How to make a Smart Battery Trustworthy

Improving system-reliability with Diagnostic Battery Management

By Isidor Buchmann

www.cadex.com www.batteryuniversity.com Info@cadex.com Isidor.Buchmann@cadex.com

Healthcare is highly regulated *(except in batteries)*

A US FDA survey says:
"Up to 50% of issues in hospitals are battery related."

Battery management emerged as a top 10 medical-device challenge.

A two-day FDA Battery Seminar in 2013 reveals:

1. Deficiency in quality assurance in batteries by device manufacturers.
2. Lack of understanding in battery system integration.
3. Not knowing the end of battery life.

A Biomed Tech speaks up:

- Batteries are the most abused components in hospitals.
- Staff care little about batteries and only does the bare minimum.
- Recommendations for battery maintenance are vague, hidden inside service manuals.

Info@cadex.com Isidor.Buchmann@cadex.com

System Management Bus (SMBus)

SMBus was developed by Intel and Duracell in 1994.

Benefits:

- Displays battery state-of-charge (SoC)
- Reveals state-of-health (SoH) on newer systems

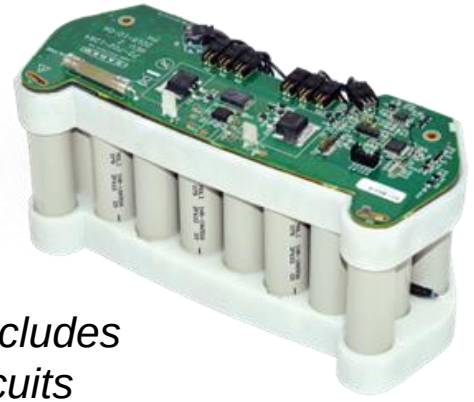
Standards:

Level 1 supported a single chemistry (no longer used).

Level 2 controls charge. Battery becomes the host; charger is the slave.

Level 3 accommodates SMBus and regular batteries.

Note: Level 3 is preferred. The hybrid charger takes over if SMBus communication fails.



Most SMBus includes BMS safety circuits

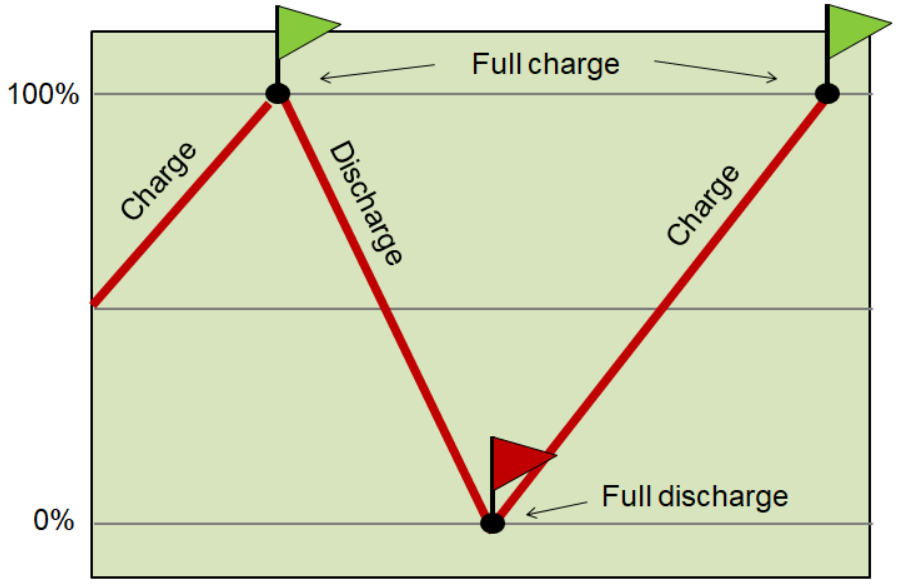
Calibrating the Smart Battery

The early SMBus battery showed SoC only.

- Without knowing the capacity, runtimes can be short on a faded battery, even when fully charged.
- The modern SMBus reveals the “digital capacity” in FCC (Full Charge Capacity).
- To maintain accuracy, device manufacturers advise to calibrate the battery every 3 months or after 40 discharges.

Reality

- Calibrations is seldom done.
- Users don’t know when to calibrate.
- Service is often not available in the field.



Full charge and discharge sets the flags

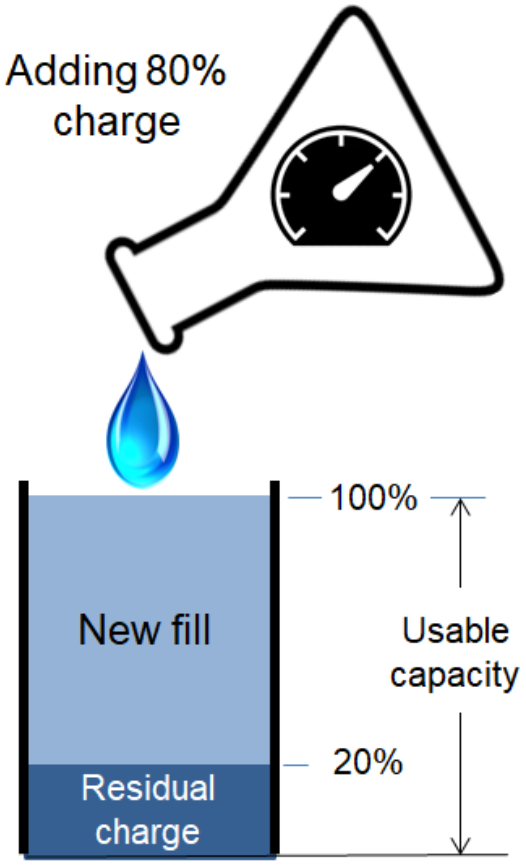
Calibration by tracking Battery Capacity

The modern smart battery estimates capacity by measuring in-and-outflowing coulombs.*

Here is how it works:

1. *Residual charge* is assessed by reading the open circuit voltage. The battery must be well rested.
2. With SoC known, charge (or discharge) is measured by coulomb counting
3. The energy units are then used to calculate the available storage space.

Formula: Capacity is the sum of residual charge plus new fill.



For best results:

- Add a 2 hour rest after charge
- Add a 5 hour rest after discharge
- Voltage must be temperature compensated

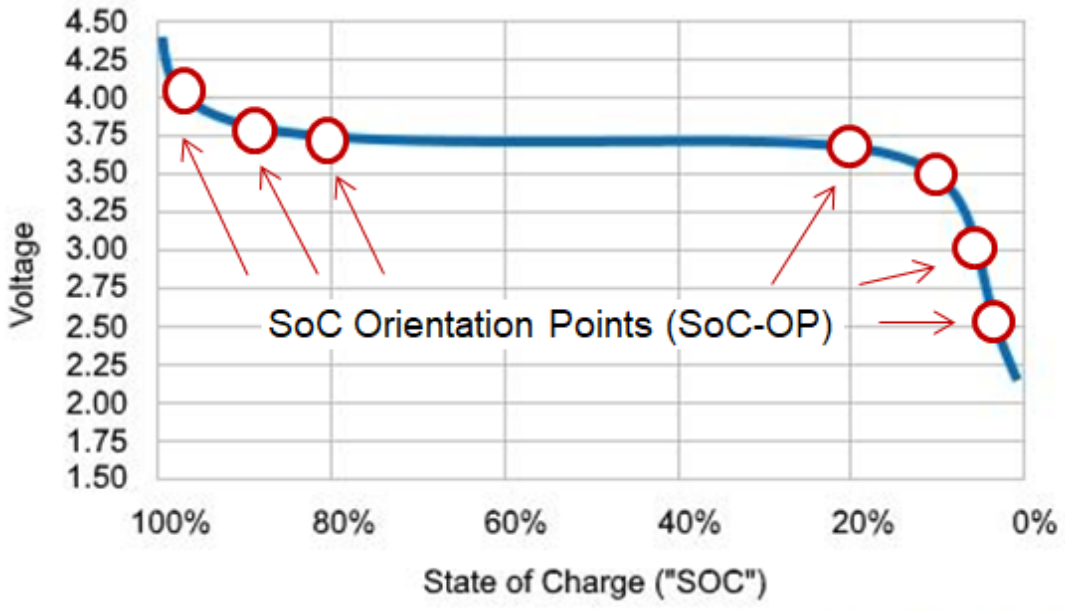
Note: A full calibration with rest periods can take 24h

* One coulomb is 1A in 1 second

Self-calibration

Self-calibration seeks "*SoC Orientation Points" (SoC-OP)* that occur when the battery reaches a relaxation state after charge or discharge.

With SoC-OP secured, adding or removing coulombs between the SoC-Ops assesses the usable capacity.



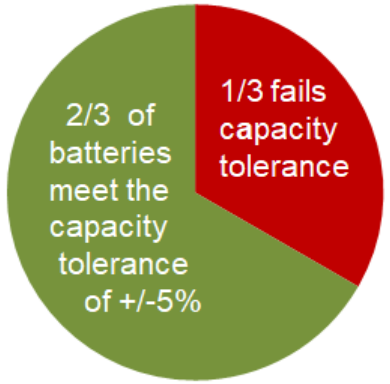
SoC Orientation Points serve as navigation beacons

How well does self-calibration work?

Only 2/3 of batteries tested had a correlation of 5% or better between FCC and the measured capacity.

Test: The *digital capacity* was based on FCC; the *measured capacity* was done on a battery analyzer.

Verdict: SMBus leaves room for improvement.



Smart batteries need calibration to keep accurate

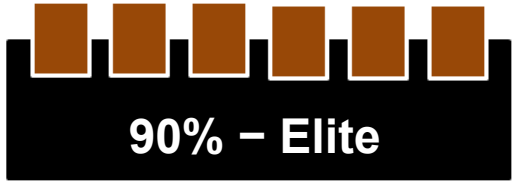
Diagnostic Charger makes SMBus data visible

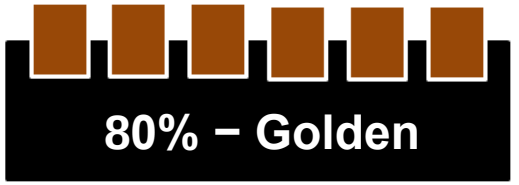
A new generation charger features a **Target Selector** to pass and fail batteries based on FCC.

Target Selector serves as gatekeeper

Suggested settings:

- **Critical mission**: 85-90%. *Fewer batteries pass*
- **Default setting**: 80%. *Golden average*
- **Moderate duty**: 60-70%. *Batteries serve longer*





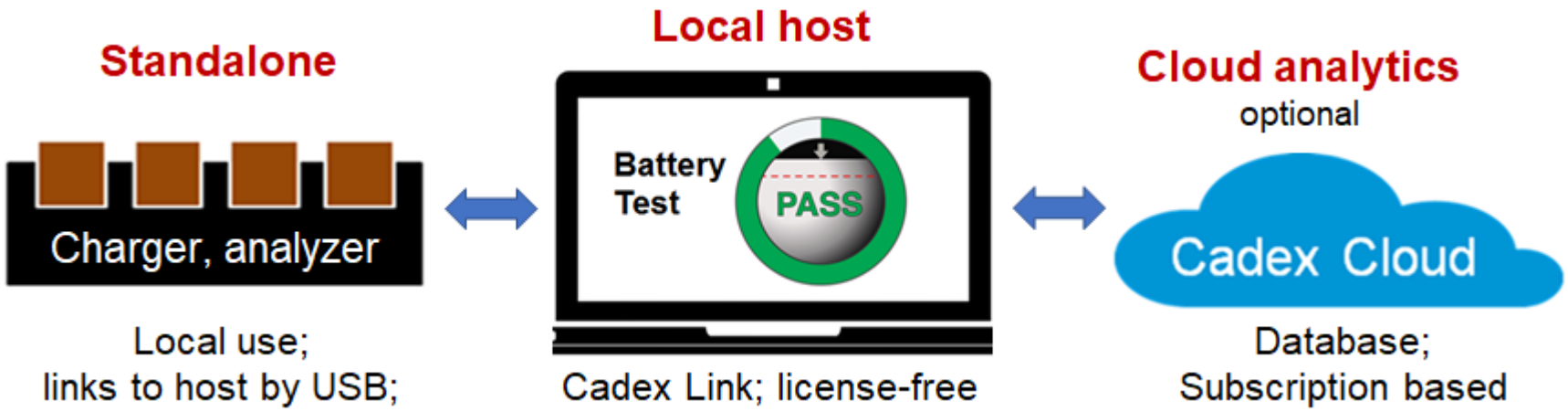
Optimal Target Setting:

The Target Selector should be set to retain 20% charge at the end of a routine day. An analogy is an aircraft carrying enough fuel for a safe landing.

Benefit:

- User knows when to retire a fading battery.
- Aging batteries can be redeployed without loss of reliability.
- Re-usage lowers operational costs and protects the environment.

Diagnostic Charger that is scalable



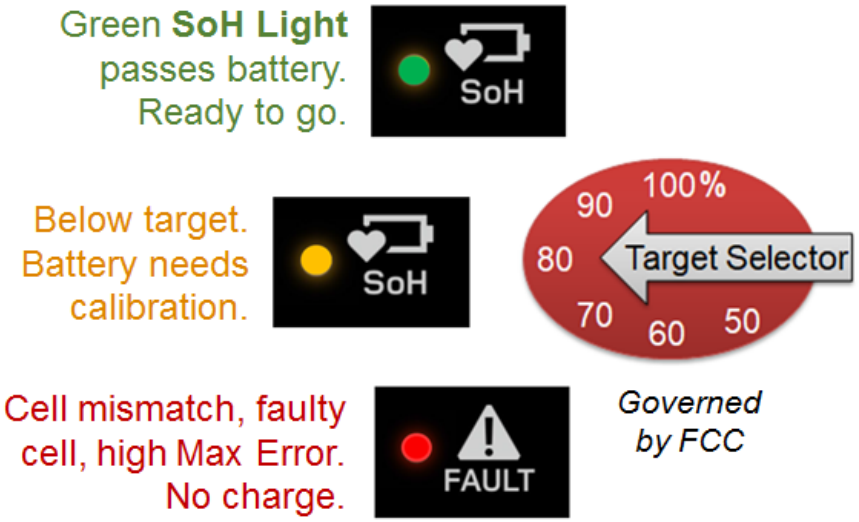
- The charger is no longer an afterthought but becomes an integral part of a system to provide risk management in batteries.
- SoH is a growing concern because the battery can be the least reliable part in a system that may need several replacements during the life of a product.
- End of battery life should be determined by capacity, the leading health indicator, not mere date stamp or number of cycles.

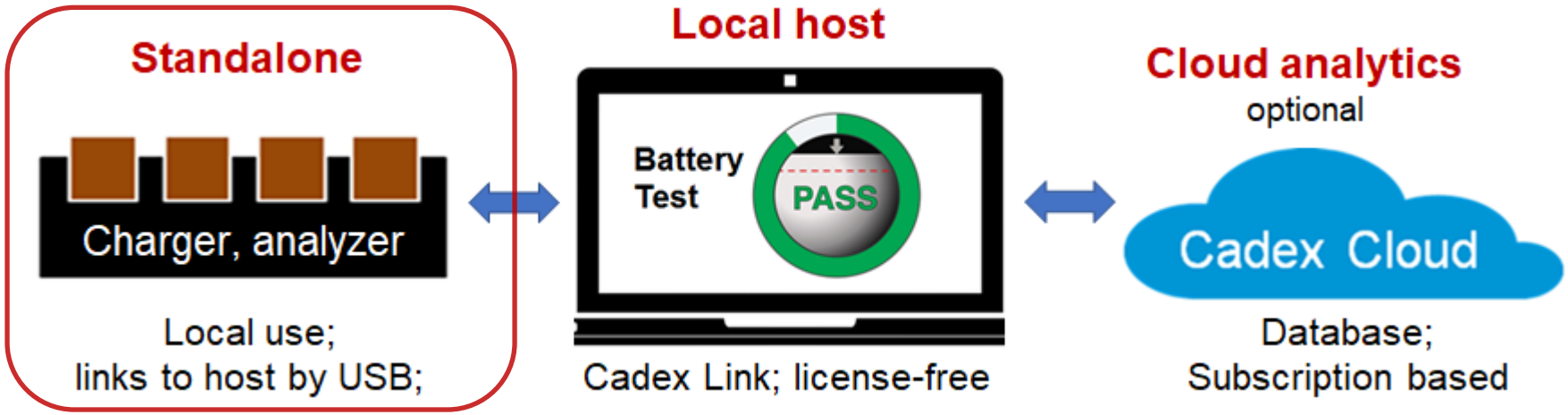
Standalone

The Diagnostic Charger evaluates the SMBus battery on insertion:

- The green SoH Light gives a pass. Charge begins.
- Amber advises calibration. Battery still charges.
- Red indicates fault. No charge applied.

Note: Calibration can be done in the charger.

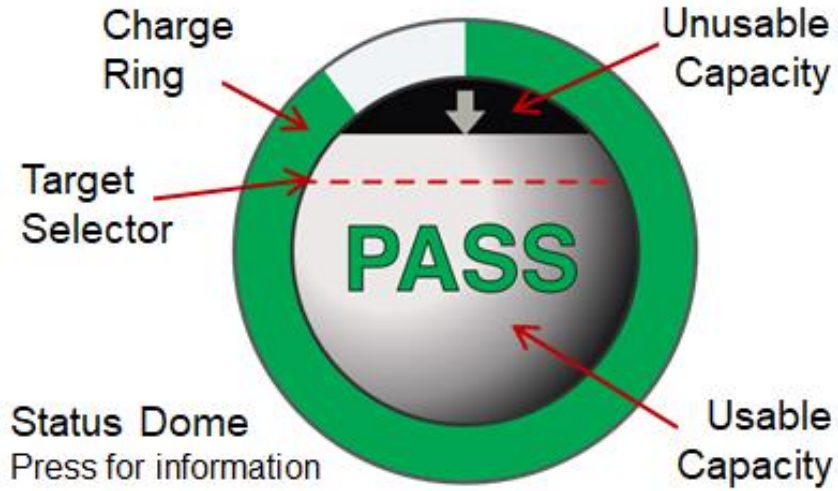


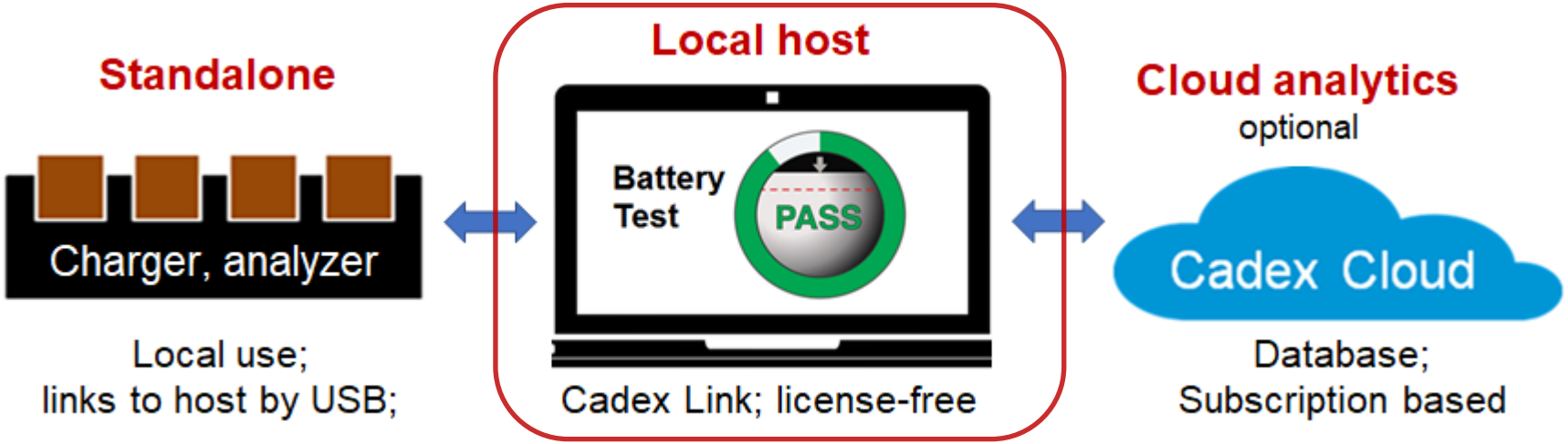


Local host

The host shows battery state-of-function by **Fishbowl** icon.

- The green outer ring reveals state-of-charge that moves clock-wise on charge and counter-clockwise on discharge.
- The hanging black ceiling shows capacity fade that slowly drops towards the Target Selector redline with aging.
- Touching the Status Dome displays the smart battery data.

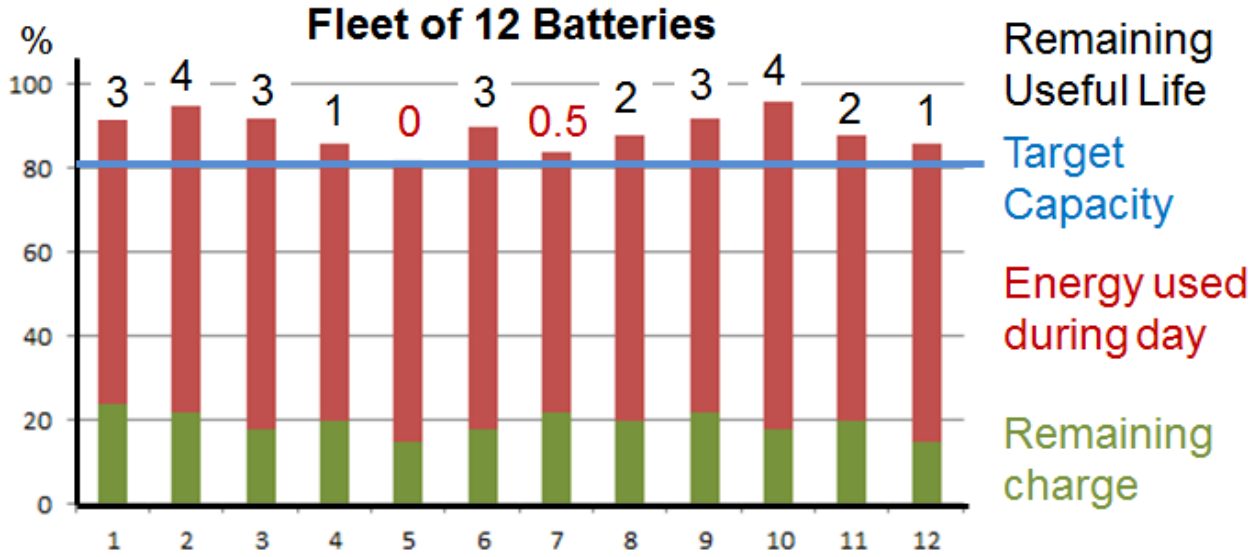


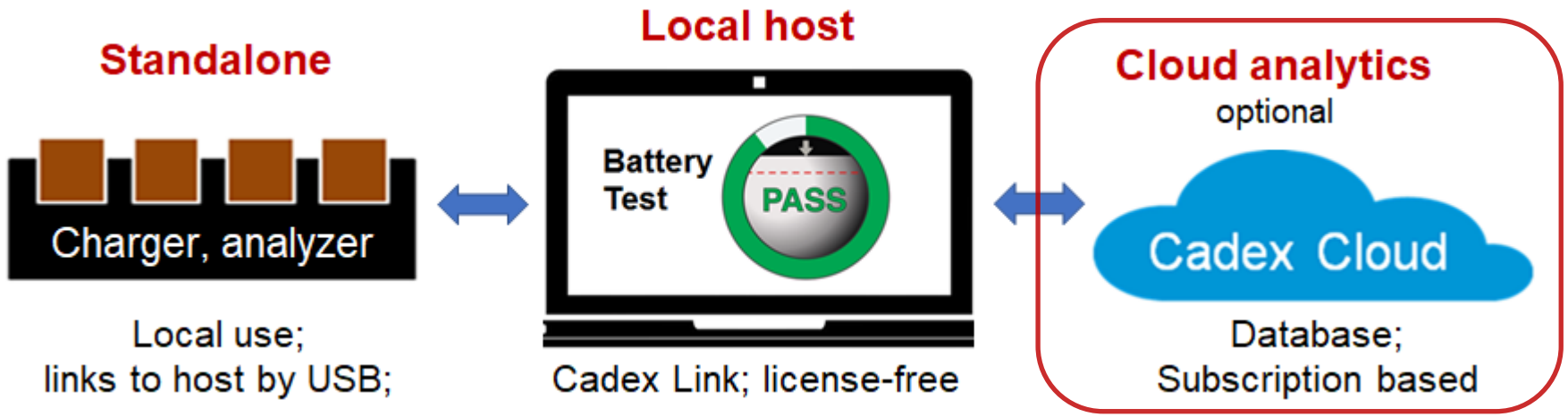


Cloud Analytics

Cloud Analytics advances the Diagnostic Charger into a battery management system.

- Reveals remaining charge, energy used and the *Remaining Useful Life* in years.
- Tracks battery anomalies similar to a pharmaceutical product.
- Runs systems in the background with minimal user intervention.

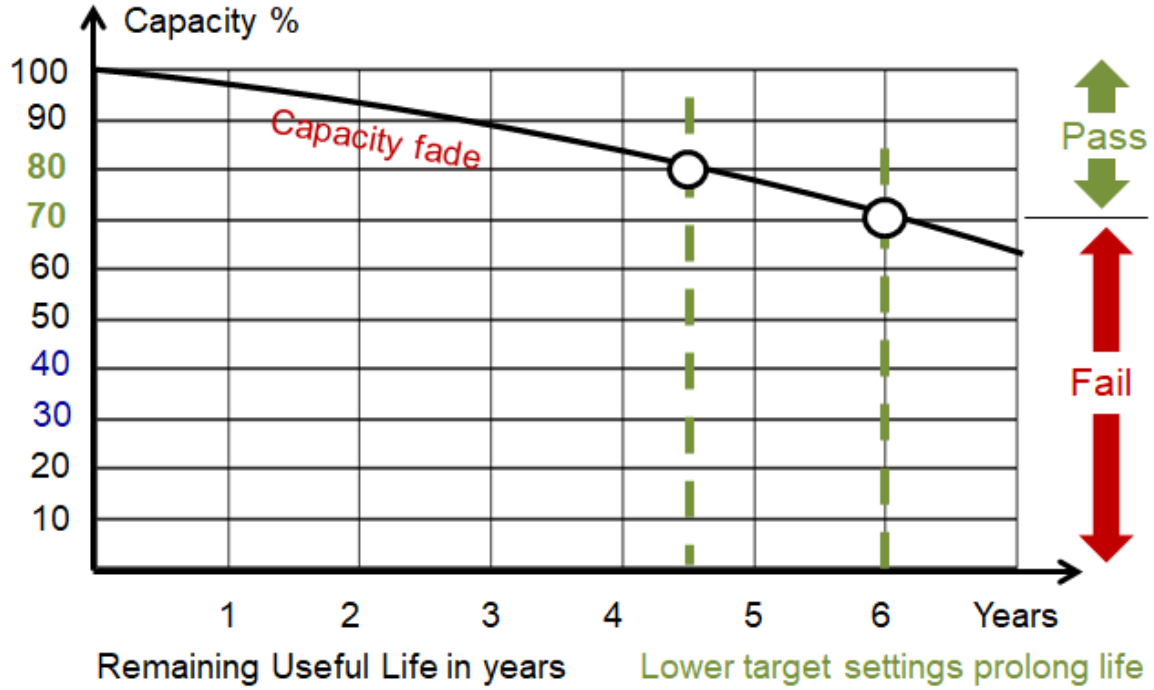




Prediction of Battery Life

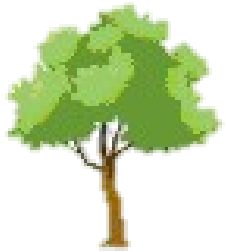
The Remaining Useful Life of a battery can be observed by tracking capacity fade over time based on usage and environment with AI.

- Capacity is the leading health indicator.
- With solid battery management, sudden failures are rare (but smart batteries do fail).
- Replacement can be based on capacity rather than date stamp or cycle count.



A manager at DOE discovered that:

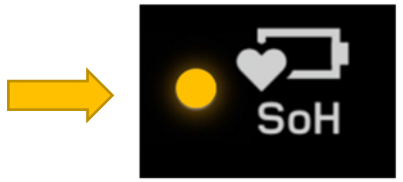
"Every year roughly one million usable lithium-ion batteries are being sent for recycling with most having a capacity of up to 80%."



Conclusion

Smart batteries contain important SoH information that is often hidden or is inaccurate.

- The Diagnostic Charger keeps performance data accurate by requesting calibration when required.



Amber calls for calibration

- Inserting a battery reveals the battery status.
- Calibration can be done in the charger or on a battery analyzer.

Charger with Target Selector

Battery analyzer

Five batteries pass; one needs service

New SoH Standards in Batteries

As batteries take on critical uses, new standards are being developed to reveal SoH. UN and EU are working on norms to disclose the *Usable Battery Energy* to an accuracy of 95%. Battery safety is also addressed.

In the 1960s, *Reliability-centered Maintenance (RCM)* set runtime-intervals between maintenance based on wear-and-tear. RCM was first used on the Boeing 747 to improve air safety. Nuclear plants, defense, railway and other industries followed.

In 1911, the *Lococomotive Boiler Inspection Act* began regulating boiler safety to avoid accidents caused by hotspots, over-pressure, sediments and leaks.

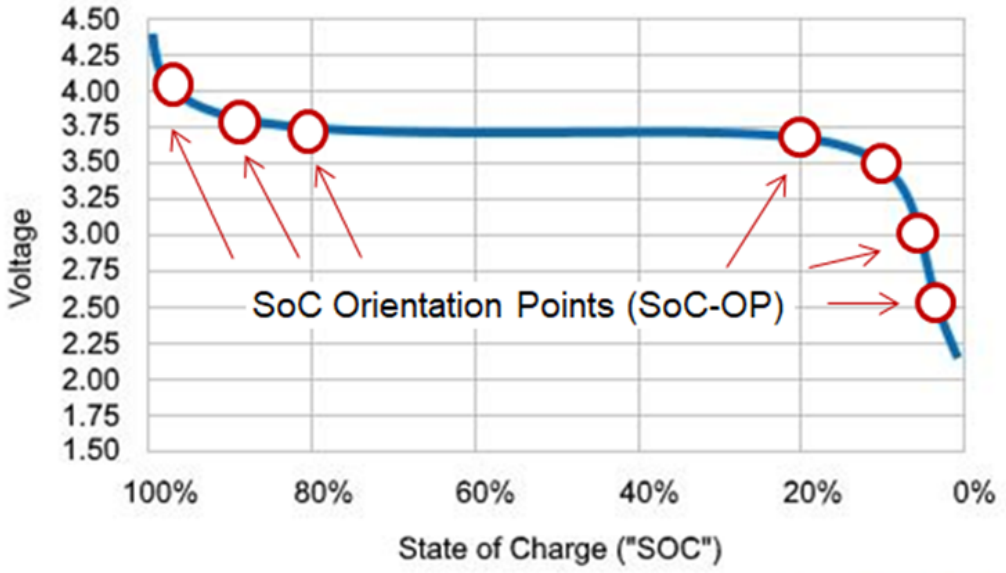
How to calibrate your EV without Tools

The BMS in an EV works similar to a SMBus battery.

To calibrate:

1. Discharge the battery by driving the extra mile to set the low SoC-OP.
2. Allow the battery to rest for 4-6 hours at low SoC without load.
3. Charge and add a 2-4-hour rest at full charge before use.

- Battery life is still based on cycle count.
- The EV will change old-school thinking.



Thank you. Questions?

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www.cadex.com www.batteryuniversity.com Info@cadex.com Isidor.Buchmann@cadex.com

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