AIRBUS Space Battery:

Life Phases and Battery Aging: A Critical Study for Satellite Missions

Space Power Workshop 2026

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AIRBUS

SPACE BATTERY PRODUCTS | AGENDA

1. Who we Are, Our Products and our Heritage
2. Battery Ageing Dependencies
3. Battery Ageing Prediction
4. Conclusion ?

1 - Who we Are, Our Products and our Heritage

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SPACE BATTERY PRODUCTS | WHO ARE WE ?

AIRBUS > AIRBUS DEFENCE & SPACE > SPACE SYSTEMS > SPACE SYSTEMS ENGINEERING > OPTICAL, MICROWAVE & ELECTRICAL SYSTEMS > **ADVANCED ELECTRICAL PRODUCTS & BATTERY**

Europe's **number 1** Defence and Space company

More than **35 000 people** employed **worldwide,** including in the USA

One single entity active all along the Space value chain

- Satellite manufacturing
- Launchers equipment
- Launchers & launch services
- Ground segment
- Satellite operations (services)
- Earth observation / Telecoms

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PIONNEERING ON BATTERY DEVELOPMENT

- **Dedicated department for Battery Development** since **2002**
- **More than 20 years heritage with the Lithium-Ion (Li-Ion) technology** – 1st satellite with Li-ion battery launched in **2004** and still in-orbit!
- **New strategy** deployed in **2016:**

*~ **100 employees**, based in Toulouse, **France***

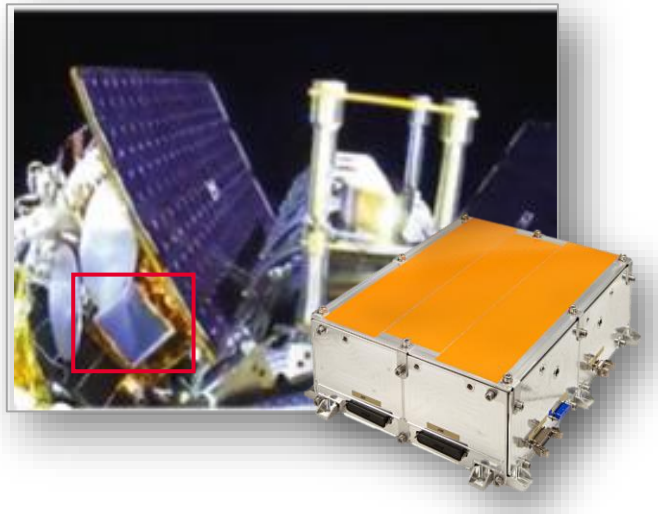
From BUY…

- Dedicated cells for Space
- External supply
- Airbus as "integrator"

- Costs
- Mass
- Obsolescence

To MAKE…

- COTS cells
- End-to-End battery products



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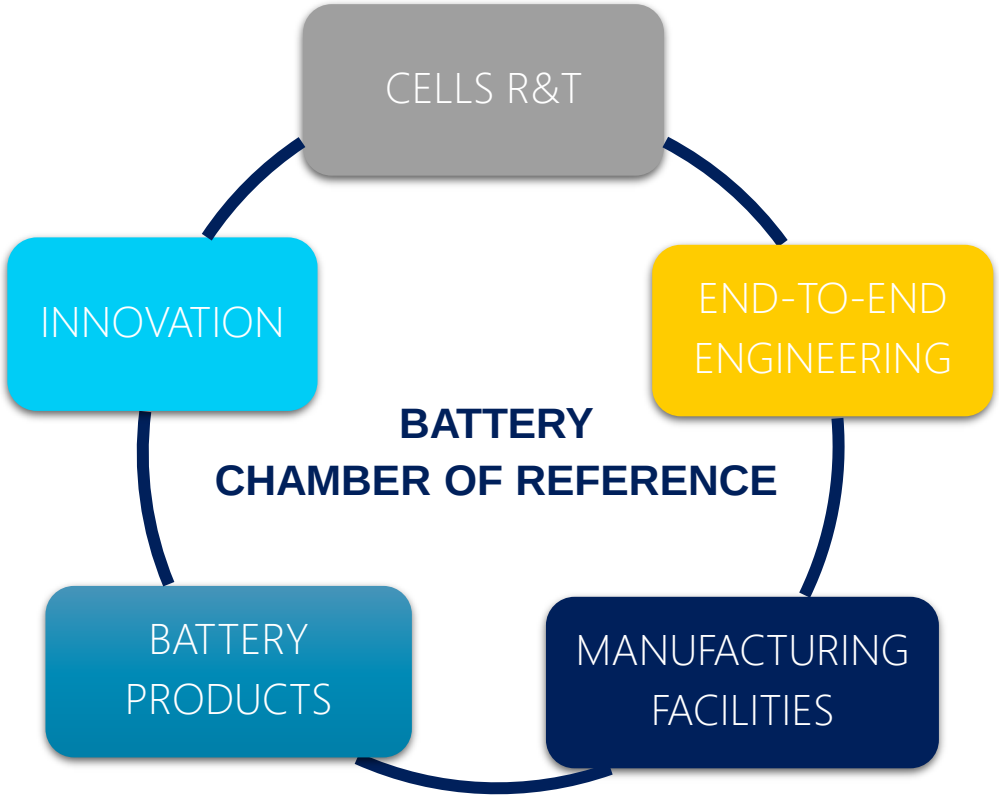
3 MAIN MISSIONS

Battery Chamber of Reference for AIRBUS Group

End-To-End Battery H/W products to internal/external customers **for Space, Aeronautics** and **Military** applications

Pushing **innovation** to **decrease cost & leadtime** at system level



Space Systems

Military / Air Systems

Unmaned Aerial Systems

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SPACE BATTERY PRODUCTS | KEY FIGURES

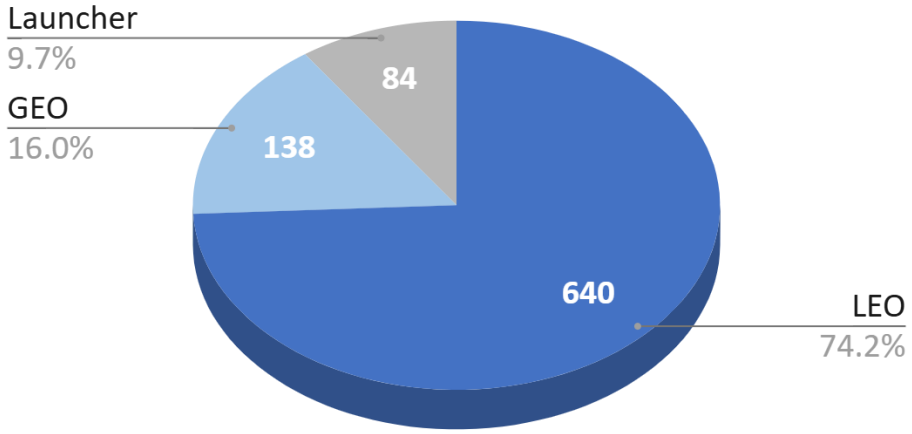
[Airbus Amber]

34 Different battery programs

> 2460 Ordered battery modules

> 1700 Manufactured battery modules

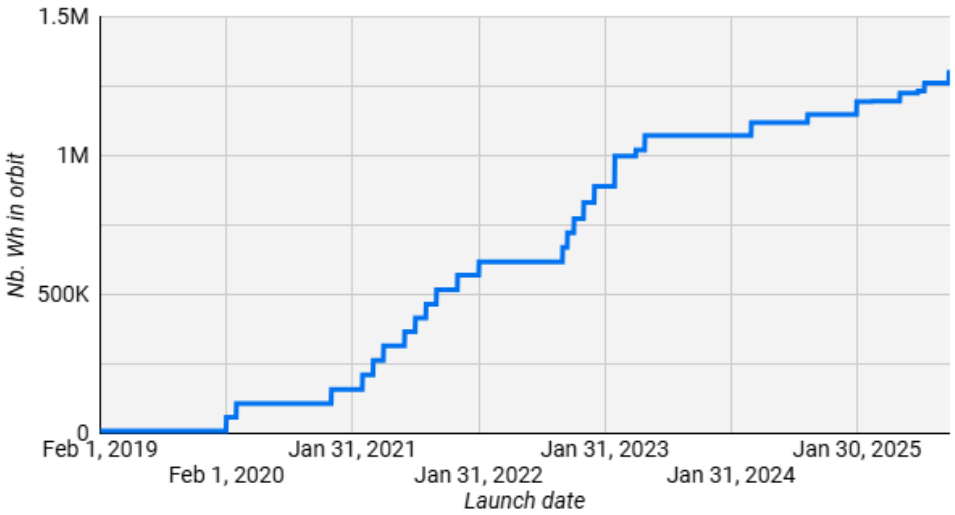
> 860 battery modules **in orbit**



> **235k** COTS cells used, equivalent to **2,7MWh**

> **115k** COTS cells in orbit, equivalent to **1,3MWh**

> 105 Billion cell hours of successful space operation with **no reported failure**



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SPACE BATTERY PRODUCTS | PRODUCT LINES

4 MAIN PRODUCT LINES

BASED ON AIRBUS HERITAGE

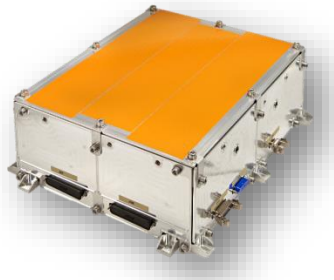
SCAN ME TO KNOW MORE!

AIRBUS BATTERY ON GOING PRODUCT

- NOVA-BATT: TRL6 for 2027
  - Versatile product customisable
  - Cost production optimized
  - Mass production designed
  - Double deck compatible
- POUCH CELL: TRL6 for 2028
  - Versatile product customisable
  - Advanced Li-ion / SSB compatible

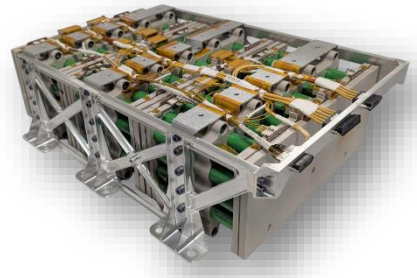
LEO CONSTELLATIONS

STELLAR-BATT



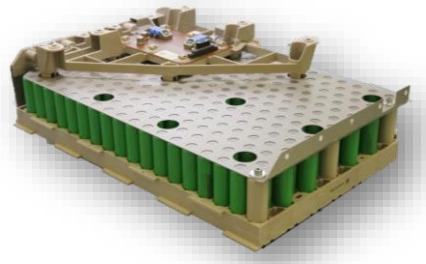
LEO OPTICAL/RADAR MISSIONS

ASTRO-BATT



GEO/MEO TELECOMMUNICATION AND NAVIGATION

COSMO-BATT



LAUNCHERS

LAUNCHER-BATT

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2 - Battery Ageing Dependencies

OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

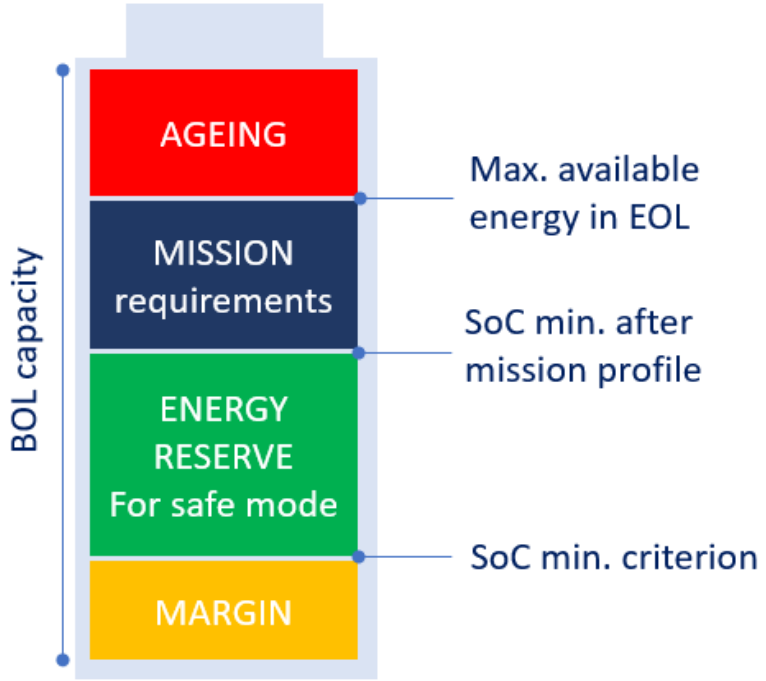
UNDERSTANDING
PREDICTING

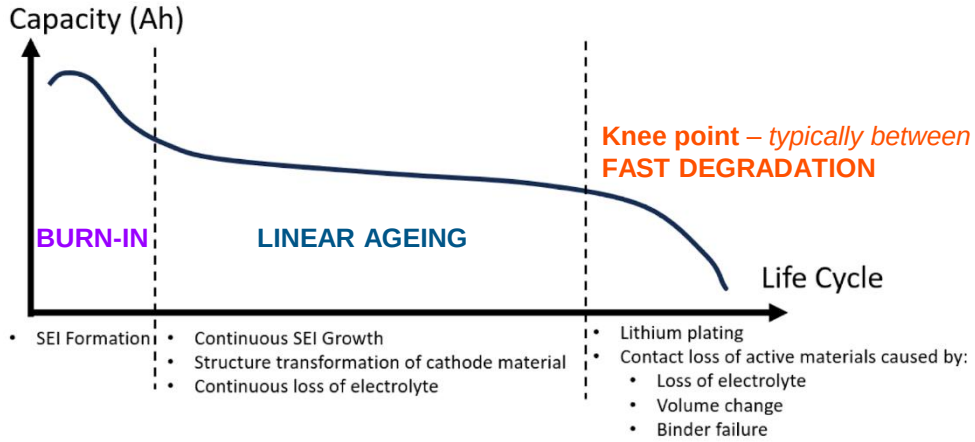
Battery degradation is **crucial** for optimizing **battery sizing** and is therefore the **key driver** of space batteries

MASS | **COST** | **RELIABILITY**

Calendar ageing – degradation that occurs simply with the passage of time, even if the battery is not being used

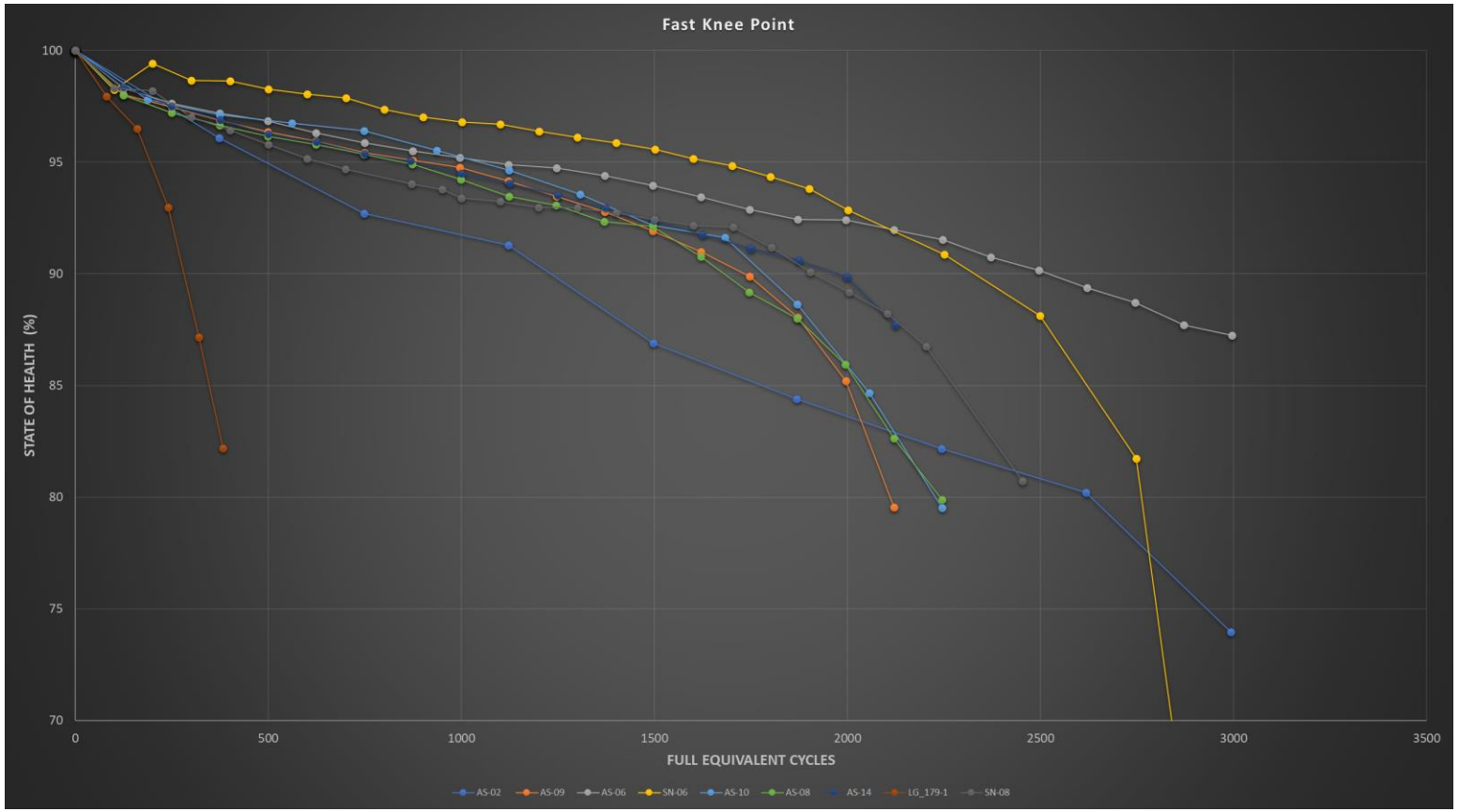
Cycle ageing – degradation that occurs with each charge/discharge cycle





OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

The **Knee point** is significantly influenced by **cycling** / **calendar** conditions.



CYCLING

- *Temperature*
- *End of Charge voltage*
- *Depth of Discharge*
- *Charging rate*
- *Discharging rate*

CALENDAR

- *Temperature*
- *State of Charge*

IMPACT

The status and results presented are dependent on the cell technology / reference used.

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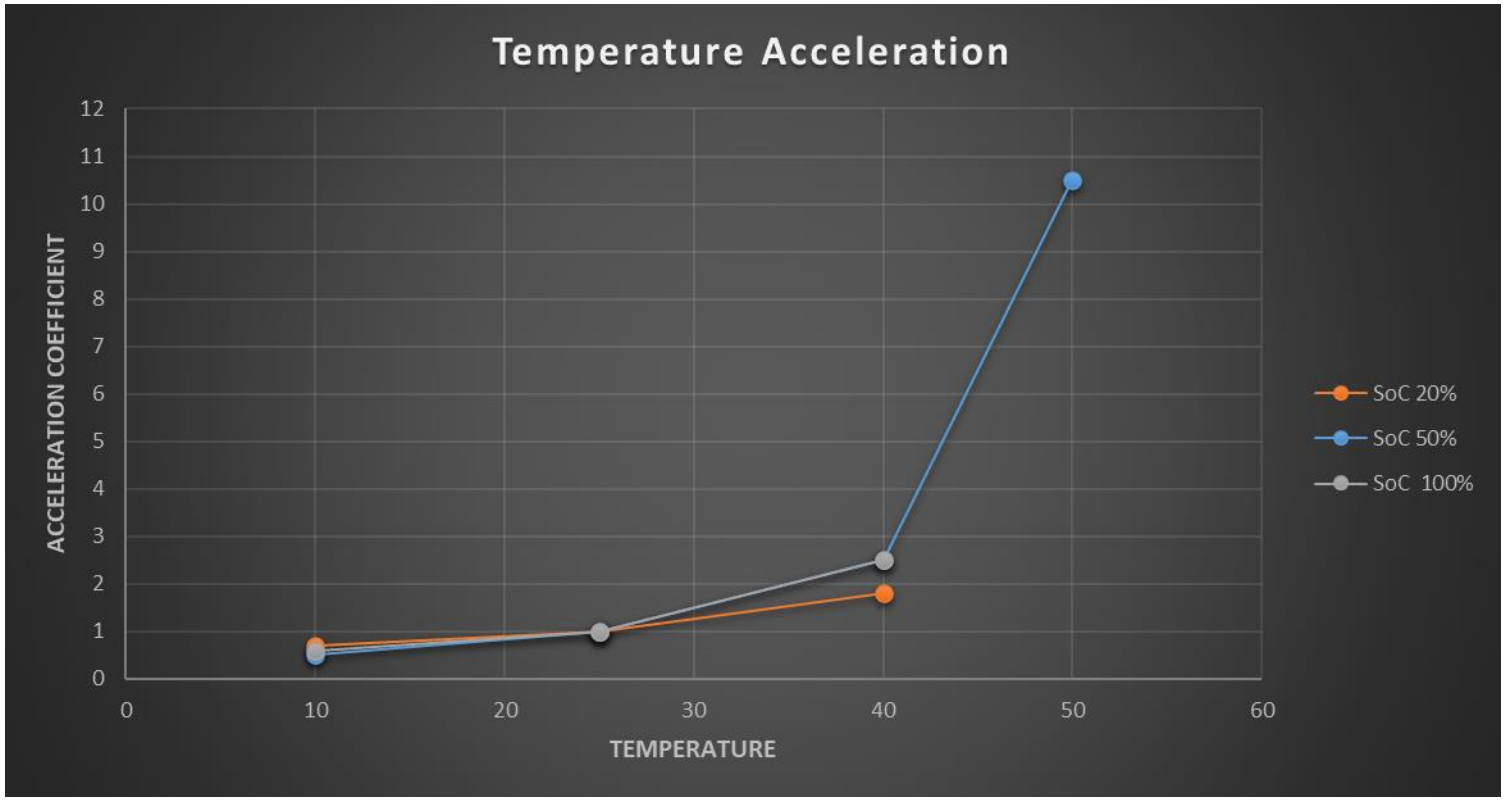
OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

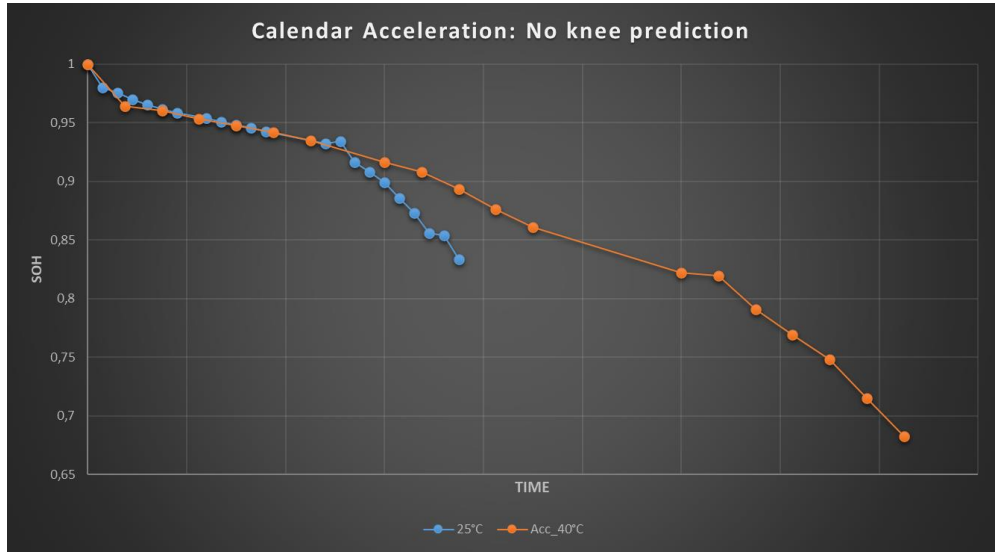
CHARACTERIZATION TESTING

Characterization test is a key to supply all predictions models, but that is also **very long.**
Acceleration & **Discretization** is frequently used to reduce time.

Acceleration – Temperature is a good driver to do it for calendar ageing (Arrhenius law)
=> 50°C is our acceleration limit based on characterization campaign



Acceleration – Could miss a knee



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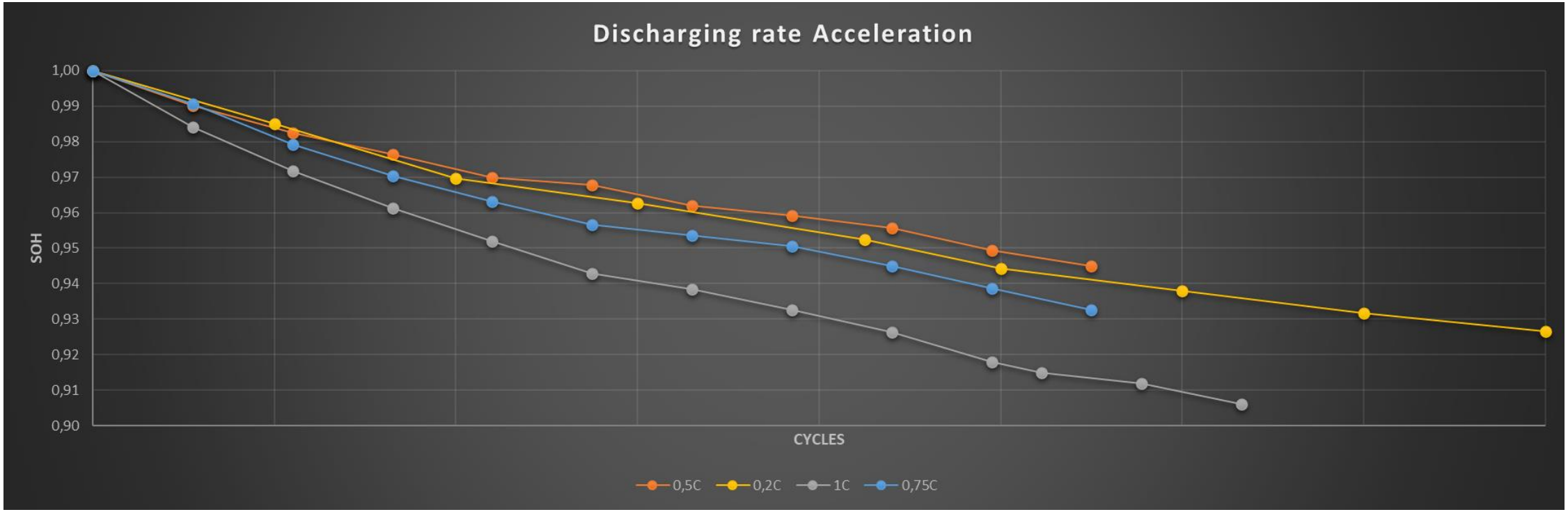
OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

CHARACTERIZATION TESTING

Characterization test is a key to supply all predictions models, but that is also **very long.**
Acceleration & **Discretization** is frequently used to reduce time.

Acceleration – Discharging rate is a good driver to do it for cycling ageing (Until a certain level to not reach)



Based on our reference, the upper limit seems to be 0,75C (Waiting data to confirm)

The status and results presented are dependent on the cell technology / reference used.

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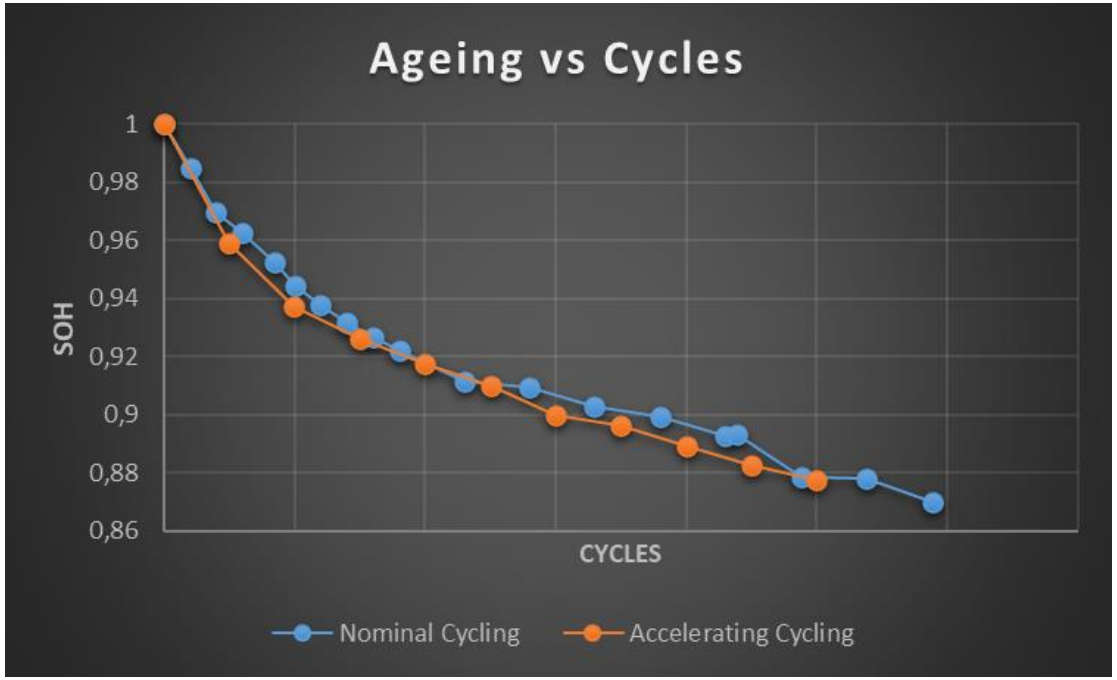
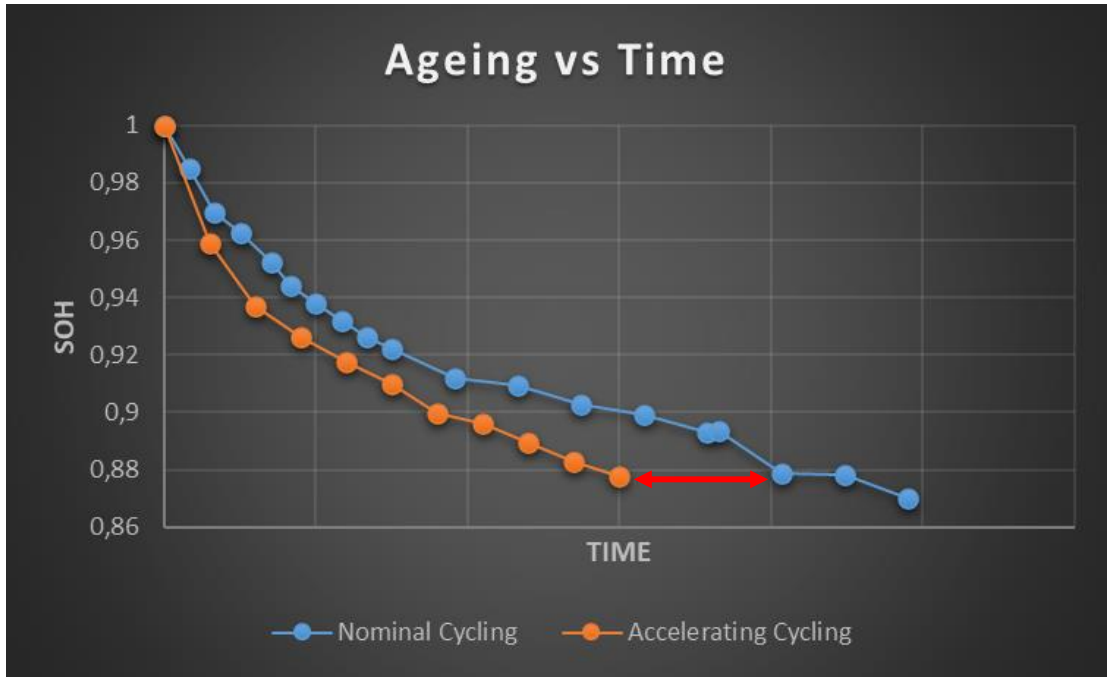
OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

CHARACTERIZATION TESTING

Characterization test is a key to supply all predictions models, but that is also **very long.**
Acceleration & **Discretization** is frequently used to reduce time.

Acceleration – Reduced cycling time have no visible impact on the ageing behavior.





This acceleration permit to reduce time by ~35%

The status and results presented are dependent on the cell technology / reference used.

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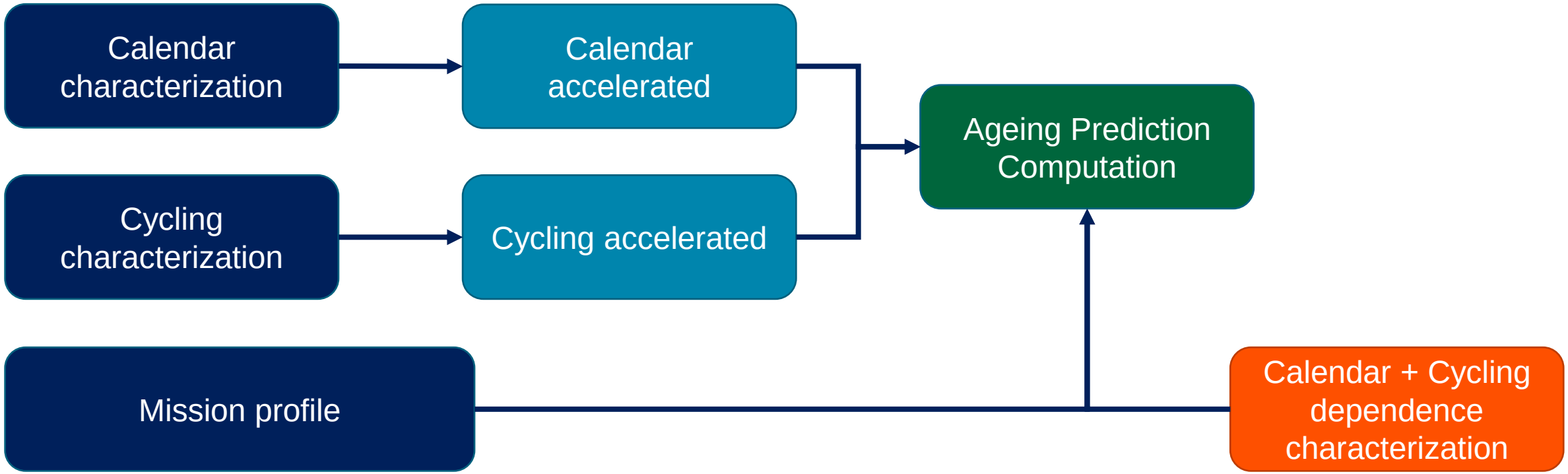
OUR KNOW-HOW | BATTERY AGEING DEPENDENCIES

CHARACTERIZATION TESTING

Characterization test is a key to supply all predictions models, but that is also **very long.**
Acceleration & **Discretization** is frequently used to reduce time.

Discretization – Allows to do parallel calendar & cycling tests or different cycling tests in order to be mixed together



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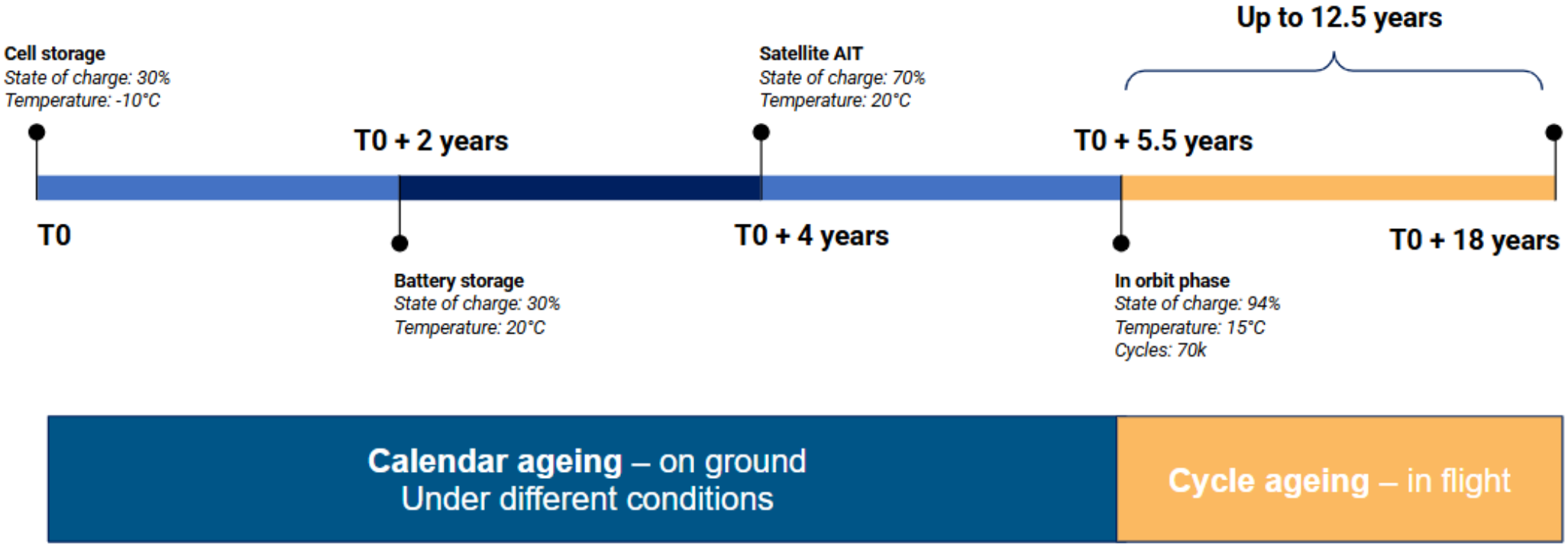
3 - Battery Ageing Prediction

OUR KNOW-HOW | BATTERY AGEING - MISSIONS

LEO MISSIONS

Master the full **production schedule**, battery to satellite could be **very long :** *Impacts of cycling after long calendar ?*
LEO missions are typically characterized using **full-cycle testing at various DoD :** *What is the impacts of mixed DoD*



Charging Strategy – If **charging rate** is sized on the **end of mission**, if no evolution on the mission then a **hidden flying calendar** could be present.

Complex LEO Orbit – Do not underestimate LEO Orbit, some of them include flying calendar.

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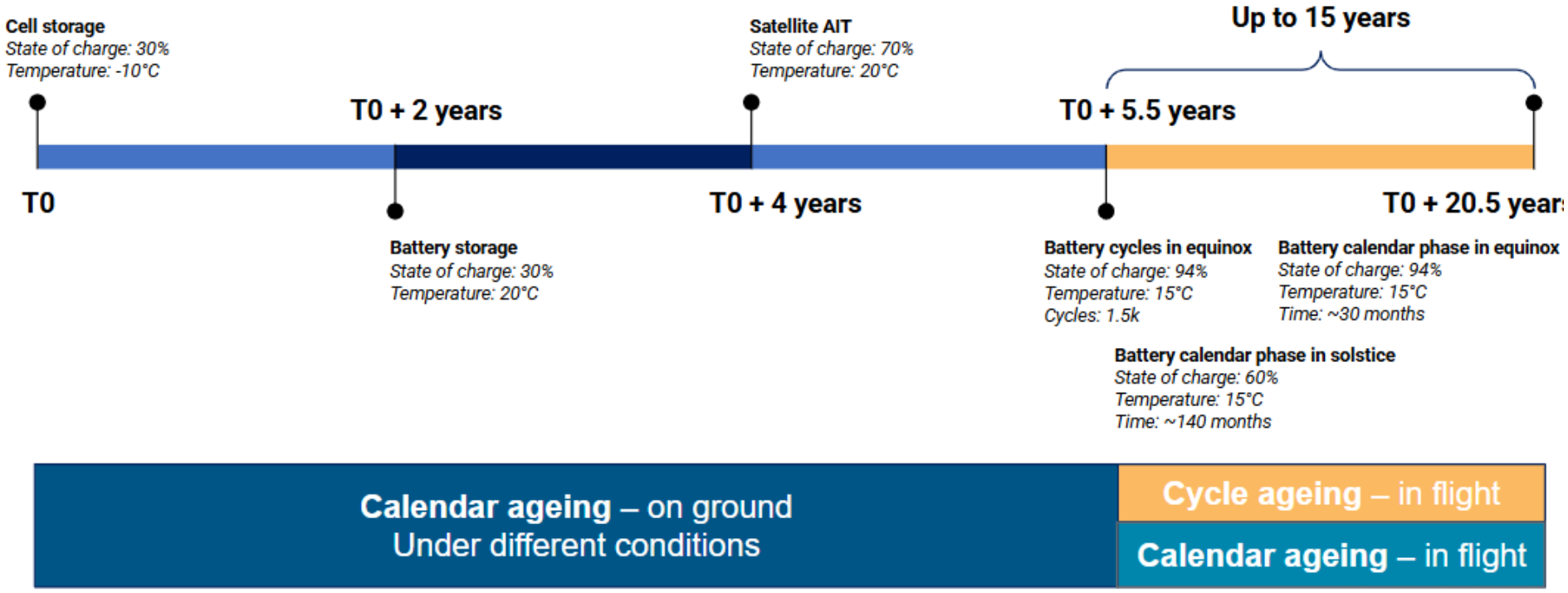
OUR KNOW-HOW | BATTERY AGEING - MISSIONS

GEO MISSIONS

Same questions as LEO.
In flight GEO missions also have **2 frequent calendars** phases at equinox & solstice: *Impacts of cycling interrupted by frequent calendars ?*



Calendar Strategy – During Solstice everything is possible Temperature, SoC & even discharging.
On the other hand during Equinox the calendar duration is a consequences of charging rate.

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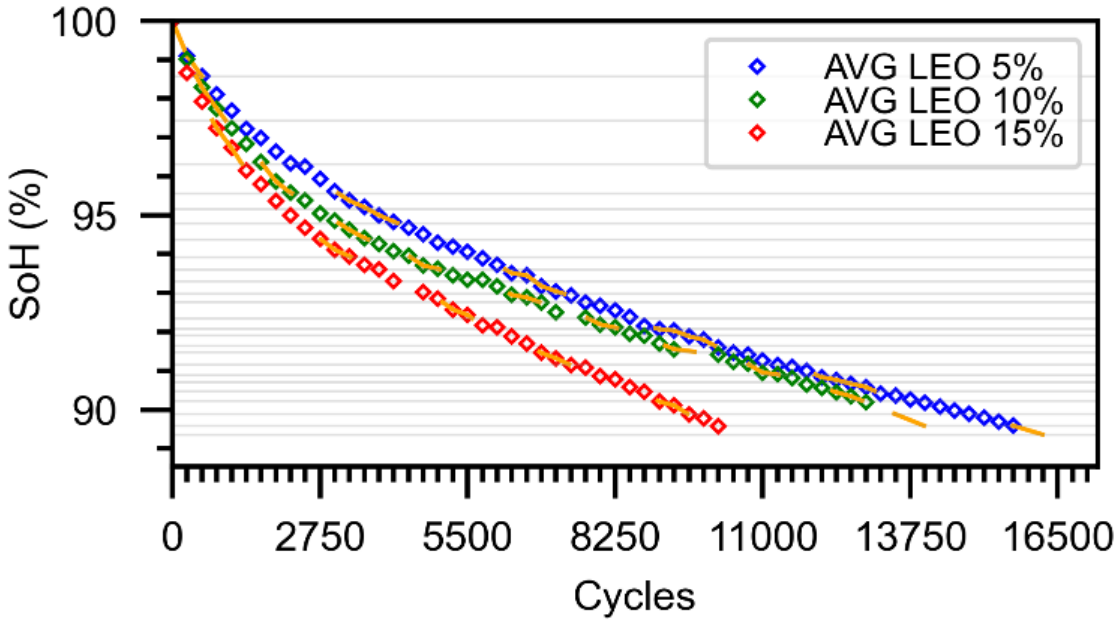
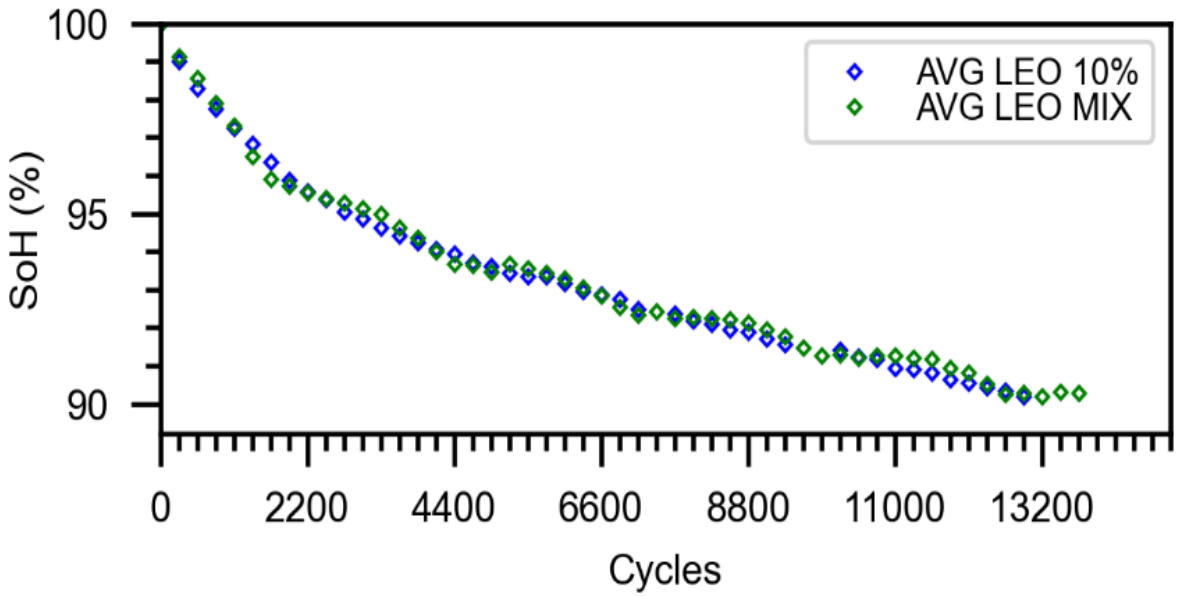
OUR KNOW-HOW | BATTERY AGEING DoD

DoD Mixed | Full-cycle testing at different DoD can be approximated by an equivalent mean DoD, which significantly simplifies ageing prediction.

SoH addition to be representative of the cycling mixed:

LEO_5% (0cycles to 1000cycles) + LEO_10% (1000cycles to 2000cycles) + LEO_15%(2000cycles to 3000 cycles) + …





The status and results presented are dependent on the cell technology / reference used.

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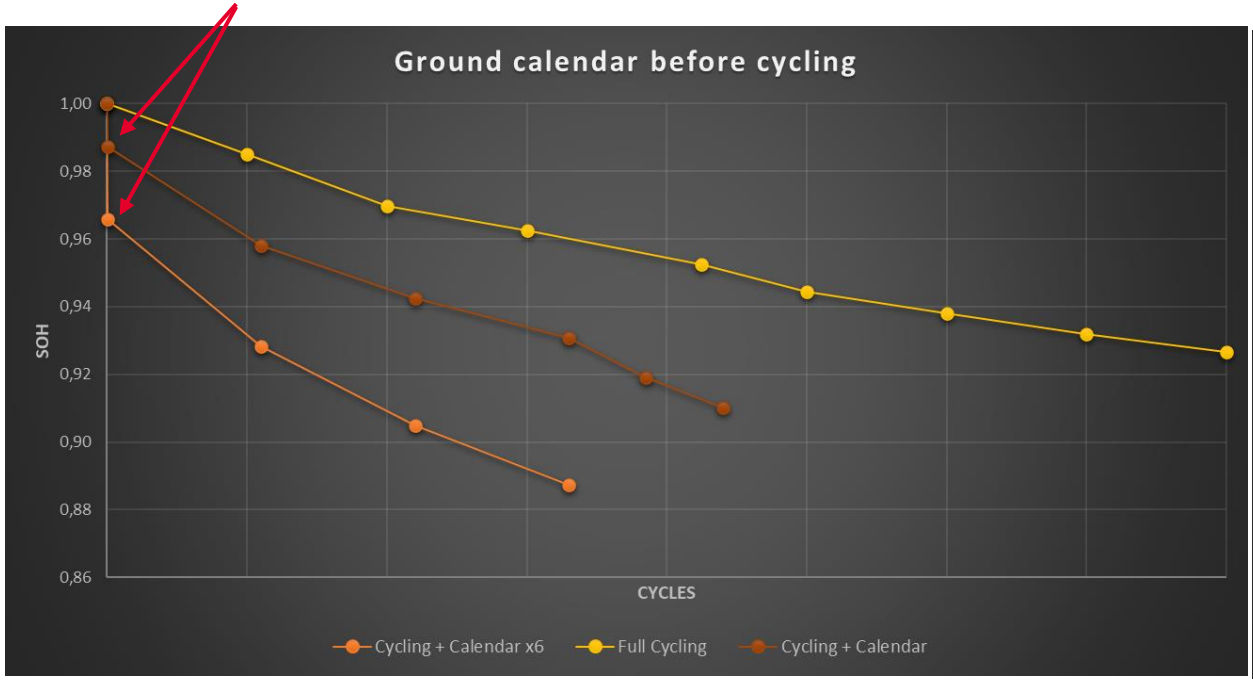
OUR KNOW-HOW | BATTERY AGEING CALENDAR

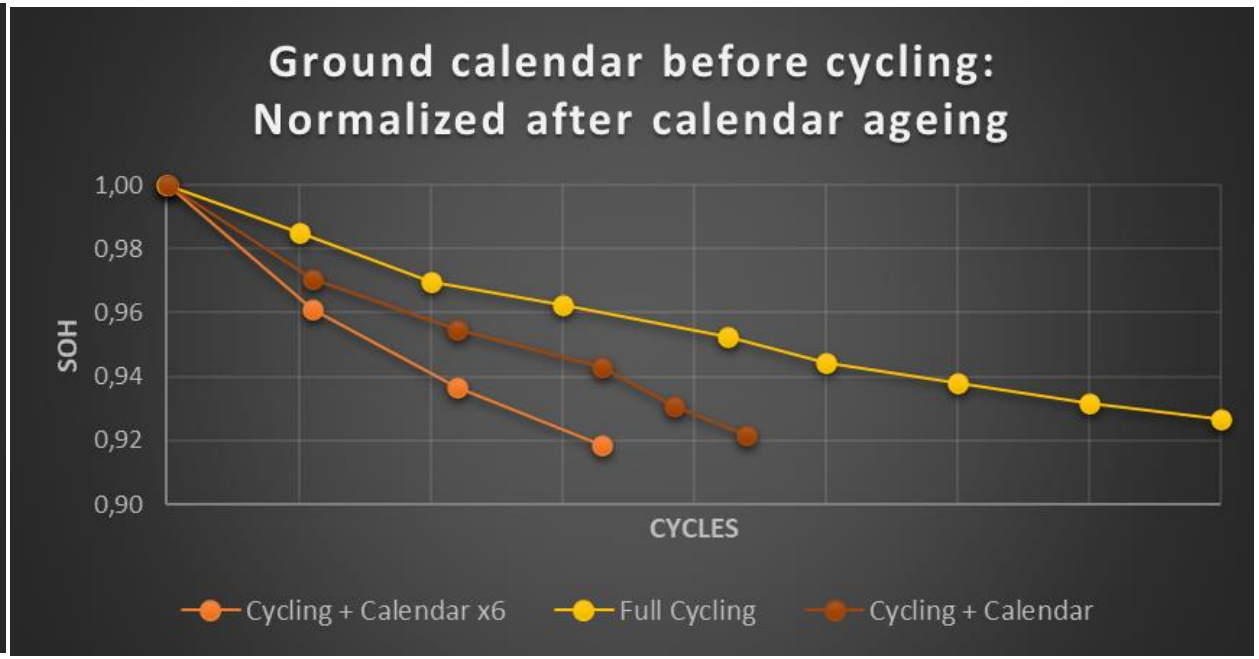
GROUND CALENDAR BEFORE FLIGHT

Extended calendar **prior to cycling influence** the **flight cycling** ageing behavior.

Preliminary results on dedicated test with different accelerated calendar ageing before cycling (same cycling conditions)

Ground calendar ageing before starting to cycle





Cycling linear ageing is impacted by ground calendar duration

The status and results presented are dependent on the cell technology / reference used.

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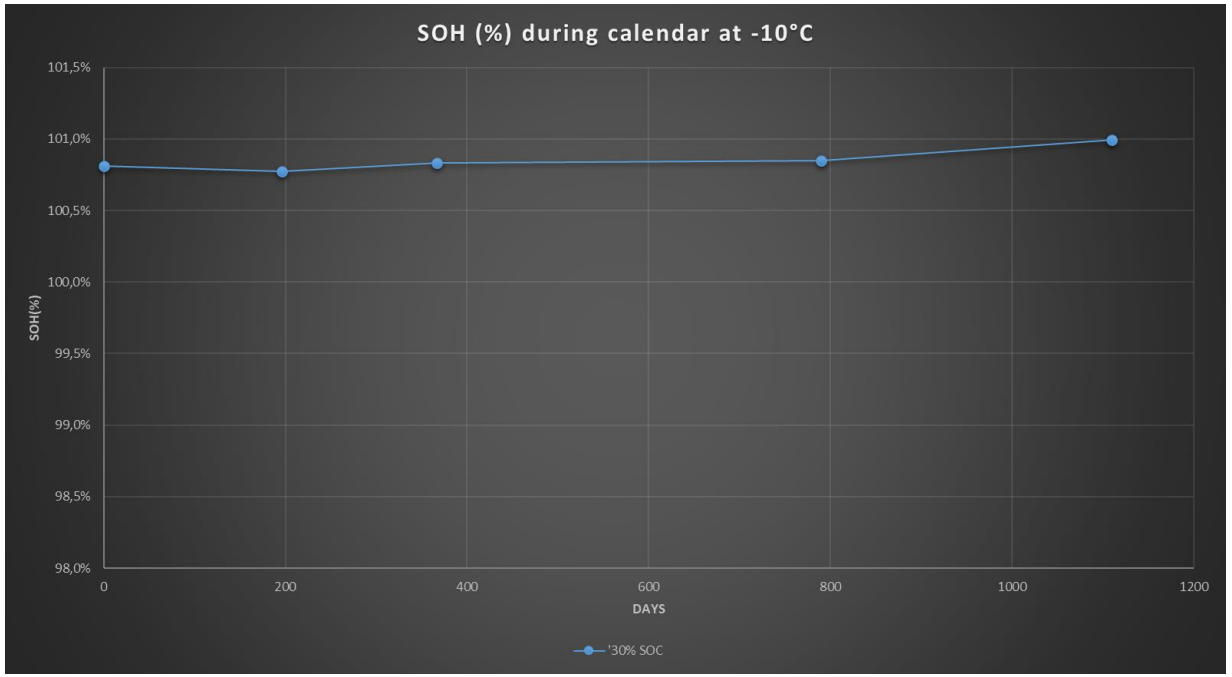
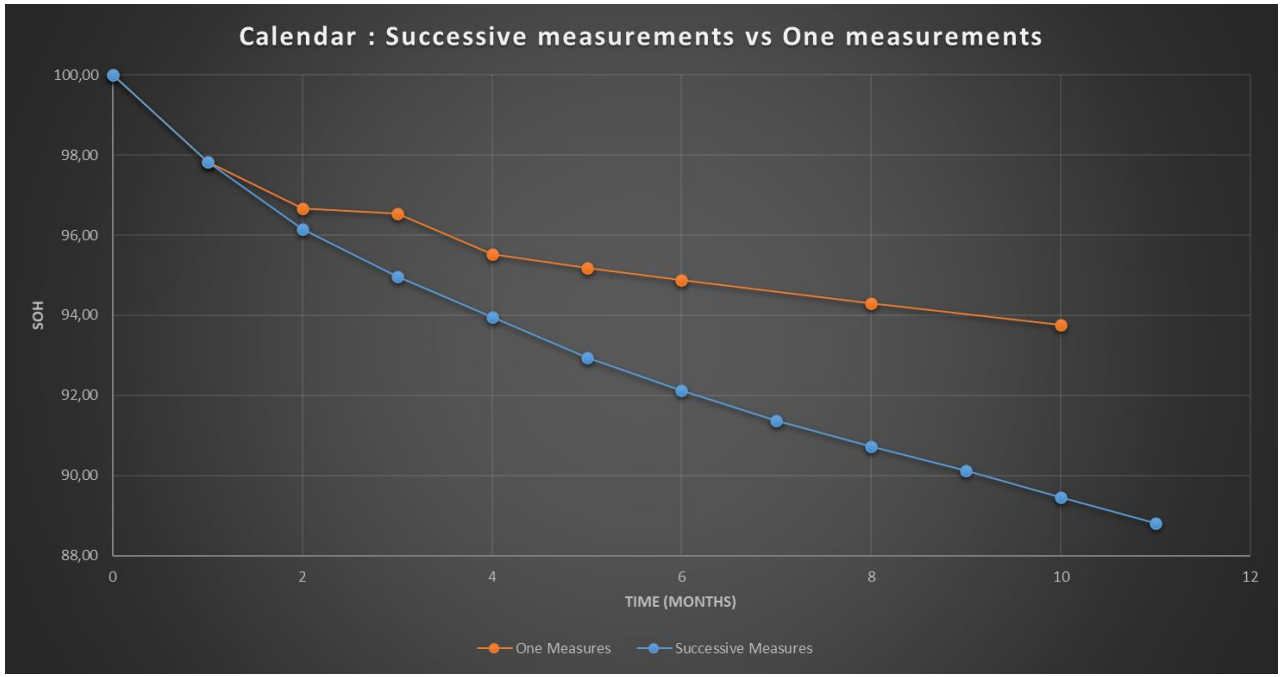
OUR KNOW-HOW | BATTERY AGEING CALENDAR

GROUND CALENDAR BEFORE FLIGHT

Ground calendar could be **minimized** through pertinent storage: **-10°C**

Pay attention to the impact of reference measurement when you are doing calendar characterization :
10 references could add 4% of additional ageing





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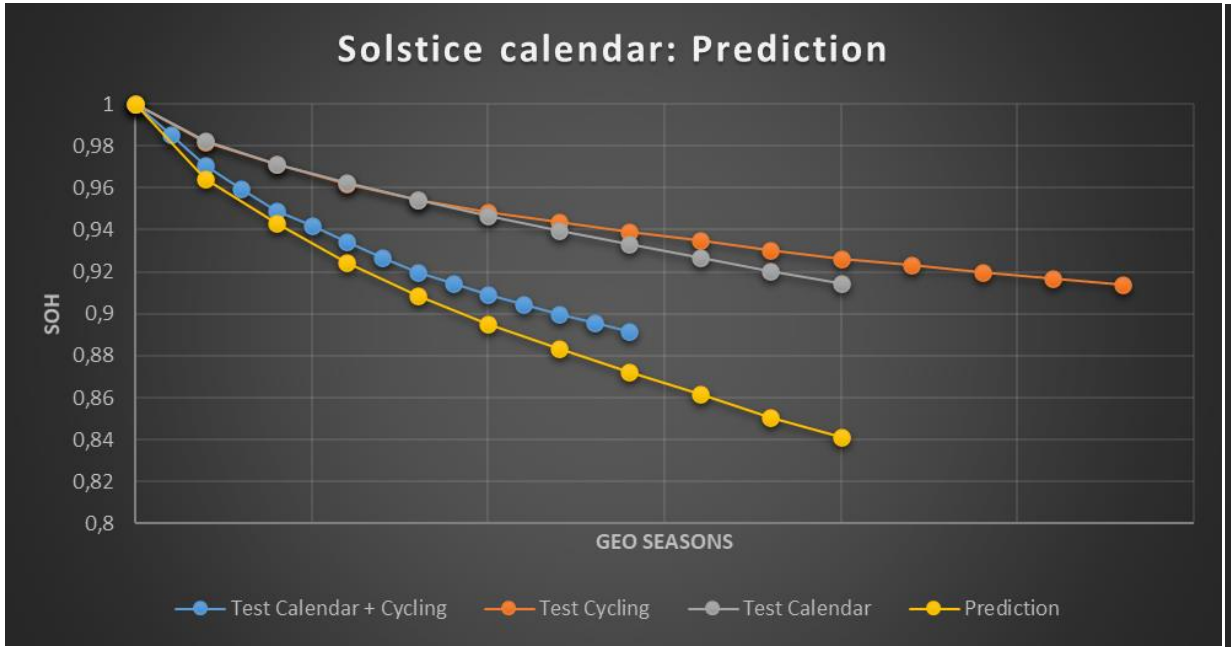
OUR KNOW-HOW | BATTERY AGEING DoD

CYCLING / CALENDAR LOOP

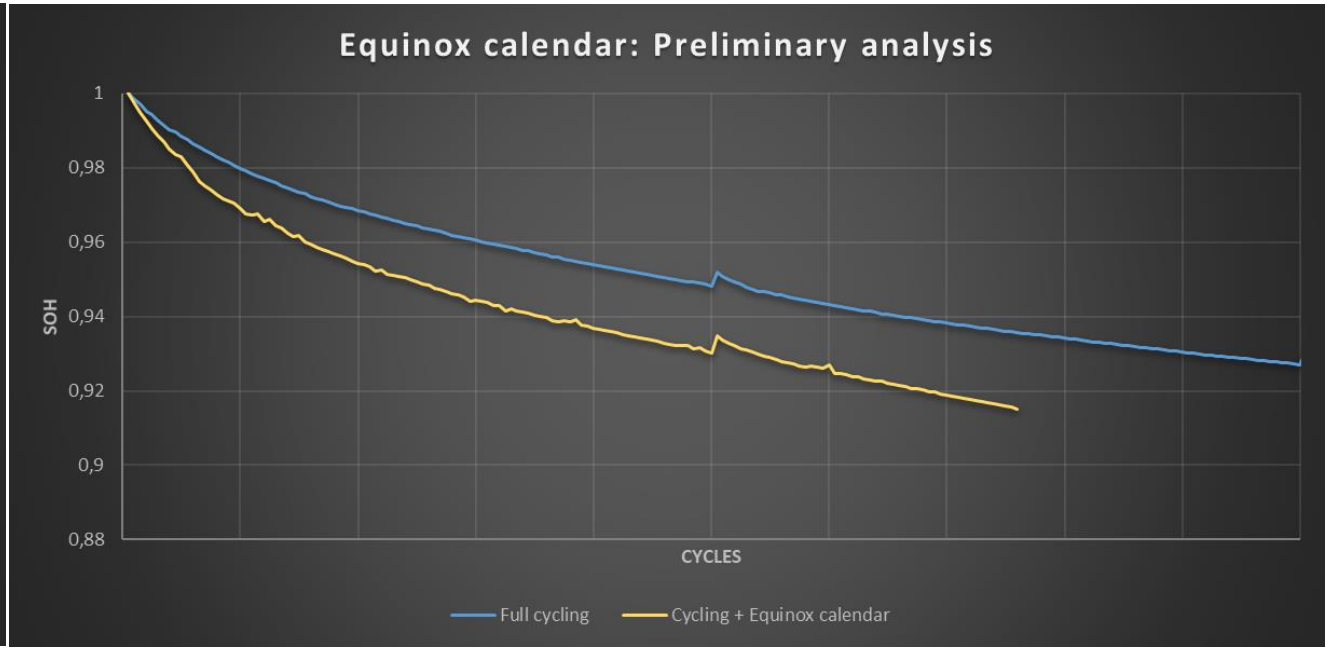
Cycling with **calendar** phases inside shows an inner **dependency** between both conditions.

Study based only on solstice calendar / cycling mixing analysis



Prediction based on **pure cycling and calendar** with successive measurements is **conservative**.

Study <u>on going</u> based only on equinox calendar / cycling mixing analysis



Equinox calendar have an **influence** on **burning** phase, after the **linear** phase is **less** impacted.

A focus must be done on equinox calendar due to the higher state of charge

The status and results presented are dependent on the cell technology / reference used.

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4 - Conclusion

SPACE BATTERY PRODUCTS | CONCLUSION

Acceleration

- *Discretization is feasible but characterize all dependencies*
- *High temperature for calendar ageing*
- *Discharging rate for cycling ageing*
- *Nominal mission are required to evaluate your prediction*

Dependencies

- *Mixed depth of discharge can be simplified to the average of DoD*
- *Ground calendar influences your in-flight cycling ageing*
- *Ground calendar can be minimized through low temperature storage*
- *In flight mixed calendar and cycling are interdependent but predictable via total ageing summation*

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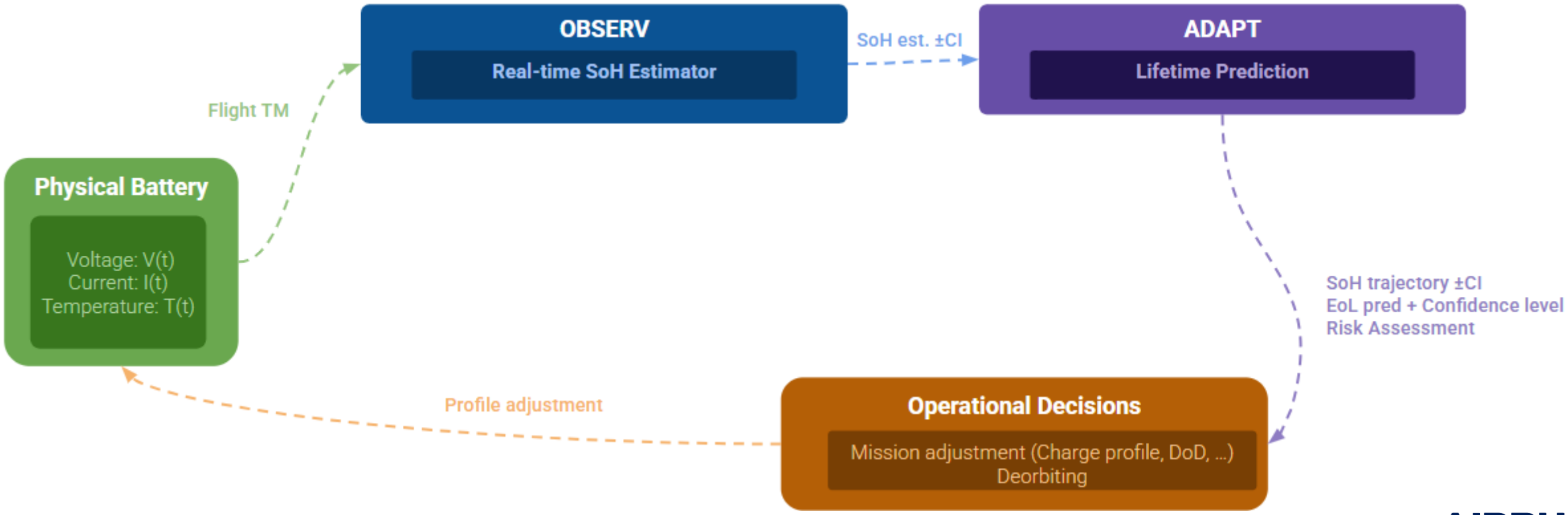
SPACE BATTERY PRODUCTS | ANTICIPATING THE FUTURE

OBSERV-ADAPT
Battery Digital Twin

TRL 6 - 2028

A closed-loop architecture supporting informed decision-making:

- *A behavioral model (2RC-ECM): capturing the essence of battery performance*
- *A Synchronization Engine (**OBSERV**): bridging the gap between virtual & real worlds*
- *A Predictive Engine (**ADAPT**): forecasting the future of battery performance*
  - *Standalone design: can be used independently during the design phase for sizing activities, allowing engineers to optimize battery specifications and configurations*



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Thank you

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