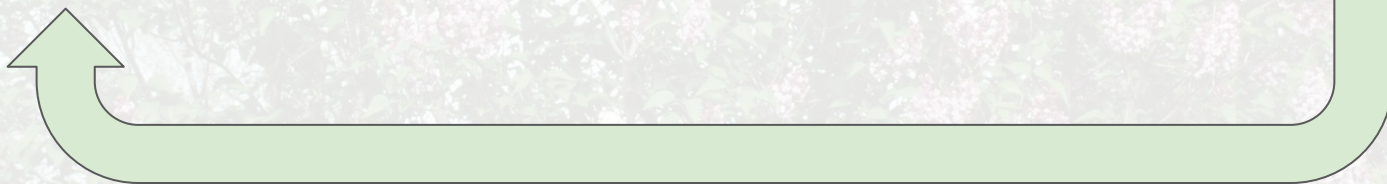
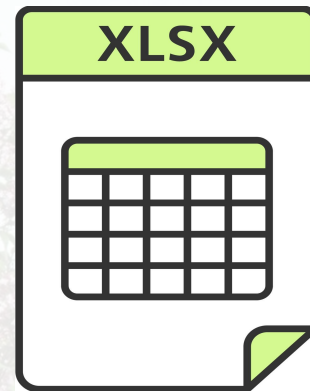
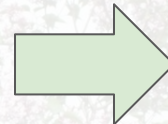
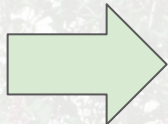
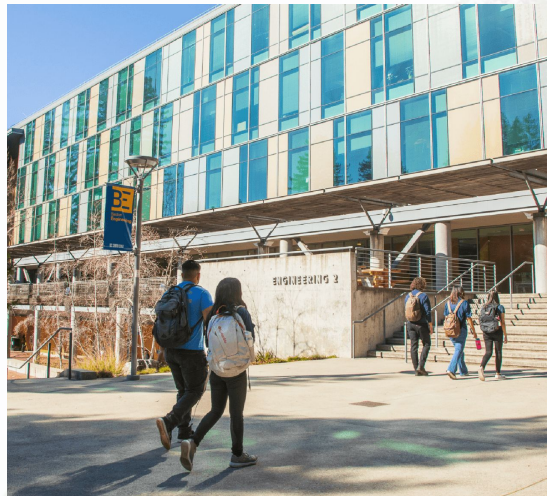
Shrub (v2)

Tree (v3)

Forest (v4)



Problem: Hand collected data is slow



Seed (v0)

Sapling (v1)

Shrub (v2)

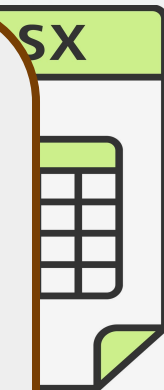
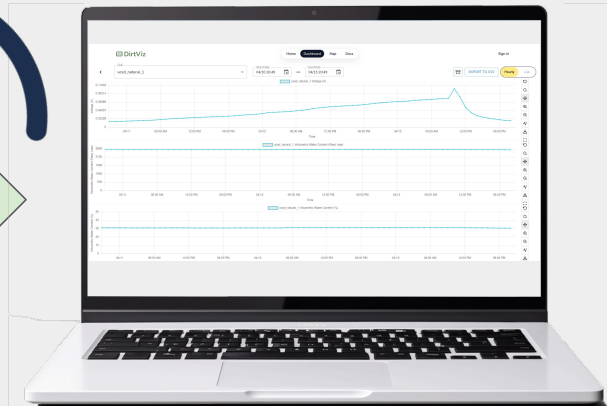
Tree (v3)

Forest (v4)





Goal: Enable wireless data collection



Seed (v0)

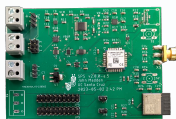
Sapling (v1)

Shrub (v2)

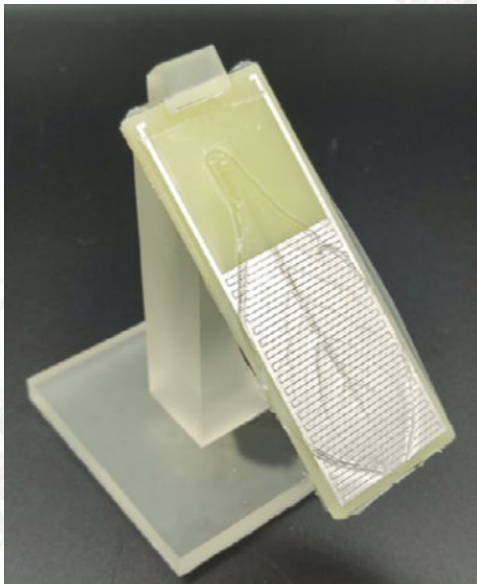
Tree (v3)

Forest (v4)





Use case: Biomimetic leaf wetness sensor



[1] B. H. Nguyen, G. S. Gilbert, and M. Rolandi, "A Bio-Mimetic Leaf Wetness Sensor from Replica Molding of Leaves," *Advanced Sensor Research*, vol. 2, no. 6, p. 2200033, Jun. 2023, doi: [10.1002/adrs.202200033](https://doi.org/10.1002/adrs.202200033).

Seed (v0)

Sapling (v1)

Shrub (v2)

Tree (v3)

Forest (v4)



Use case: Biomimetic leaf wetness sensor

Takeaway: Extensibility drives a platform's longevity.

[1] B. H. Nguyen, G. S. Gilbert, and M. Rolandi, "A Bio-Mimetic Leaf Wetness Sensor from Replica Molding of Leaves," *Advanced Sensor Research*, vol. 2, no. 6, p. 2200033, Jun. 2023, doi: [10.1002/adrs.202200033](https://doi.org/10.1002/adrs.202200033).

Seed (v0)

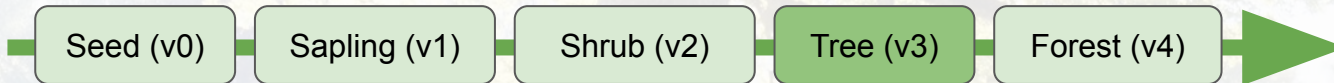
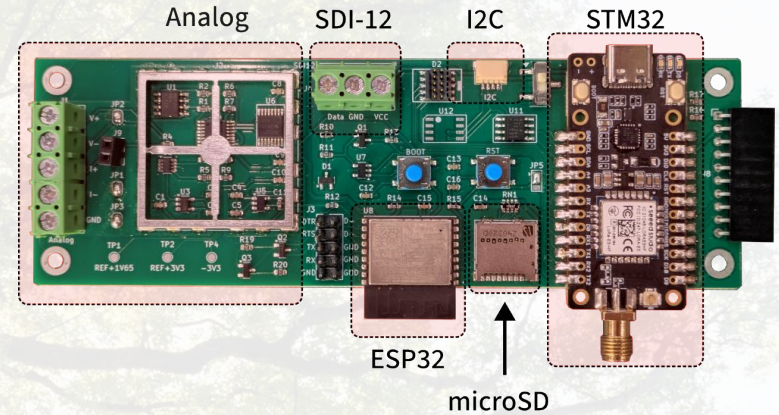
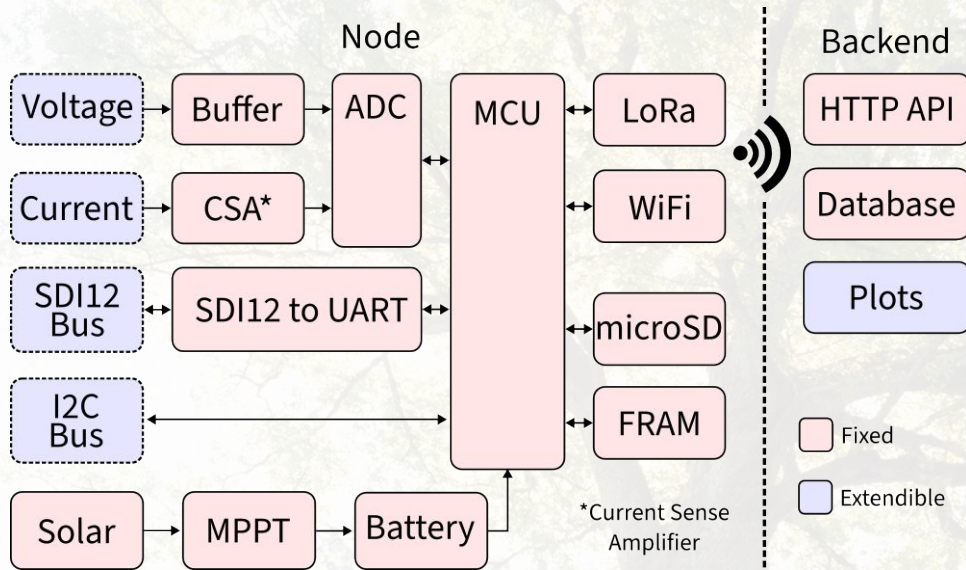
Sapling (v1)

Shrub (v2)

Tree (v3)

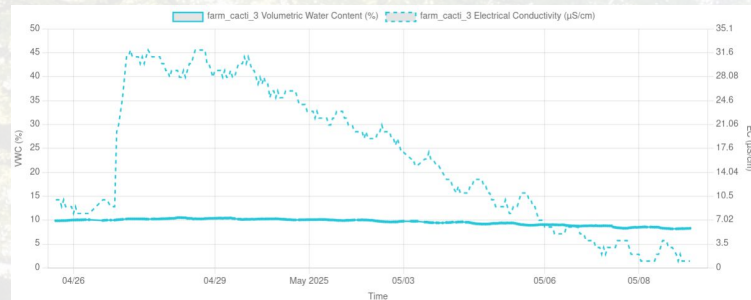
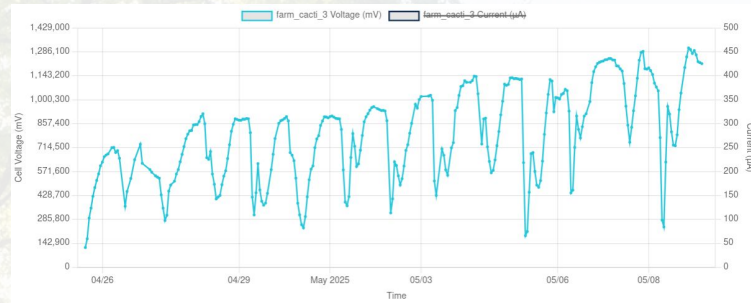
Forest (v4)

Observation: Need for field logging platform





Use case: Energy harvesting from cacti



Seed (v0)

Sapling (v1)

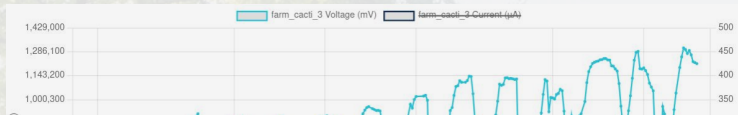
Shrub (v2)

Tree (v3)

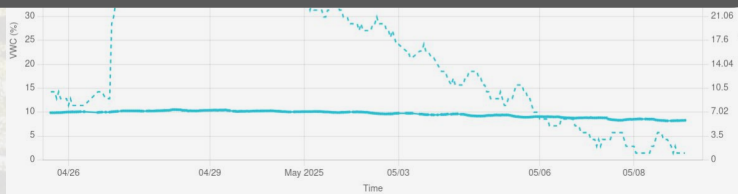
Forest (v4)



Use case: Energy harvesting from cacti



Takeaway: Co-design drives development



Seed (v0)

Sapling (v1)

Shrub (v2)

Tree (v3)

Forest (v4)



UC SANTA CRUZ

36

ENTS bears fruit: Reasons for success



Open source ecosystem

Contributions from: GSOC, undergradutes, external collaborators.

Metric	Hardware	Firmware	Visualization
Internal Contributors	6	7	10
External Contributors	0	2	5
Commits	404	1259	1158
Forks	0	4	18

ENTS bears fruit: Reasons for success



Open source ecosystem

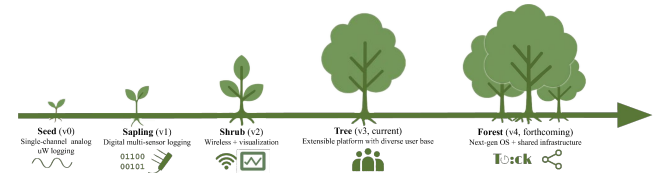
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Design for extensibility

Allowed the project to adapt to various needs over time.

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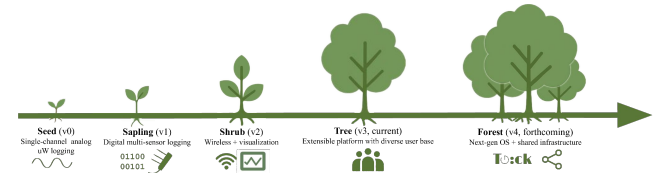
Allowed the project to adapt to various needs over time.



Domain science partnerships

Informed development efforts and engineering decisions.

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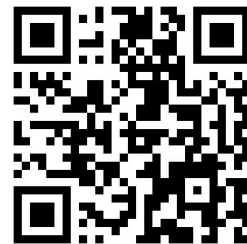


Where to find us

- Josephson Lab Website
<https://sensors.soe.ucsc.edu/>
- John Madden (Me)
<https://www.jmadden173.com/>
- Stephen Taylor (Co-author)
<https://stevegtaylor.github.io/>
- Live Data
<https://dirtviz.jlab.ucsc.edu/>



Project Repos



Paper Link

