

Grab an attendance sheet



Lecture 3

February 10, 2026

We are going to use screens today

This week

- EX02
 - Peer review of sensor board schematics – **due this Thu!**
 - Sensor board PCB layout
 - Buck converter schematic design and related problem
 - BMS design – so you can charge your battery!
 - Plotly
- Lab 2
 - Start on project!
 - We will do part of this today!
- Not everyone has signed up for Piazza...It's our main communication channel from now on



It's a busy week!

Some thoughts on week 1

This class has lots of moving parts: HW, FW, SW, server, etc.

Some issues can take a while to debug

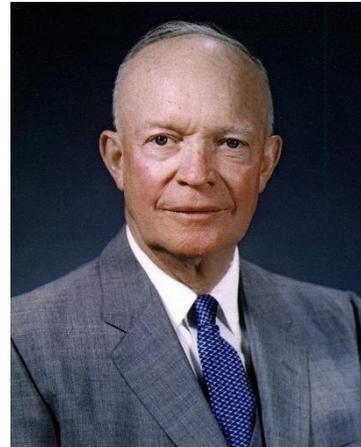
Don't wait until the last minute to get started on stuff

TODAY

- The HW/SW product development process *with a focus on engineering design*
- With some team activities thrown in the mix

“In preparing for battle I have always found that plans are useless, but planning is indispensable”

--Dwight D. Eisenhower



MITOS Personal Heat Monitor

* → ***: level of importance

1. It should accurately measure the exterior air temperature and humidity as a person walks around, with dynamics appropriate for the use case.***
2. It should measure sun exposure as a person walks around, with dynamics appropriate for the use case.*
3. It should be very small, portable, and able to be easily affixed to a backpack or similar object so a person can walk around with it without too much trouble.***
4. It should report faults, such as battery failure, mechanical destruction, etc.**
5. It should be as inexpensive as possible, with a COGS of no more than 20USD.***
6. The electronics should be able to be fabricated and assembled by JLCPCB.***
7. Environmental data from each sensor node should connect to the location at which the data is obtained as the person walks around.***
8. It should maintain privacy.***
9. It should operate with a battery lifetime of 3 mo or at least 24+ between recharging.***
10. It should be rugged and able to withstand a summertime Boston-area environment (heat, rain) and typical jostling during transit.***
11. Transit environmental data should be able to be connected to spot measurements of the person's body temperature.**
12. Multiple systems should be able to be used simultaneously.***
13. The system should present the information on a dashboard in real-time or near real-time, and also allow downloading of raw data.***

City of Cambridge Bike Lane Monitor

1. It should measure bicycle volume (number and direction, velocity is less critical) across a variety of Cambridge separated bike paths.***
2. It should operate without being connected to line voltage.***
3. It should be installable by a technician, and should be easy to set up without requiring alteration to the roadway.***
4. It should report faults, such as battery failure, falling, vandalism, etc.**
5. It should be as inexpensive as possible, with no or minimal on-going cost. **
6. It should operate ideally at all times, but at minimum during the hours 6am to 1am.***
7. It should communicate data wirelessly, ideally in real time.**
8. Data from a sensor node should be able to be tied to a location.***
9. It should not identify individuals.***
10. It should operate independently without user intervention or servicing for at least one year.**
11. It should be rugged and able to withstand operation across typical Cambridge weather.***
12. Multiple systems should be able to be used simultaneously.***
13. The system should present information to the end-user in a useful way. *

* → ***: level of importance

Hoyt Field Occupancy Monitor

1. It should measure the number of people inside the park, in priority order of Basketball courts, Baseball Field, Tennis Courts, Playground, and Park entrances.***
2. It should operate without being connected to line voltage.***
3. It should be installable by a technician, and should be easy to set up without requiring alteration to the park structures.***
4. It should report faults, such as battery failure, falling, vandalism, etc.**
5. It should be as inexpensive as possible, with no or minimal on-going cost. **
6. It should operate between dawn and dusk, and ideally 2 h on either side of those times.***
7. It should communicate data wirelessly throughout the operating hours.**
8. Data from a sensor node should be able to be tied to a location.***
9. It should not obtain any personal identifiable information.***
10. It should operate independently without user intervention or servicing for at least 6 months in that environment.**
11. It should be rugged and able to withstand operation across typical Cambridge weather.***
12. Multiple systems should be able to be used simultaneously.***
13. The system should present the information on a dashboard and also allow downloading of raw data in csv format.***

* → ***: level of importance

Hoyt Field Weather Monitor

* → ***: level of importance

1. It should measure the local weather, at least temperature, humidity and sun exposure, and ideally also ground surface temperature, all with dynamics appropriate for the use case.***
2. The priority order for weather monitoring are the Basketball courts, Baseball Field, Tennis Courts, and Playground. Within these locations, we prioritize areas exposed to sun.***
3. It should operate without being connected to line voltage.***
4. It should be installable by a technician, and should be easy to set up without requiring alteration to the park structures.***
5. It should report faults, such as battery failure, falling, vandalism, etc.**
6. It should be as inexpensive as possible.***
7. It should be as small as possible, with no or minimal on-going cost. **
8. Data from a sensor node should be able to be tied to a location.***
9. It should not obtain any personal identifiable information.***
10. It should operate independently without user intervention or servicing for at least 6 months in that environment.**
11. It should be rugged and able to withstand operation across typical Cambridge weather. ***
12. Multiple systems should be able to be used simultaneously. ***
13. The system should present the information on a dashboard and also allow downloading of raw data in csv format.***
14. It should engage the community.**

Teams

- Sent out yesterday on Piazza
- We may need to adjust over the next week or so
- Teams are not competitors – develop independent designs but collaborate on key pain points

Teams

MIT Office of Sustainability Weather Monitor

- **Team 1**
Mentor: Paige
Meeting Time: W10-11 (location TBD)

- **Team 2**
Mentor: Joel
Meeting Time: W4-5 (location TBD)

City of Cambridge Bike Lane Monitor

- **Team 3**
Mentor: Hasan
Meeting Time: W12-1 (location TBD)

- **Team 4**
Mentor: Joe
Meeting Time: T3-4 (location TBD)



City of Cambridge Hoyt Field Occupancy Monitor

- **Team 5**
Mentor: Joel
Meeting Time: W2:30-3:30 (location TBD)

- **Team 6**
Mentor: Paige
Meeting Time: Th2:30-3:30 (location TBD)

City of Cambridge Hoyt Field Weather Monitor

- **Team 7**
Mentor: Hasan
Meeting Time: M12-1 [note first meeting will be rescheduled] (location TBD)

- **Team 8**
Mentor: Joe
Meeting Time: T4-5 (location TBD)

Teams

- You will meet with your mentor each week for an hr
...including this week
- All team members need to attend these meetings
- Starting next week, these meetings will include going over milestones and deliverables
- Our first review is the week of Feb 23

Success on this project will require the team to start work *right away*

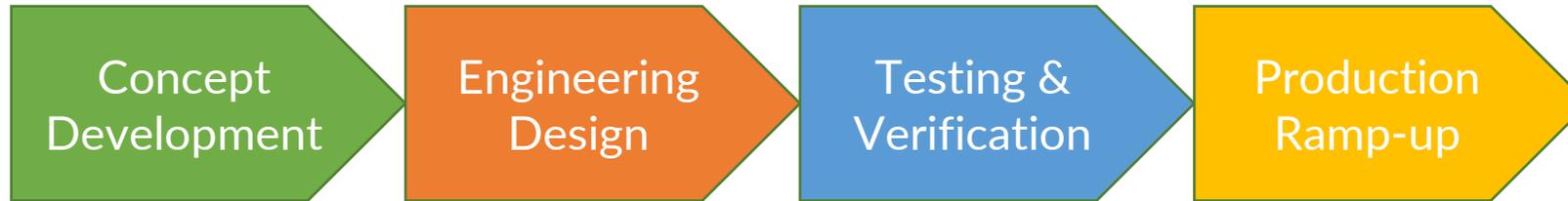
Team activity [10 min]

- Go find your team
- Open up lab02 and work through the first set of activities



Product development process

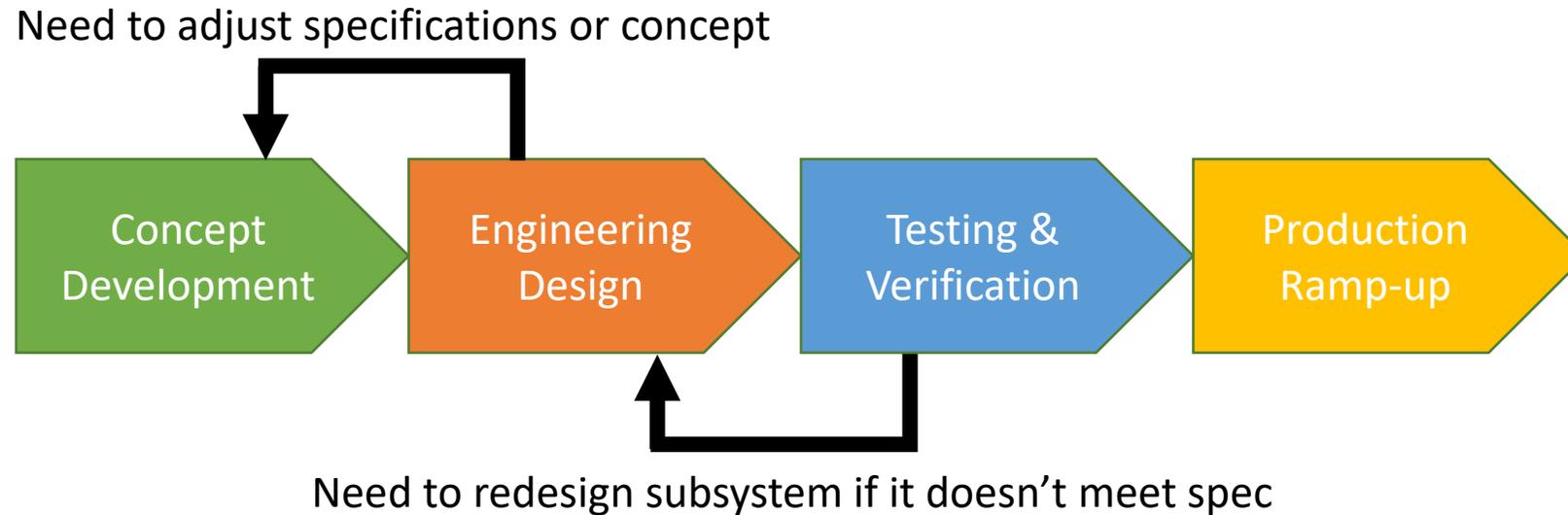
- Many different specific processes, terminology, number of steps, and so on, but generally



- **Concept development:** identify requirements, establish target specifications, generate concepts, refine and select most promising concept
- **Engineering design:** develop product's system-level architecture, partition into subsystems, design subsystems, prototype subsystems, integrate back into system
- **Testing & verification:** Evaluate the subsystems and complete system, verifying that it meets spec
- **Production ramp-up:** Transfer to manufacturing, verify quality, ramp up production, commercialization

Product development process

- This process is not linear...iteration will be necessary



- Farther to the right → more \$\$\$
- So the more you can figure out early on...the better

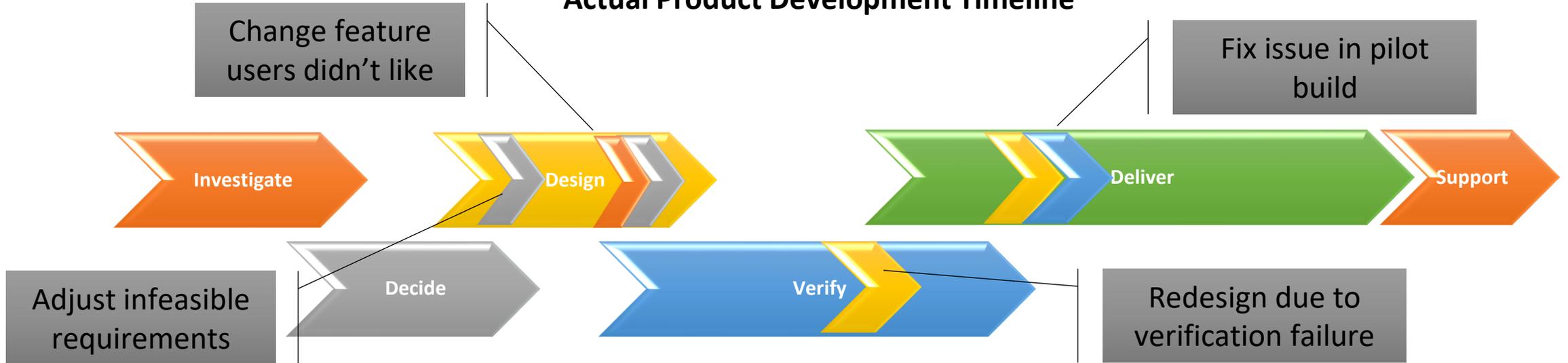
Product development process

- Here is Milwaukee Tool's product development process

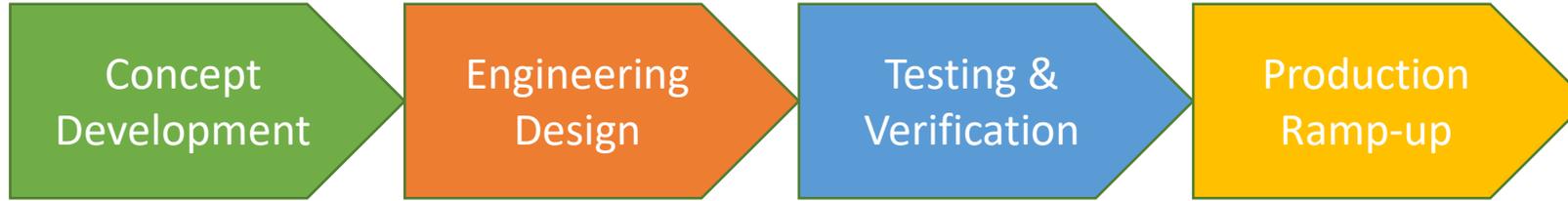
Ideal Product Development Plan



Actual Product Development Timeline



Concept development



- Concept development: identify requirements, establish target specifications, generate concepts, prototyping (as needed), refine and select most promising concept
- Requirements [needs]
 - Focus on **what** the system should do, rather than **how** to do it
- Identify requirements: who's requirements? → stakeholders' requirements
- Stakeholders: the people affected by your product
 - Customer, end-user ← these often most important
 - But also retailer, employee, installer, etc.
- Stakeholders can have conflicting needs!

Stakeholders

Customers are not always end-users...



Customer

Stakeholder

ICU monitor

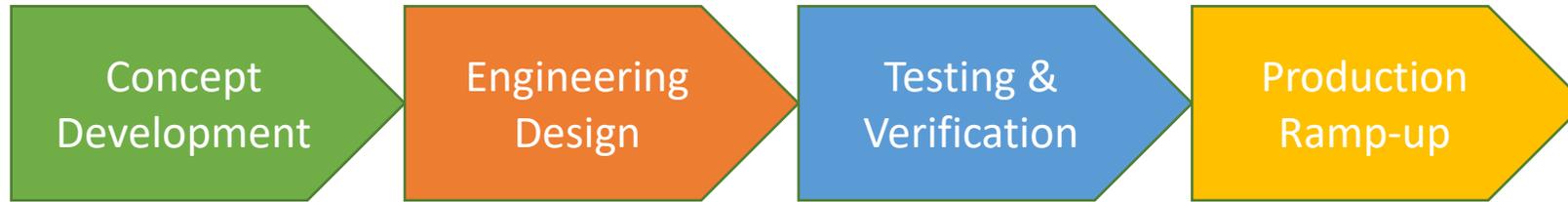


End-user

Team activity [5 min]

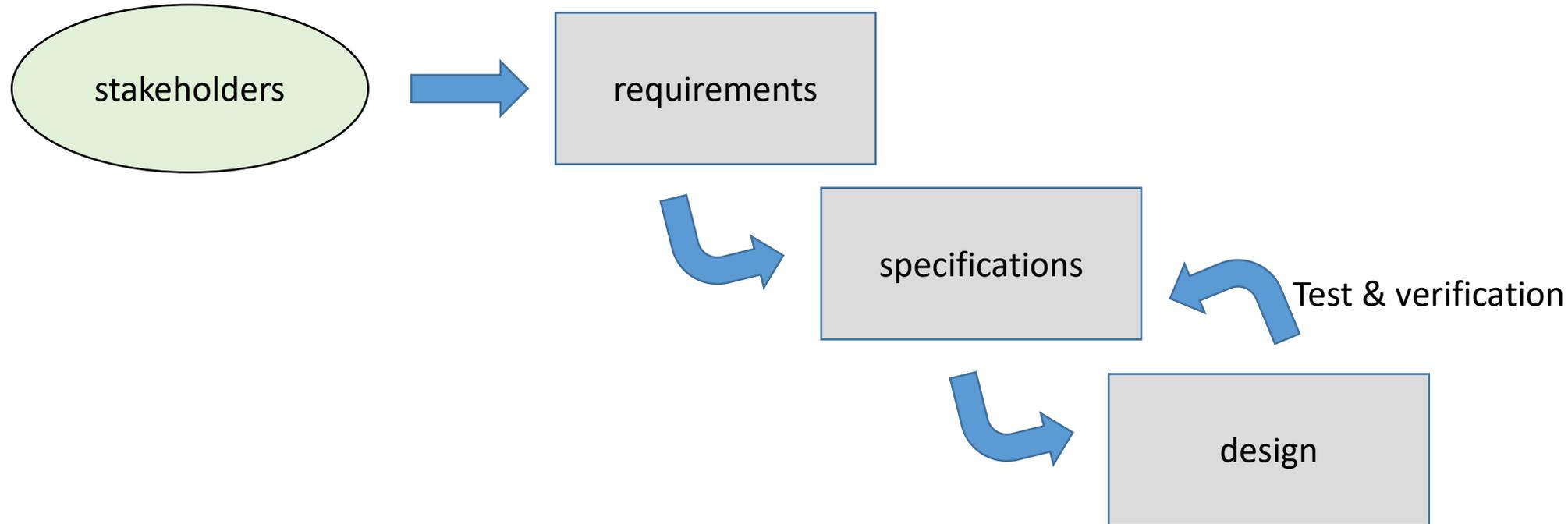
- Who are the stakeholders for your semester projects?
- For each stakeholder, list at least one requirement that they care about

Now what?



- We iterate between settings specs, developing concepts, prototyping, doing design, and developing a testing plan
- Not everything will necessarily be defined yet (and thus able to be concretely specified)
 - This may not be ok for some products (aerospace, medical)
 - But is often the case for consumer, etc. → Iteration can be important

Requirements, specs, and so on



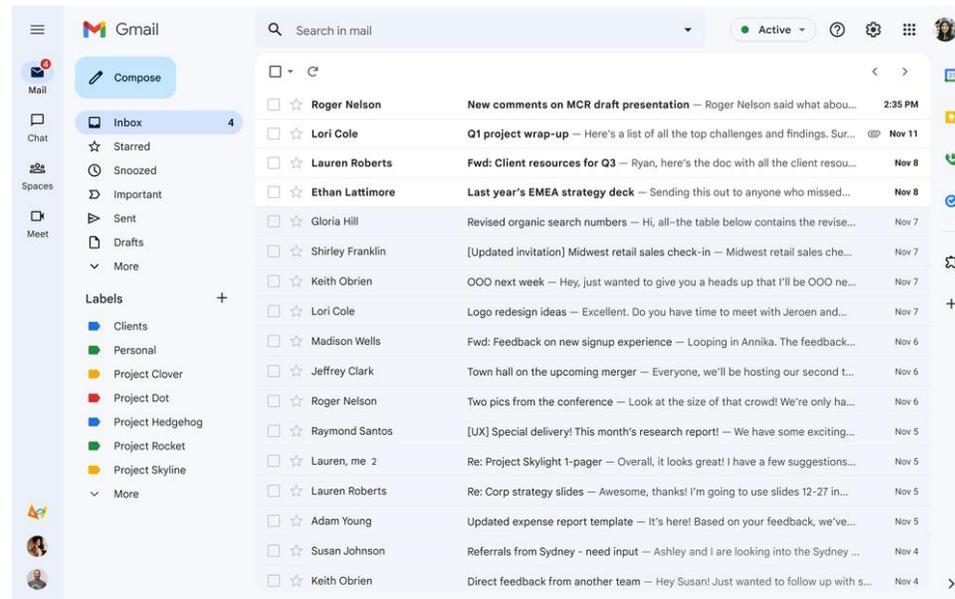
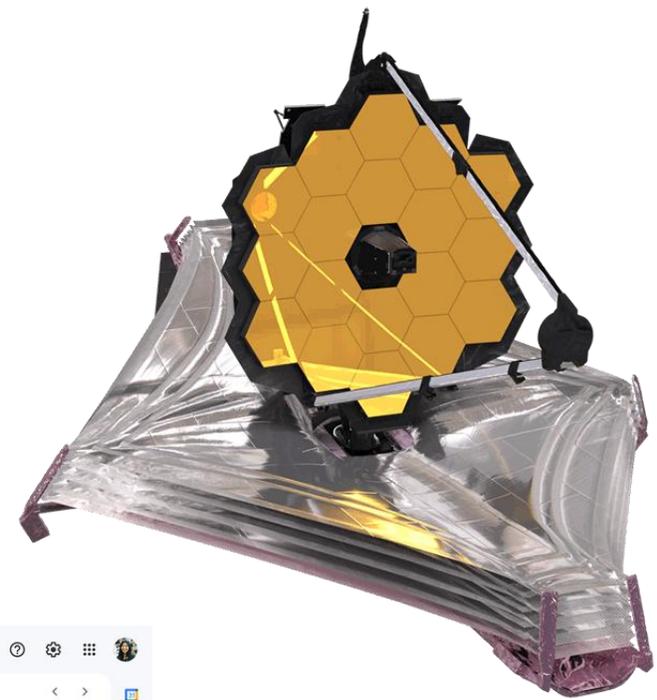
Done well, a design that passes all the tests will meet the specifications and thus the requirements, making the stakeholders happy

Specifications

- Translate requirements into a specification document
 - Covers both HW and SW aspects
 - The goal is to have constraints for our system → *engineering is design under constraints*
 - If our specs are complete, and if we build something that meets spec, then it will meet our requirements
 - Some specifications will directly imply a specific approach
 - The need for interoperability with another product (that has WiFi) may immediately specify WiFi
 - The company may impose use of MySQL dB or STM32 MCU because that's what's used by the rest of the company
 - Sometimes specifications will be much more open-ended
 - An opportunity for creativity & innovation!

Specifications

- What aspects do we need to specify?
 - There is no all-encompassing approach
 - These three products are all specified differently



Common specifications for HW/SW products

- Financial
 - BOM, COGS, etc.
 - Time to market
- Regulatory – safety, emissions*
 - Anything with a radio, plugged into wall, etc.
 - For medical (and other regulated sectors) this can be quite extensive
- Industrial design & environmental
 - What does it look like, what materials are used, how does it interact with the user, etc.
 - Is it used indoors? In salt water? In an auto engine? On Mars?
 - IP [Ingress Protection] rating
- Engineering
 - Sensing, actuation, compute, comms, firmware, software, etc.
- Security & Privacy
 - Typically, user data is being communicated...what data? how is it being secured? who has access?
 - There may be regulatory requirements here as well: HIPAA
- Packaging*
 - How is sent to the customer, could be simple/elaborate
- Installation, provisioning, and servicing
 - How does one go from “in the box” to “in use”?
 - Will it be serviced in the field? Will the SW be updated? Can the HW be fixed? Warranty?

These are not disjoint:

Needing to be updated after install: is that installation or engineering?

All that matters is that it's *somewhere* in document

*We will ignore for our project

Ultimately, the specification document should encompass all requirements

Don't get hung up if you don't know all of the specs at the beginning

The two most important points:

- 1. Have a plan:** Work hard to plan ahead...and adjust the plan as needed
- 2. Write stuff down:** Your team should use your **single** specifications document – a common understanding

Writing a good spec

What makes a good specification? No single approach for all of HW & SW

- It might be a well-defined metric and value (or range of values)
 - Example: BOM \leq \$100
 - Example: Measurement interval \leq 10 min
- It could be qualitative
 - Example: HTTP GET/POST for server comms
- It could directly imply a particular implementation
 - Example: Connectivity: WiFi 802.11a/b/g/n [2.4 GHz]
- Or you might not know what it should be yet
 - Example: Sensor accuracy: ???
- Or, you might not even know about that specification
 - Example: ???

A good spec is verifiable...else how do you know if you meet the specs?

Writing a good spec

A good spec is verifiable

- Bad: “should be rugged” [this is really a requirement]
- Better: “survive 1 m drop onto plywood; enclosure intact; device still logs data”
- Test: drop test procedure

Team activity [15 min]

- Choose one of your project requirements
- Propose specification(s) accordingly
- How will you test it?
- What are some unknowns/questions you need to answer to finalize this spec?

Market research

- There are (almost) always similar products out there
- They can be used to help determine specifications, feasibility, and even design

HOBO MX2302A

There are almost always existing products that you can draw from to help set specifications

Specifications

Temperature Sensor

Range	MX2301A and MX2305 internal sensors: -40 to 70°C (-40 to 158°F) MX2302A external temperature sensor: -40 to 70°C (-40 to 158°F) MX2303 and MX2304 external sensors: -40 to 100°C (-40 to 212°F), with tip and cable immersion in fresh water up to 50°C (122°F) for one year
Accuracy	±0.25°C from -40 to 0°C (±0.45 from -40 to 32°F) ±0.2°C from 0 to 70°C (±0.36 from 32 to 158°F) ±0.25°C from 70 to 100°C (±0.45 from 158 to 212°F), MX2303 and MX2304 only
Resolution	MX2301A and MX2302A: 0.02°C (0.036°F) MX2303, MX2304, and MX2305: 0.04°C (0.072°F)
Drift	<0.01°C (0.018°F) per year

Relative Humidity Sensor* (MX2301A, MX2302A only)

Range	0 to 100% RH, -40° to 70°C (-40° to 158°F); exposure to conditions below -20°C (-4°F) or above 95% RH may temporarily increase the maximum RH sensor error by an additional 1%
Accuracy	±2.5% from 10% to 90% (typical) to a maximum of ±3.5% including hysteresis at 25°C (77°F); below 10% RH and above 90% RH ±5% typical
Resolution	0.01%
Drift	<1% per year typical



Price: \$255

HOBO MX2302A

Response Time (typical, to 90% of change)

Temperature	Without Solar Radiation Shield	With RS1/M-RSA Solar Radiation Shield	With RS3-B Solar Radiation Shield
MX2301A internal sensor	17 minutes in air moving 1 m/sec	24 minutes in air moving 1 m/sec	NA
MX2302A external sensor	3 minutes, 45 seconds in air moving 1 m/sec	7 minutes, 45 seconds in air moving 1 m/sec	6 minutes, 30 seconds in air moving 1 m/sec
MX2303/MX2304 external sensors	3 minutes in air moving 1 m/sec; 20 seconds in stirred water	7 minutes in air moving 1 m/sec	4 minutes in air moving 1 m/sec
MX2305 internal sensor	17 minutes in air moving 1 m/sec	24 minutes in air moving 1 m/sec	NA
RH	Without Solar Radiation Shield	With RS1/M-RSA Solar Radiation Shield	With RS3-B Solar Radiation Shield
MX2301A internal sensor	30 seconds in air moving 1 m/sec	40 seconds in air moving 1 m/sec	NA
MX2302A external sensor	15 seconds in air moving 1 m/sec	30 seconds in air moving 1 m/sec	30 seconds in air moving 1 m/sec

HOBO MX2302A

Logger

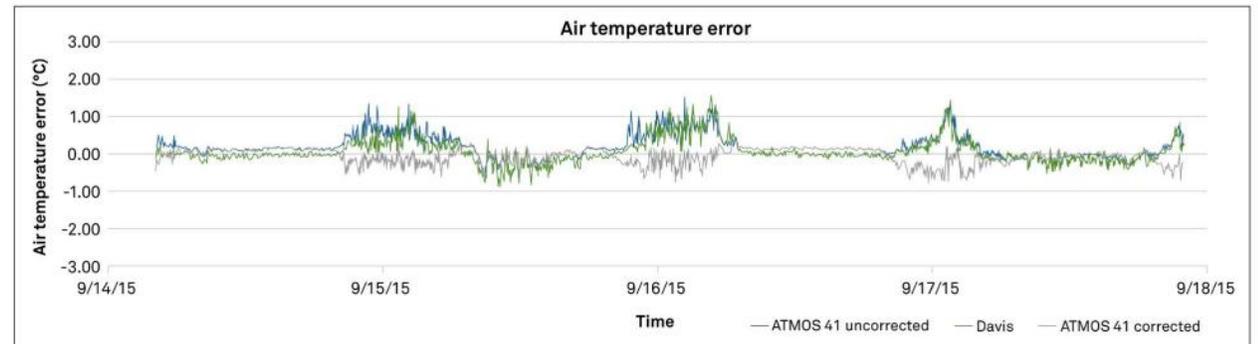
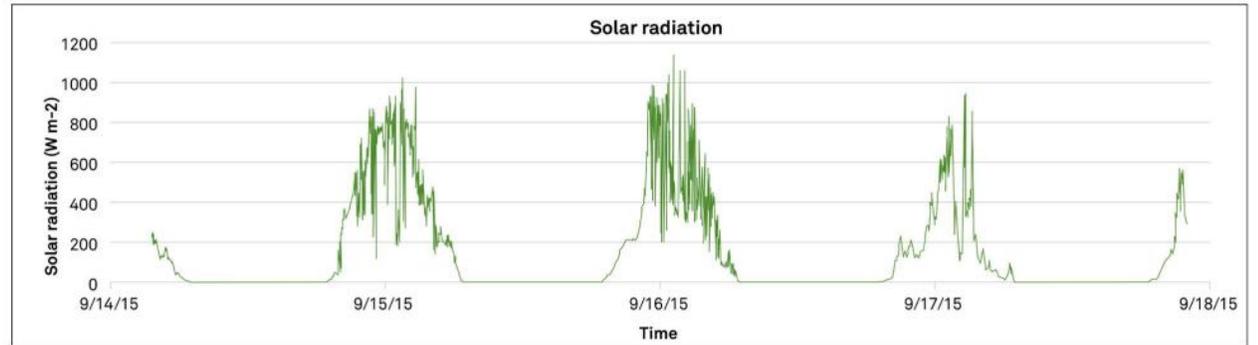
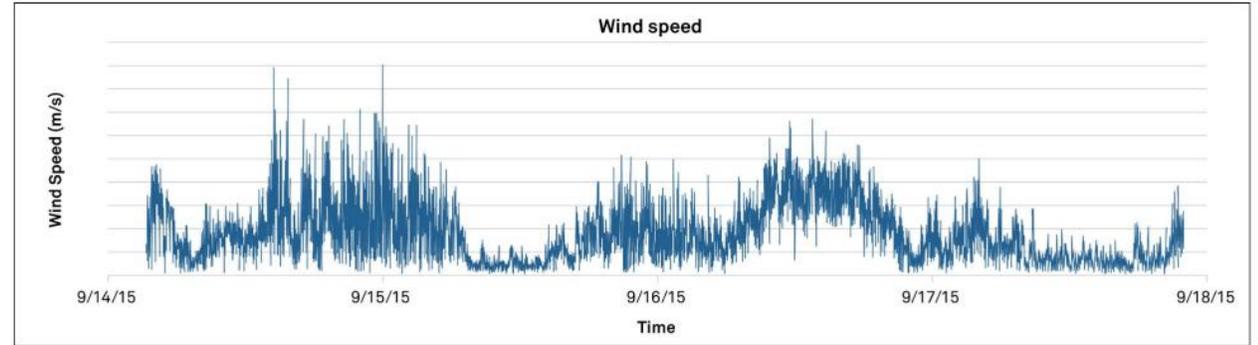
Operating Range	-40° to 70°C (-40° to 158°F)
Radio Power	1 mW (0 dBm)
Transmission Range	Approximately 30.5 m (100 ft) line-of-sight
Wireless Data Standard	Bluetooth Low Energy (Bluetooth Smart)
Logging Rate	1 second to 18 hours
Logging Modes	Fixed interval (normal, statistics) or burst
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, push button, date & time, or next interval
Stop Modes	When memory full, push button, date & time, or after a set logging period
Time Accuracy	±1 minute per month 0° to 50°C (32° to 122°F)
Battery Type	2/3 AA 3.6 Volt lithium, user replaceable
Battery Life	2 years, typical with logging interval of 1 minute and Bluetooth Always On enabled; 5 years, typical with logging interval of 1 minute and Bluetooth Always On disabled. Faster logging intervals and statistics sampling intervals, burst logging, remaining connected with the app, excessive downloads, and paging may impact battery life.
Memory	MX2301A and MX2302A: 128 KB (63,488 measurements, maximum) MX2303, MX2304, and MX2305: 128 KB (84,650 measurements, maximum)
Full Memory Download Time	Approximately 60 seconds; may take longer the further the device is from the logger
Dimensions	Logger housing: 10.8 x 5.08 x 2.24 cm (4.25 x 2.0 x 0.88 in.) External temperature sensor diameter: 0.53 cm (0.21 in.) External temperature/RH sensor diameter: 1.17 cm (0.46 in.) External sensor cable length: 2 m (6.56 ft) Solar radiation shield bracket: 10.8 x 8.3 cm (4.25 X 3.25 in.)
Weight	Logger: 75.5 g (2.66 oz) Solar radiation shield bracket: 20.4 g (0.72 oz)
Materials	Acetal, silicone gasket, stainless steel screws
Environmental Rating	NEMA 6 and IP67
	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).
	See last page

*Per RH sensor manufacturer data sheet

ATMOS 41W



Price: \$2620



<https://www.youtube.com/watch?v=Xf34bOmZET4>

https://publications.metergroup.com/Sales%20and%20Support/METER%20Environment/Website%20Articles/atmos-41-correction-air-temperature-measurements-radiation-exposed-sensor.pdf?_gl=1*1y81m63*_gcl_au*MjExMzcyNTAwNi4xNzM5MTk3OTgz

ATMOS 41W MX2302A

Measurement Specifications

Upload Frequency

Hourly upload (default)

Contact Customer Support for more frequent reporting options. Additional charges may apply.

Measurement Interval

5 min to 12 h (average or accumulation of more frequent sensor readings) ([Section 2.2.7 of ATMOS 41W User Manual](#)).

Time Keeping

Synchronize automatically and on-demand; GPS, cellular, or ZENTRA Utility software.

Solar Radiation

Range: 0–1,750 W/m²

Resolution: 1 W/m²

Accuracy: ±5% of measurement typical

Relative Humidity (RH)

Range: 0–100% RH (0.00–1.00)

Resolution: 0.1% RH

Accuracy: Sensor measurement accuracy is variable across a range of RH. [See chart](#).

Air Temperature

Range: –63 to 60 °C

Resolution: 0.1 °C

Sensor Accuracy: ±0.2 °C at 25 °C

Measurement Accuracy: ±0.6 °C from –20 to 50 °C

For more information see [Section 3.2.6 of the ATMOS 41W User Manual](#)

Humidity Sensor Temperature

Range: –63 to 80 °C

Resolution: 0.10 °C

Accuracy: ±0.2 °C

ATMOS 41W MX2302A

Communication Specifications

Internet Downloads

SSL/TLS encrypted

Cellular Communication

3G Specifications: UMTS 3G 5-band cellular module with 2G fallback

3G Coverage: 550+ global partner carriers

Cellular and data hosting service provided by METER

4G Specifications: 4G LTE-M and NB-IoT cellular

4G Coverage: VERIZON, AT&T®, and T-Mobile in the USA.

Select global partner carriers

Cellular and data hosting service provided by METER

NOTE: 4G is available in USA, Canada, and select other countries (Contact Customer Support or a METER sales partner for more information).

Mobile Communication

Bluetooth 5.2—supporting Bluetooth Low-Energy protocol.

GPS Communication

Type: Integrated 56-channel GPS/QZSS receiver

Update: Daily (automatic) and on-demand (manual)

Accuracy: ±4 m, with good sky view

ATMOS 41W MX2302A

Physical Specifications

Dimensions

Width: 16.5 cm (6.5 in)

Height: 31.8 cm (12.5 in)

Memory Type

Nonvolatile flash, full data retention with loss of power

Data Storage

8 MB (more than 100,000 records)

Battery Capacity

6 AA NiMH or alkaline batteries

Battery Life

Alkaline: 7 months typical for hourly uploads or 4 months with 15-min data upgrade.

NiMH: 3+ years with an unobstructed view of the sun.

Charging through solar energy harvesting.

Operating Temperature Range

Minimum: -40 °C

Typical: NA

Maximum: 60 °C

NOTE: Barometric pressure and relative humidity sensors operate accurately at a minimum of -40 °C. Alkaline batteries should be used if temperatures below -40 °C are expected.

Other

Compliance

EM ISO/IEC 17050:2010 (CE Mark)

[Prop 65 warning](#)

GSA

[View GSA details](#)

Sometimes there are reviews or other literature that provide an unbiased comparison of different products

03 DETECTION GUIDANCE 9

Loop Detectors	10
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Microwave/Radar	20
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In-Ground Radar	30
Bicyclist App - Broadcast Presence	32



PERSPECTIVES IN PRACTICE

Bicycle Detection

A review of available technologies and practical experience to aid in the creation of smarter intersections that work for all users

SUMMARY

Across the United States, approximately two-thirds of reported bicycle crashes happen at intersections. Detecting the presence of people bicycling at or approaching signalized intersections and roadway crossings can offer traffic engineers additional tools and flexibility to improve the comfort and safety for this vulnerable user group. This white paper provides a deeper discussion on the various technologies that are available and provides insight on their strengths, weaknesses and practical applications.

Contributors:

- Joe Gilpin, Vice President
- Tobin Bonnell, PE, PTOE, Engineering Associate
- Matt Fralick, PE, PTOE, Senior Engineer
- Kirk Paulson, PE, Senior Engineer
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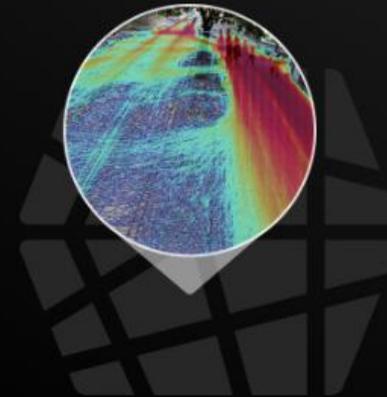


Sometimes there are startups...but you have to [marketing crap]⁻¹

Unprecedented street-level data

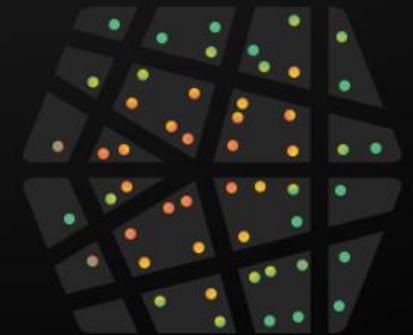
Numina's sensor is purpose-built for streets and easy to deploy.

[See how cities use Numina →](#)



Deploy one Numina sensor

To understand granular traffic safety, environmental conditions, and operational metrics in streets.



Deploy a network of Numina sensors

To build a data utility that turns streets into a developer platform.

Our sensor is a standalone solution to street metrics



Plug-and-play

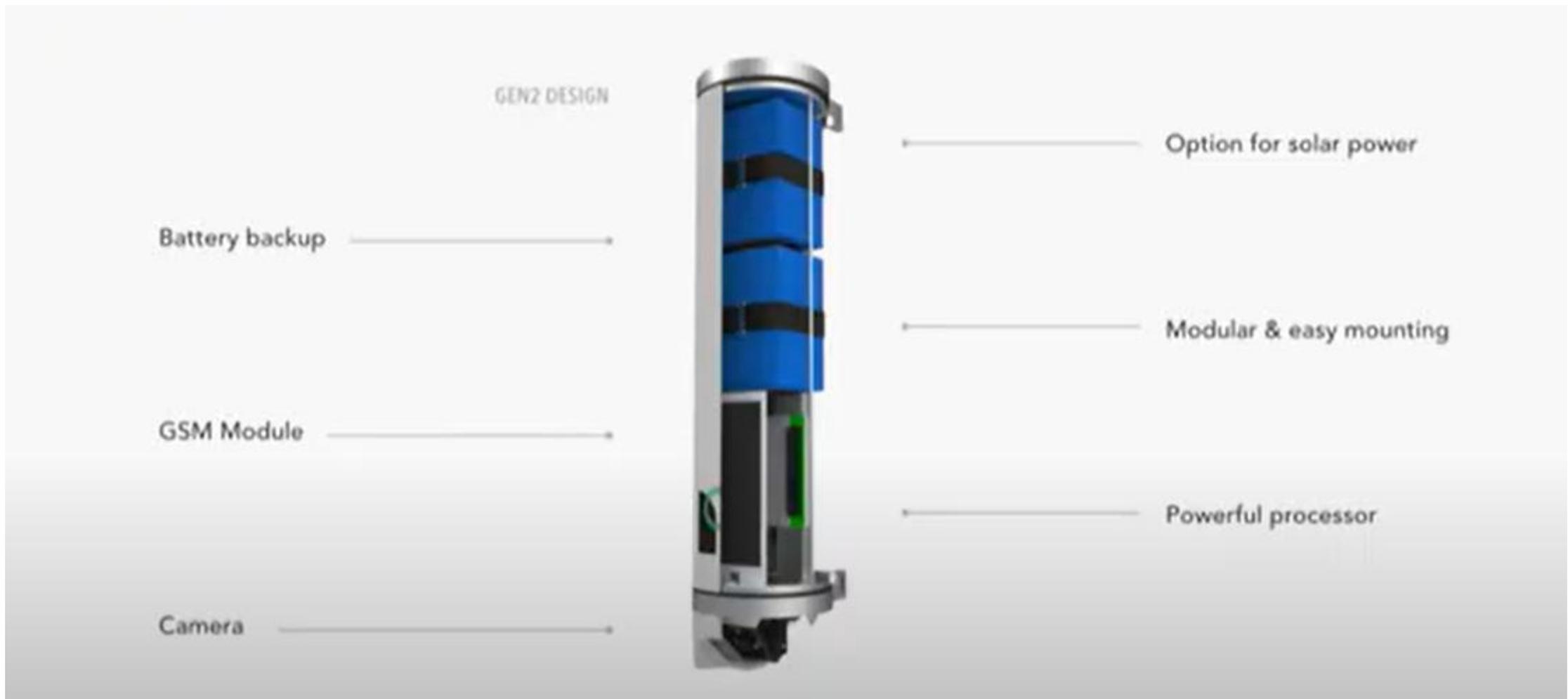
Easy to install, aim, and activate via mobile app

Deploy-anywhere

Attaches to any fixed infrastructure with standard mounting kits

Safe and secure

Gold-standard secure-by-design practices like mutual authentication and strong encryption



This talk is from 2018...



An update to Numina's Privacy Policy: Introducing Calibration Mode

 Sarah Toulmin  March 10, 2022

Today, Numina works in dozens of cities on three continents, and the demand grows as communities take more aggressive approaches to fighting climate change, recovering from the pandemic, and increasing mobility access. As we deploy ...

[Read More →](#)