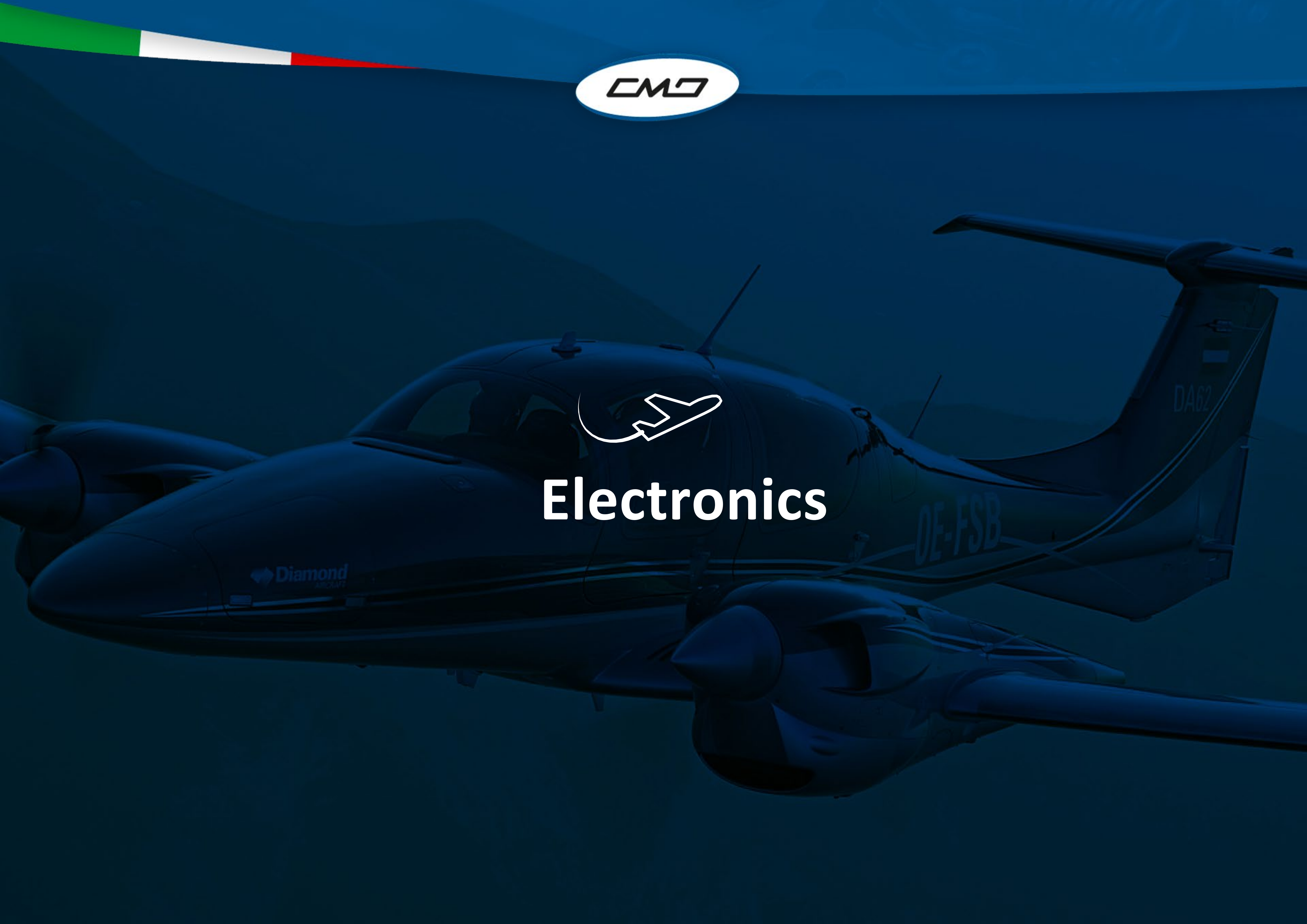
Your Partner for sustainable mobility

www.cmdengine.com

CISQ AUTOMOTIVE
Consorzio di Organismi di Certificazione Italiani dei sistemi di gestione aziendale accreditato IATF

www.cisqautomotive.it

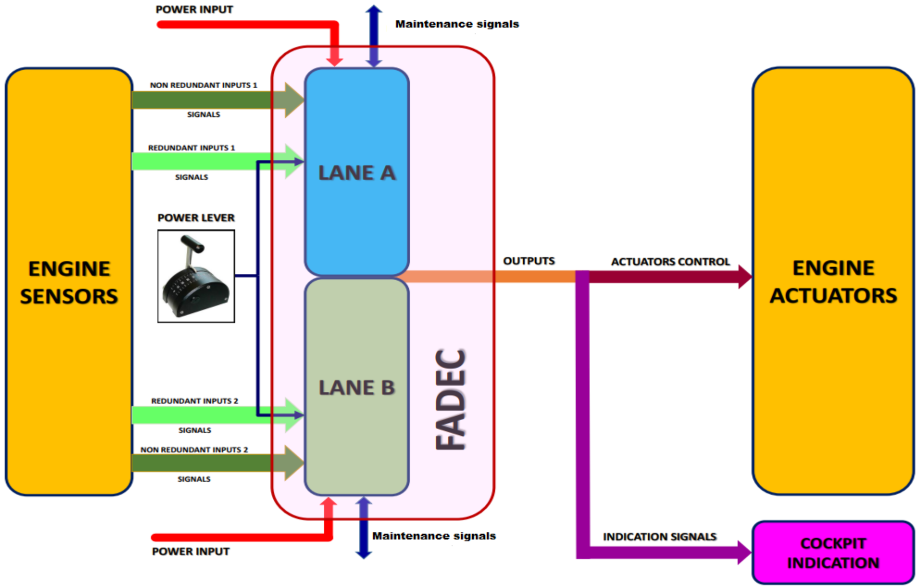


Electronics

FOCUS ON AEROSPACE – CMD FADEC

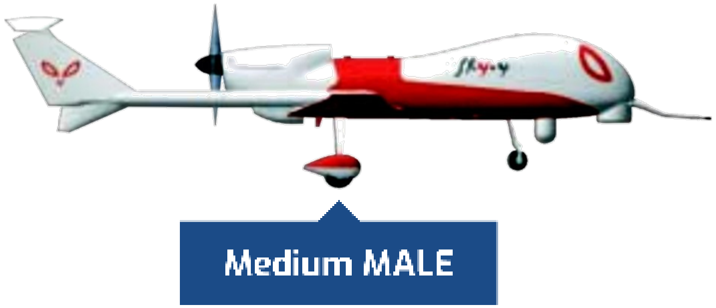
The new solution for General Aviation Diesel Engines is a full redundant electronic control unit for Common Rail Diesel Engines with single lever power control.

CMD FADEC provides the capability to control the fuel quantity depending on engine operating conditions.
CMD FADEC has a primary system and a backup system. The backup system acts as a hot-standby unit, available to assume engine control in the event of failure of the primary system.
CMD FADEC is compliant to the civil aviation standards RTCA DO-178B , DO-254 and RTCA DO-160G.



TYPICAL APPLICATIONS

CMD FADEC is a solution for aircrafts having 2 to 6 seats and certified according to EASA CS-23/FAR 23 as well as rotorcrafts certified according to EASA CS-27 and EASA CS-29.



The engines range power is from 230 to 350 horsepower (173 to 260 kw) and typical aircraft is powered by piston engines such as the Lycoming O540 family and the Continental 550 family for single and twin-engine aircraft .

CORE COMPETENCIES FOR FADEC PROJECT

CMD is capable to cover the entire development lifecycle of a safety-critical system. CMD engineers have addressed all hardware and software aspects from requirements to the final product.

SYSTEMS ENGINEERING

HARDWARE ENGINEERING

SOFTWARE ENGINEERING

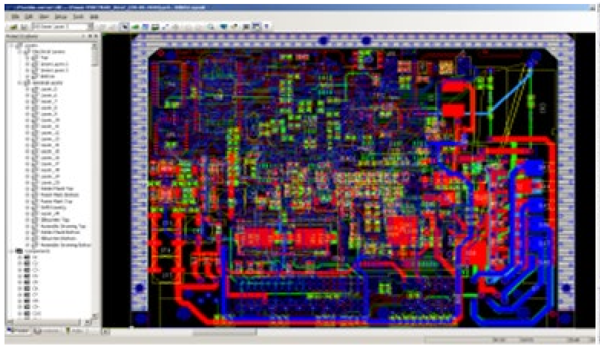
SAFETY ENGINEERING

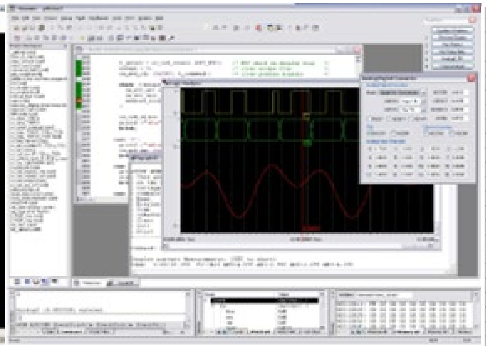
CMD FADEC is able to:

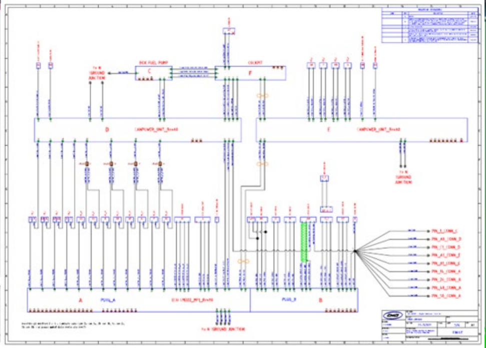
ENHANCE FLIGHT SAFETY

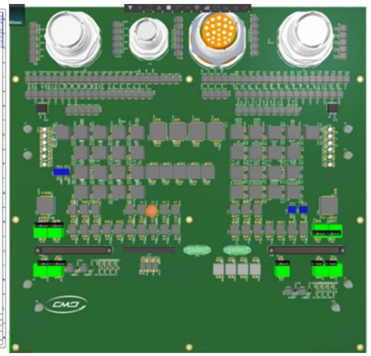
REDUCE FUEL CONSUMPTION

OPTIMIZE MAINTENANCE

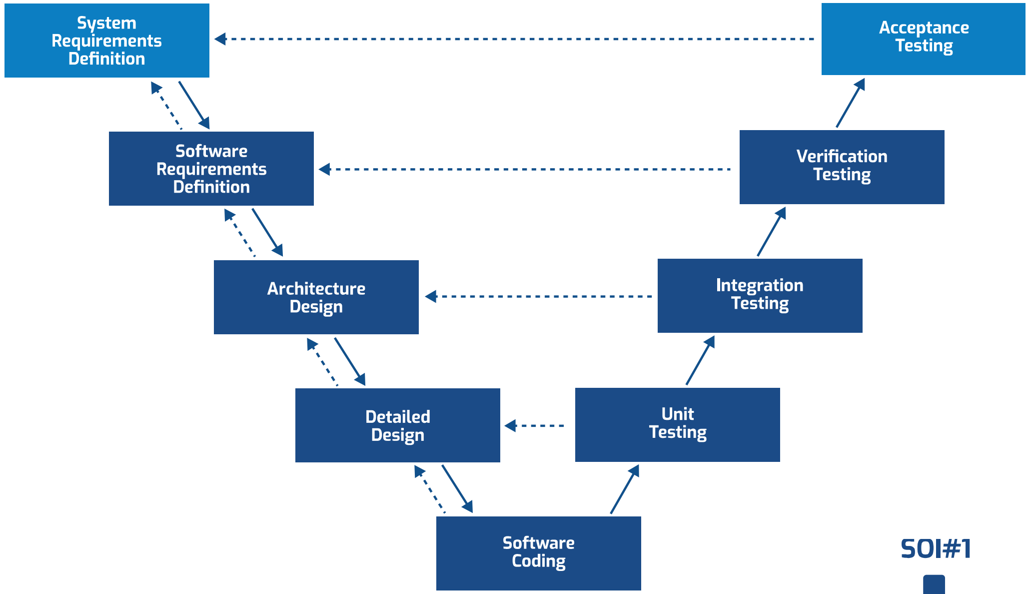






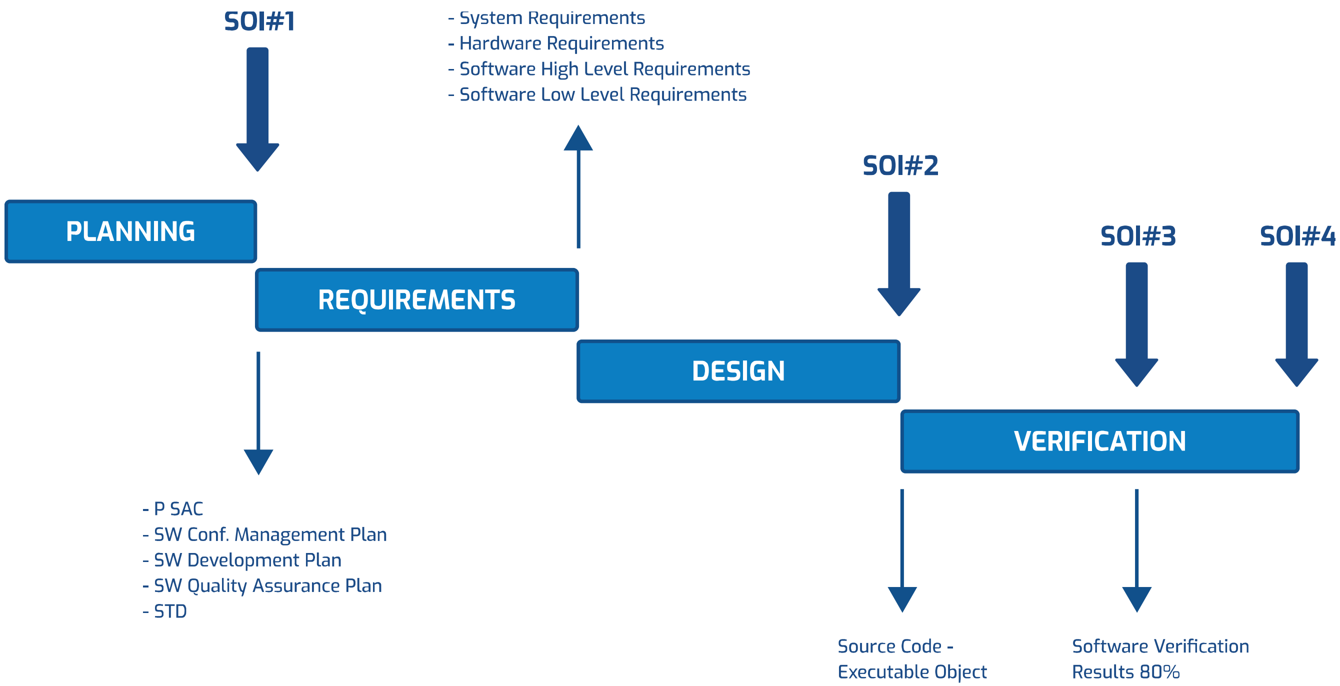


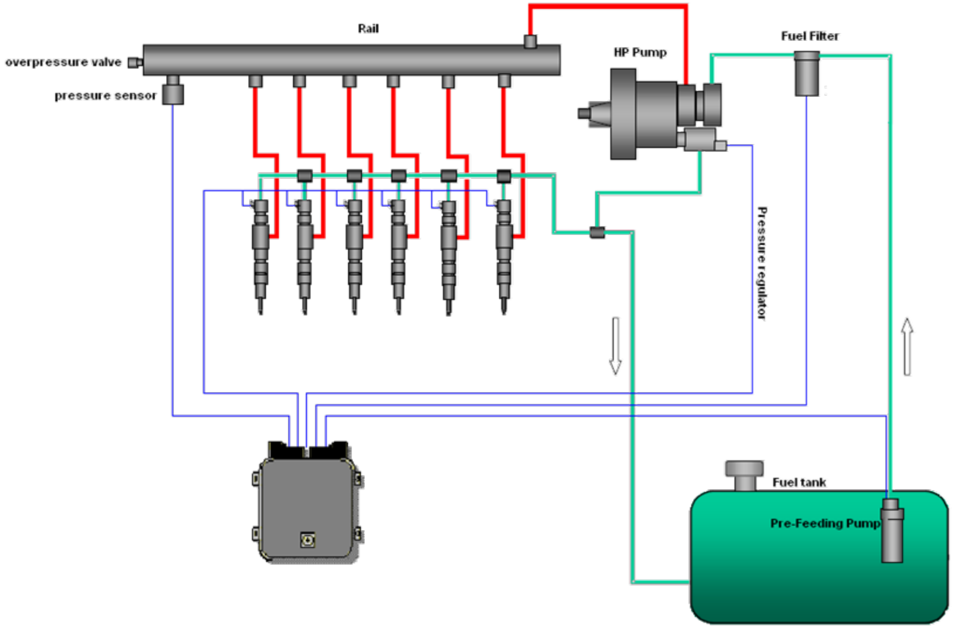
Software Development Process based on DO-178 C



According to the RTCA/DO-178C, the Software Development Process is the set of activities that produce the software product. They are:

- Software Requirements Process;
- Software Design Process;
- Software Coding
- Integration Process;
- Software Verification Process.





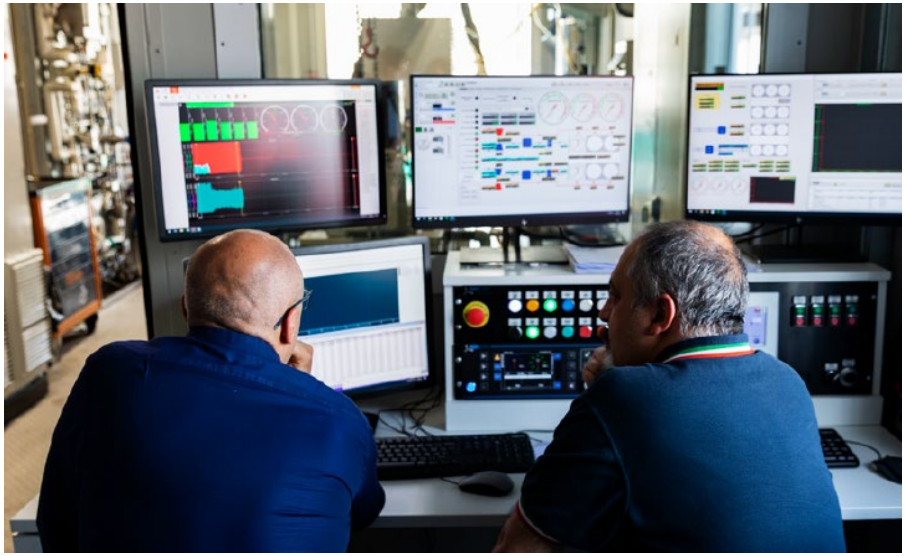
The power setpoint is determined through the power lever. The FADEC receives the power requirement data and computes the quantity of fuel, injection timing and other settings adding data received from analog sensors or through data bus connections.

By means of algorithms FADEC calculates the start-of-injection, injected-fuel-quantity , rail pressure and triggers the corresponding actuators.

Use or disclosure of the information contained herein is subject to specific written approval from CMD.

Main control algorithms are implemented by CMD engineers

- Engine synchronization
- Injection control
- High pressure control
- Low-idle governor
- Engine protection
- Propeller control
- Boost pressure control
- Self-diagnosis



The control laws model are simply parameterizable on the test bench with standard tools such as ETAS-INCA. Furthermore, the basic software already offers an extensive engine and diagnostic data communication.

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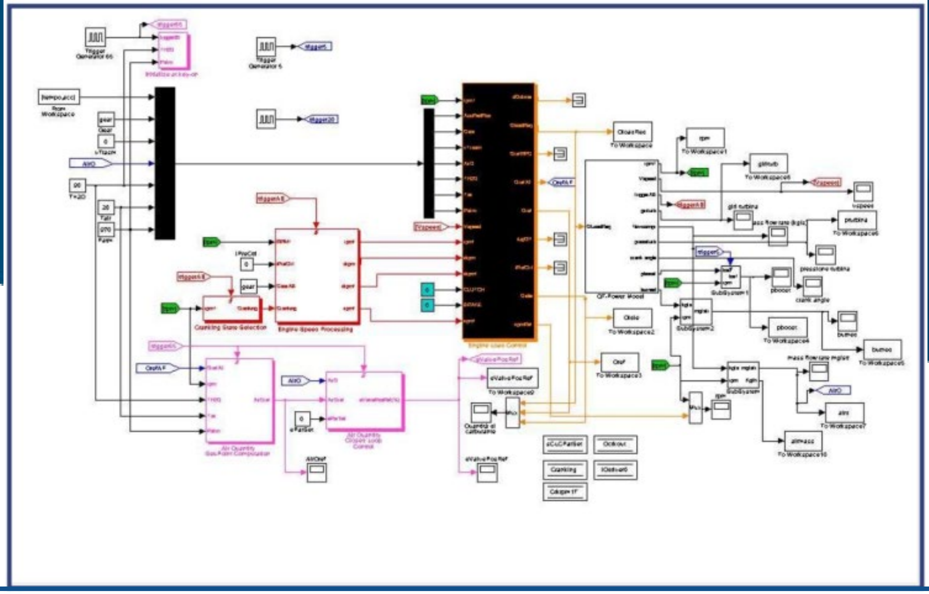
FADEC verification at HIL test systems



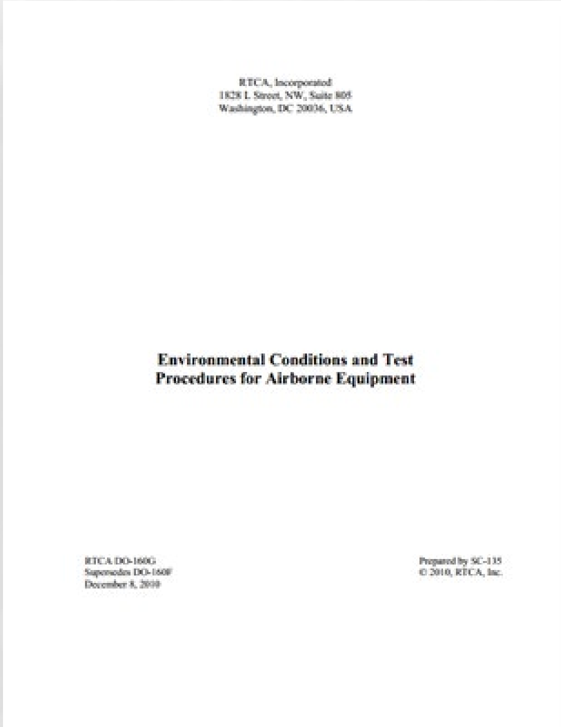
1 Complete Simulation (FADEC and Engine with Propeller)

2 Validation and verification of software design in offline simulation

3 Development of HIL Test Systems

DO-160G Tests

SECTION	DESCRIPTION	CATEGORY GF56
4.0	TEMPERATURE & ALTITUDE	B2
5.0	TEMPERATURE VARIATION	B
6.0	HUMIDITY	A
7.0	OPERATIONAL SHOCKS and CRASH SAFETY	B
8.0	VIBRATION	S, curve M and L
		U, curve G
9.0	EXPLOSIVE ATMOSPHERE	X (N.A.)
10.0	WATERPROOFNESS	S
11.0	FLUID SUSCEPTIBILITY	X (N.A.)
12.0	SAND and DUST	S or D
13.0	FUNGUS RESISTANCE	F
14.0	SALT FOG	S
15.0	MAGNETIC EFFECT	A
16.0	POWER INPUT	Z
17.0	VOLTAGE SPIKE	A
18.0	AUDIO FREQUENCY CONDUCTED SUSCEPTIBILITY - POWER INPUTS	Z
19.0	INDUCED SIGNAL SUSCEPTIBILITY	ZC-X
20.0	RADIO FREQUENCY SUSCEPTIBILITY (RADIATED and CONDUCTED)	W
		W
21.0	EMISSION OF RADIO FREQUENCY ENERGY	L
22.0	LIGHTNING INDUCED TRANSIENT SUSCEPTIBILITY	A3 (pins)
		C3 (bundle)
		G3 (bundle multi stroke)
23.0	LIGHTNING DIRECT EFFECTS	X (N.A.)
24.0	ICING	X (N.A.)
25.0	ELECTROSTATIC DISCHARGE (ESD)	A
26.0	FIRE, FLAMMABILITY	C


RTCA, Incorporated
1828 L Street, NW, Suite 805
Washington, DC 20036, USA

Environmental Conditions and Test Procedures for Airborne Equipment

RTCA DO-160G
Supersedes DO-160F
December 8, 2010

Prepared by SC-135
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BACKGROUND ON CMD'S FADEC PROJECT

On January 2018 CMD obtained the engine Type Certificate issued by EASA, European Aviation Safety Agency for CMD22 gasoline engine.
The engine is managed by a CMD FADEC qualified addressing DO160G Standard. Certificate issued from EASA, European Aviation Safety Agency.

CMD and Infineon sign an agreement to supply and support FADEC development for microcontroller Aurix family.

CMD has developed GF56 diesel engine common with a typical common rail injection system .
CMD FADEC was developed for GF56 fuel management.

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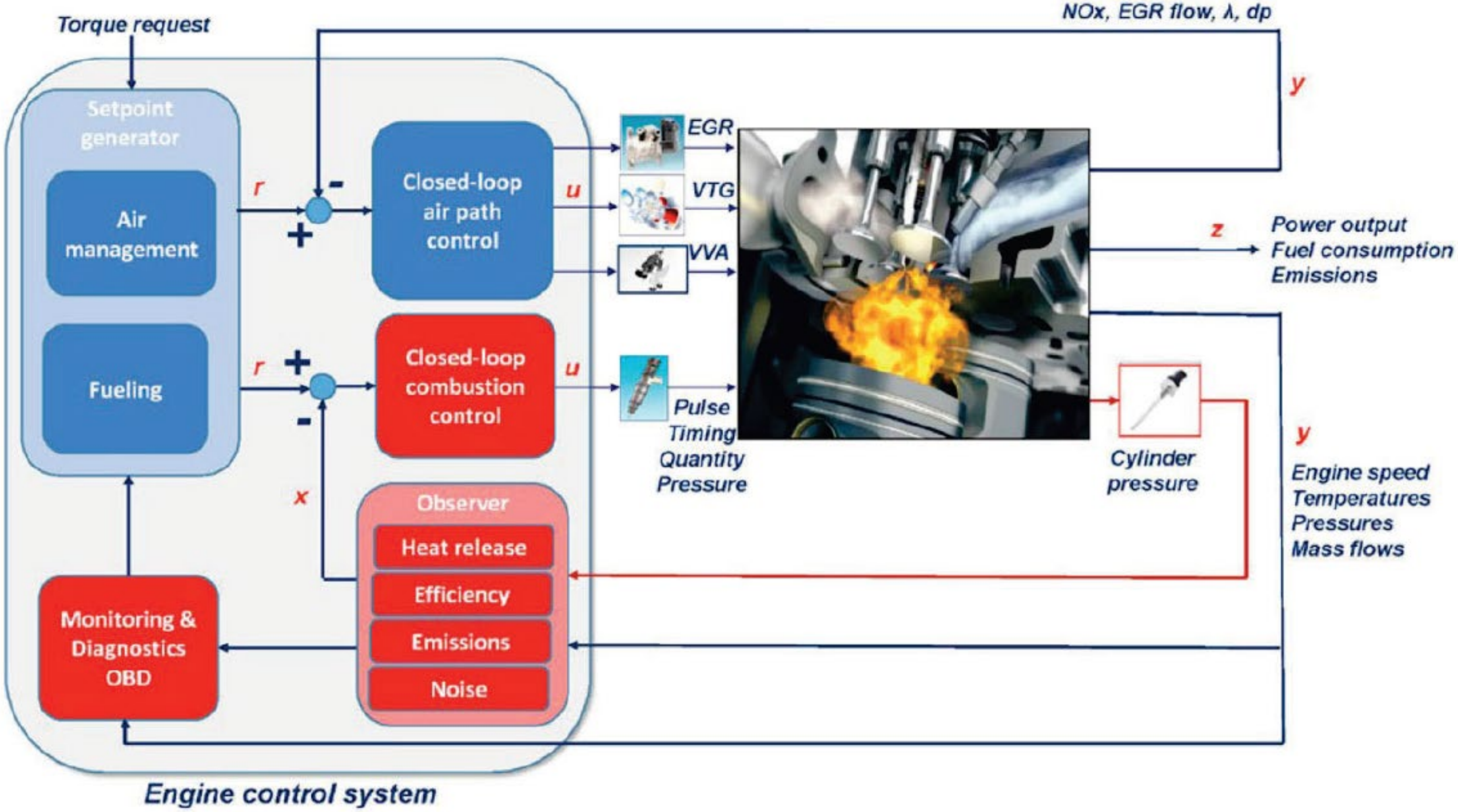
SAF (Sustainable Aviation Fuels)



Based on cylinder pressure detection and measurement of all relevant variables in flight operations the combustion process is optimizated.
The control strategy for the use of SAF fuels offers advantages as reduction in consumption, NOx and CO2.

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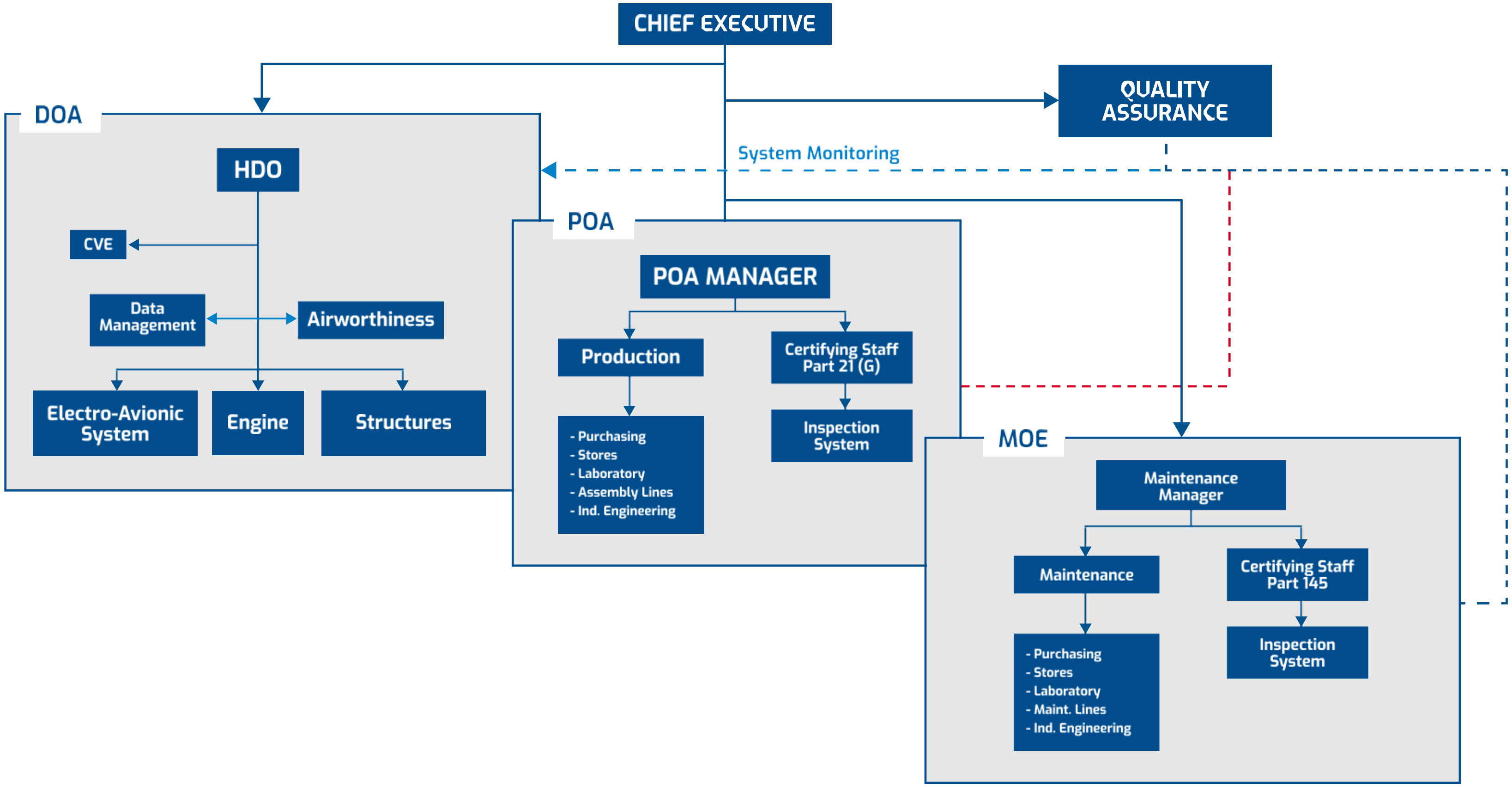
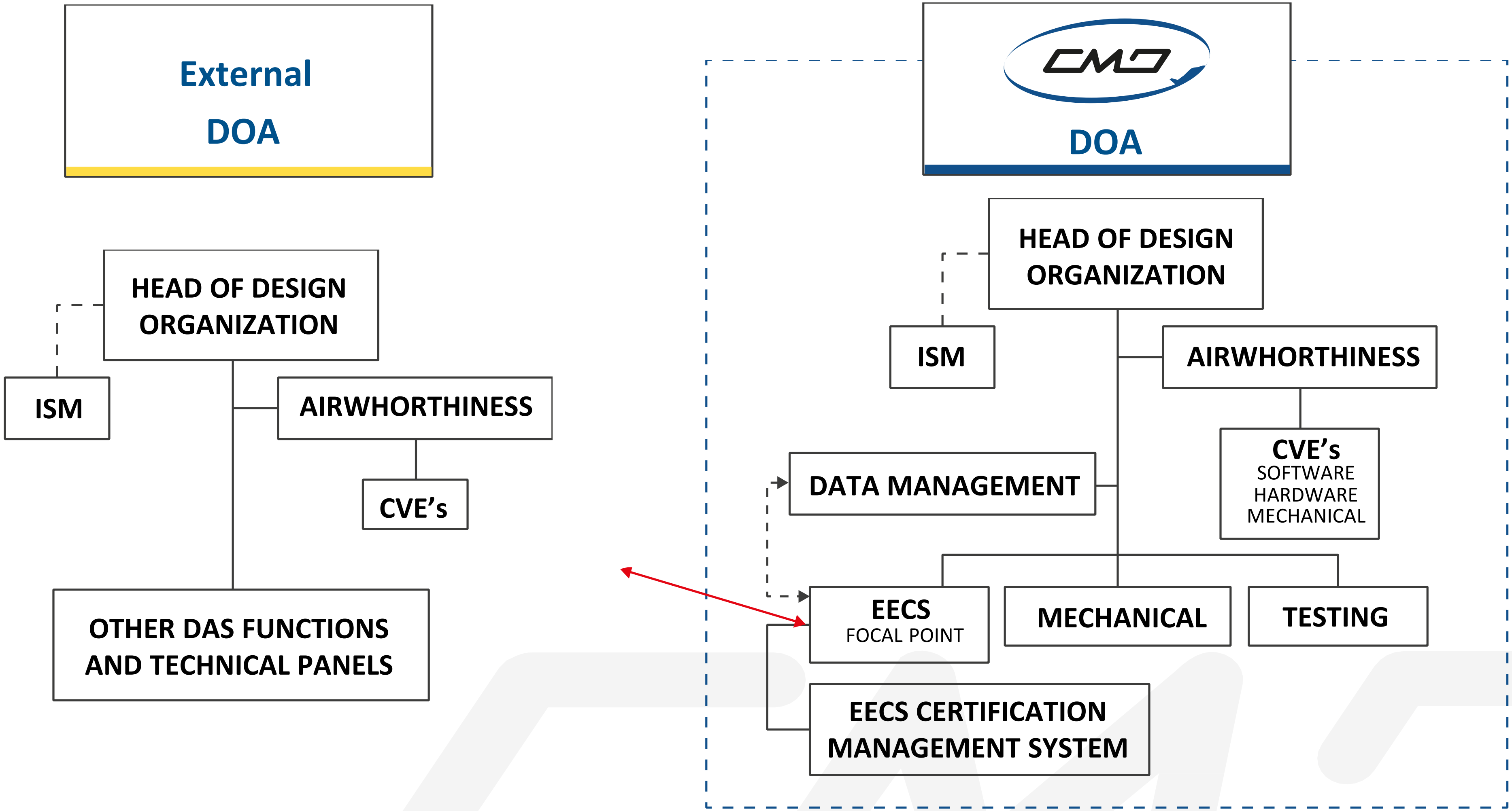
DOA and POA: advantages to compete

CMD is a company involved in the aviation market as piston engine designer and manufacturer.
CMD is among the few Italian SMEs recognized by EASA as compliant with the requirements of Part 21 Subpart J and G.

CMD has obtained a Design Organisation Approval (DOA) and a Design Organisation Approval (POA).

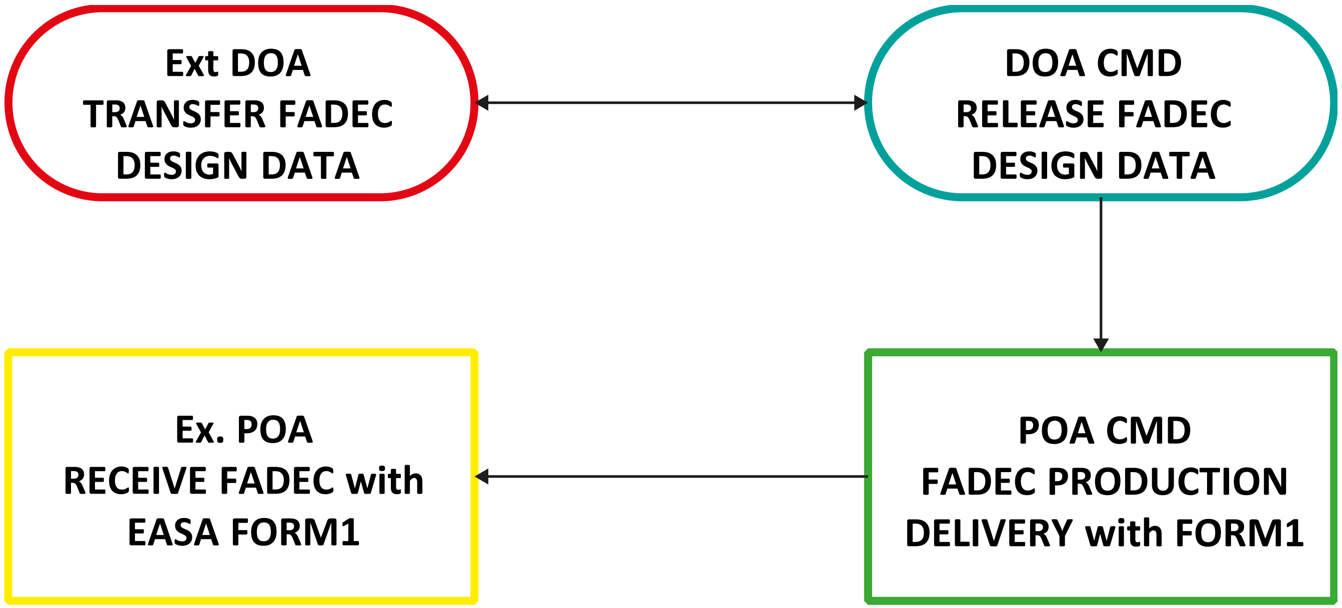


DOA – DOA Relationship



PRODUCTION PHASE

DOA – POA Relationship

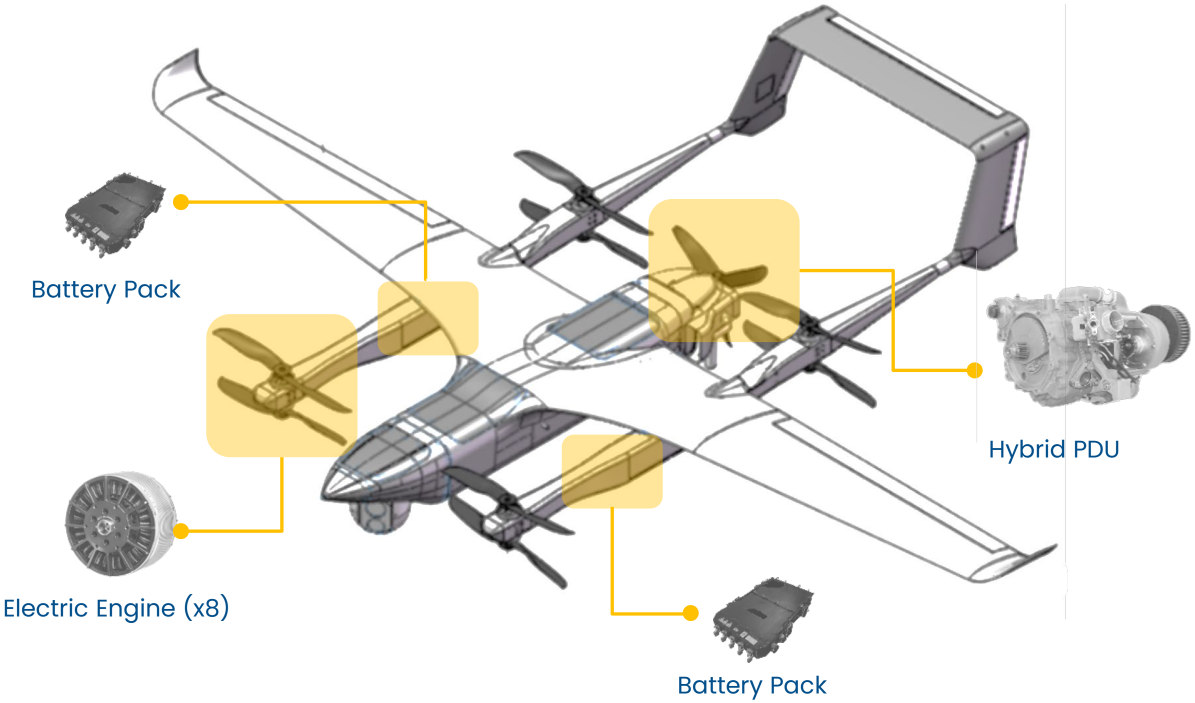


Hybrid Propulsion
and
HCU (Hybrid Control Unit)

UAV APPLICATIONS:

CMD is already developing Customers' solutions for UAV projects where a **PDU based on rotary engines** could add value to the final application:

Example of an ongoing project for an UAV eVTOL :



eVTOL SPECIFICATION:

- Automatic Vertical Takeoff and Landing
- MTOW: **350Kg**
- Max Speed: **130 km/h**
- Flight Time: **5h**
- Max altitude: **3 km**

CMD HYBRID PROPULSION PLATFORM:

- Hybrid PDU: 40 kW (ICE + Electric)
- Power Generator: 4 kW
- Lift Engines: 15 kW electric – coaxial design (x8)
- Battery Packs: NMC 5,5 kWh @ 108V
- Weight of Propulsion system: 98 kg (including batteries)

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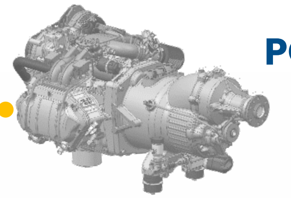
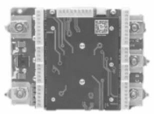
HYBRID PROPULSION ARCHITECTURE:



POWER DISTRIBUTION UNIT

PISTON HYBRID PROPULSION

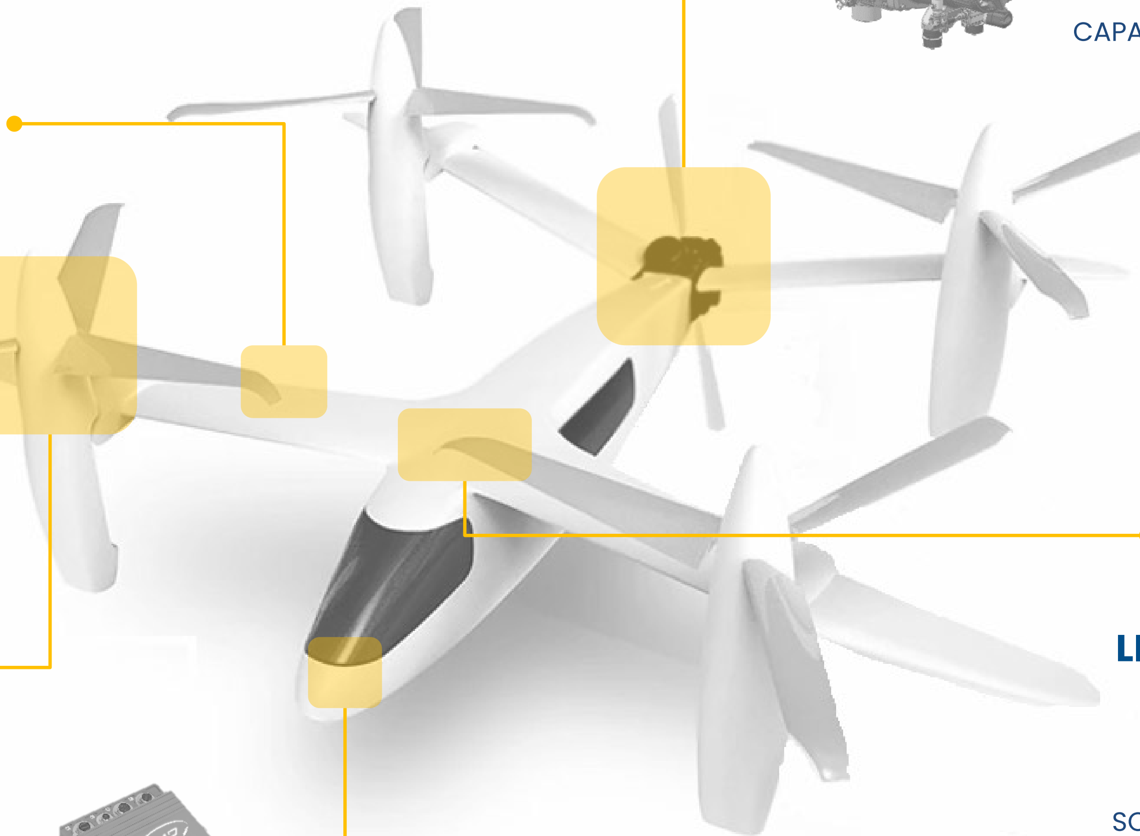
CAPABLE OF DIFFERENT OPERATION MODES



MOTOR CONTROLLERS

MEDIUM AND HIGH VOLTAGE ESC

INDUSTRIAL DRONES AND AERO APPLICATIONS SPECIALIZED

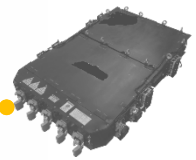


ELECTRIC ENGINES

FROM 10kW to 100kW

LIQUID /AIR COOLED BLDC MOTORS

PROVIDING LIFT, SPEED AND FLIGHT CONTROL



LI-ON BATTERY PACKS

FROM 120V TO 800V

MAIN OR ADDITIONAL POWER SOURCE DEPENDING ON PHASE OF FLIGHT

HYBRID PROPULSION CONTROL UNIT

(HPCU)

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HCU – Hybrid Control Unit

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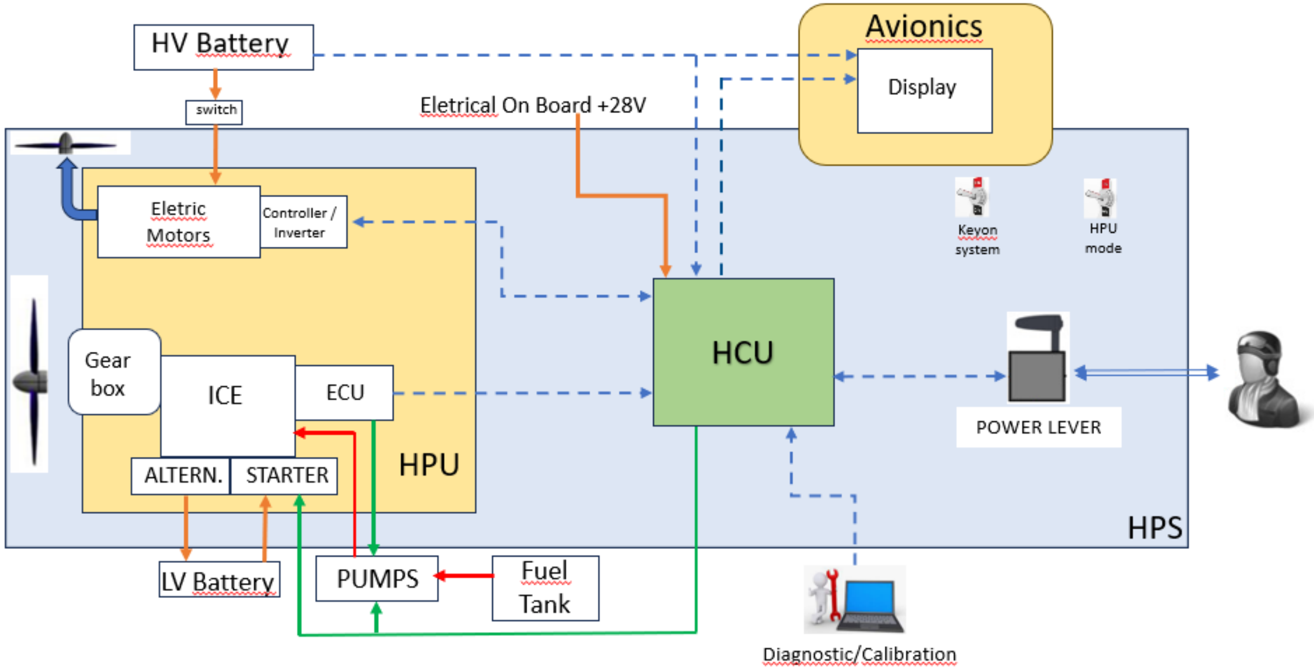
HCU is the main supervisor to manage and control automatically the hybrid powertrain in all operating and use conditions.



FUNCTIONS

Electronic Management

- electrical take-off management
- Start/ Stop Hybrid propulsion unit sand engines in regard of current energy levels
- Cooling management
- System Monitoring
- System failures/ limitations compensation

From cockpit demands

- Elaborates commands to ICE Engine and Electrical Motors ECUs accordingly the Power Lever position and selected mode
- Start and stop commands
- System parameters Display

Battery Recharge/Regenerative Braking

Managing the Propultion Battery recharge during deceleration or proluplsion, using the ICE Engine as a generator

Aviation

Marine

Main HW features:

- 4 independent CAN nodes
- 16 Digitali inputs
- 16 Analog inputs
- Up to 16 Open Drain Outputs

Reference standards

The infineon HW/SW **Aurix** Platform is ideal for safety critical embedded application that require compliance to the reference standards

- **DO-178C**
- **DO-254**
- **DO-160G**

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WELCOME TO THE NEW ERA OF AVIATION POWERTRAINS:

POWER POD

A revolutionary, self-contained **hybrid power system**, designed for Advanced Air Mobility and eVTOL flight mission profile.

- **185 kW** maximum power (200 secs)
- **40 kW** continuous power
- **130 kg** mass
- **1.334 Wh/kg** energy density (4h flight)
- Uses **AVGas** 100LL

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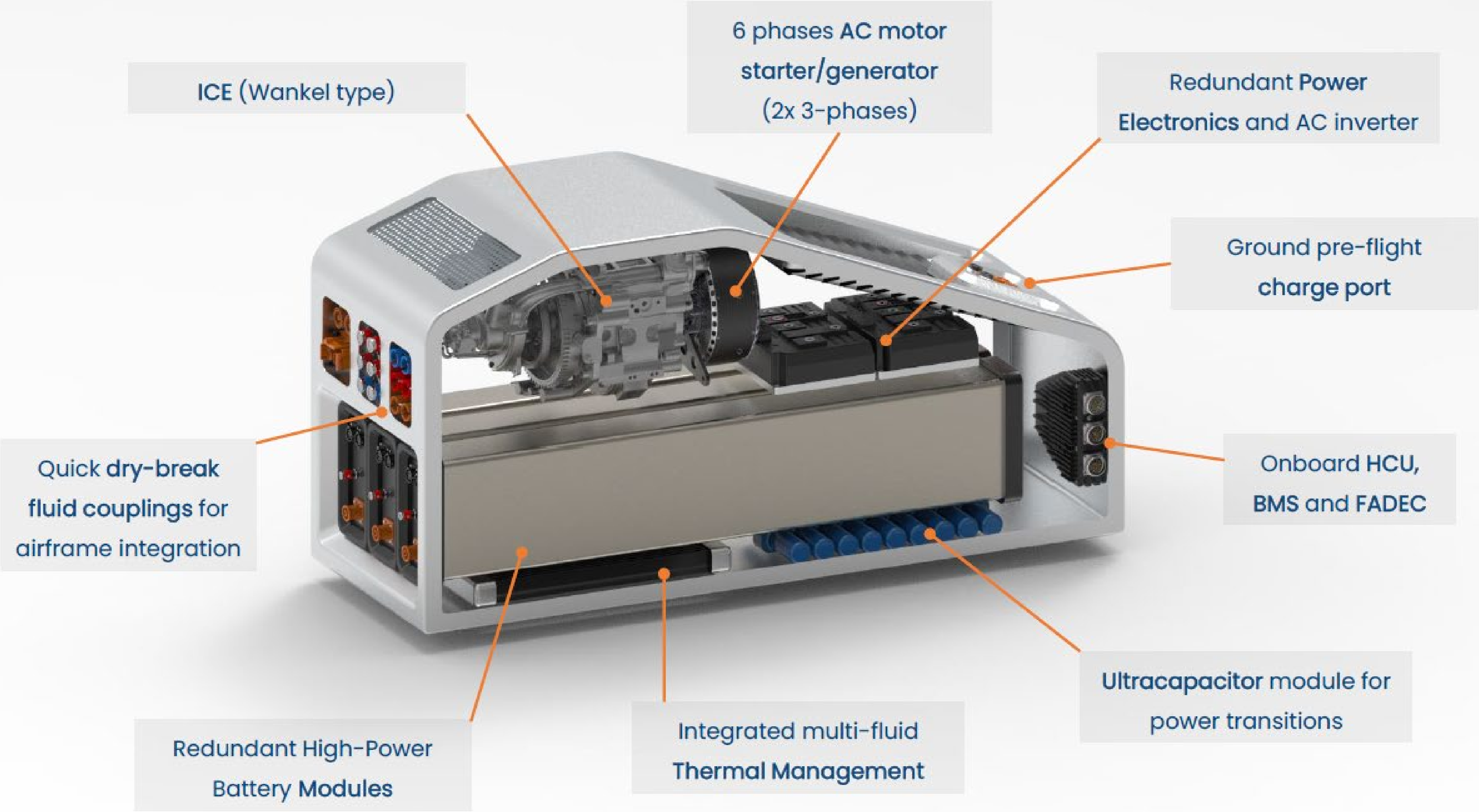


Use or disclosure of the information contained herein is subject to specific written approval from CMD.

PRODUCT ROADMAP:

2025

Power POD 40

- 40 kW generator
- Single piston Wankel ICE

2026

Power POD 150

- 150-180 kW generator
- 4 cylinders SAF fuel engine

2029

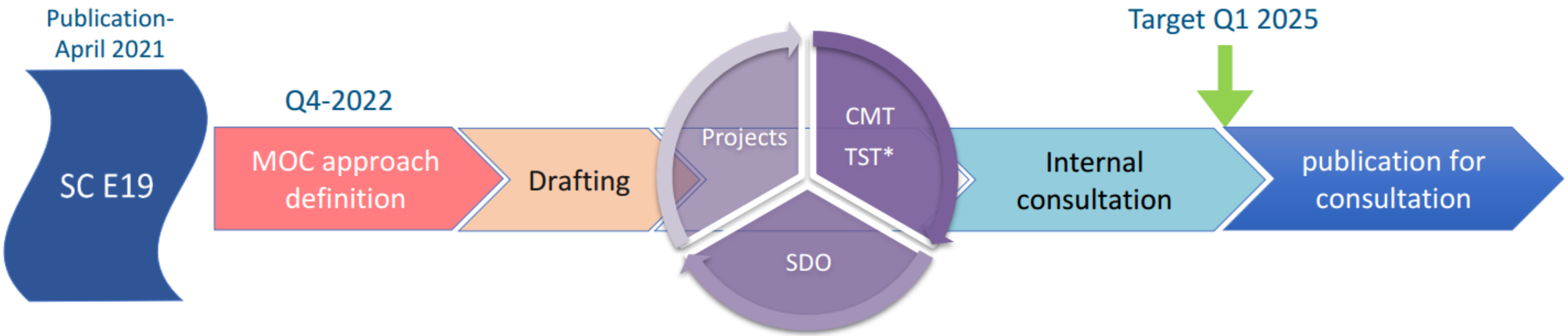
Power POD 500

- 500+ kW generator
- Turboshaft engine

Use or disclosure of the information contained herein is subject to specific written approval from CMD.

BMS
Battery Management System

SC E19 – Means of Compliance (MOC) Priority 1



MoC under definition

EHPS.370 Electrical Power Generation, Distribution and Wirings
EHPS.380 Propulsion Battery
- Electrical Charger

1st Draft Initiated

EHPS.40 Ratings and operating limitations
EHPS.100 Fire protection
EHPS.350 EHPS Control System

Under review

EHPS.80 Safety Assessment
EHPS.420 Endurance substantiation
EHPS.430 Durability demonstration
EHPS.450 Tear Down inspection

Ready for public consultation

EHPS.240 Overspeed and rotor integrity
EHPS.250 Rotating Parts Containment

*CMT – Certification management team
TST – Task Specific Team
SDO – Standards Development Organization

Working groups supporting the activity -> Join!

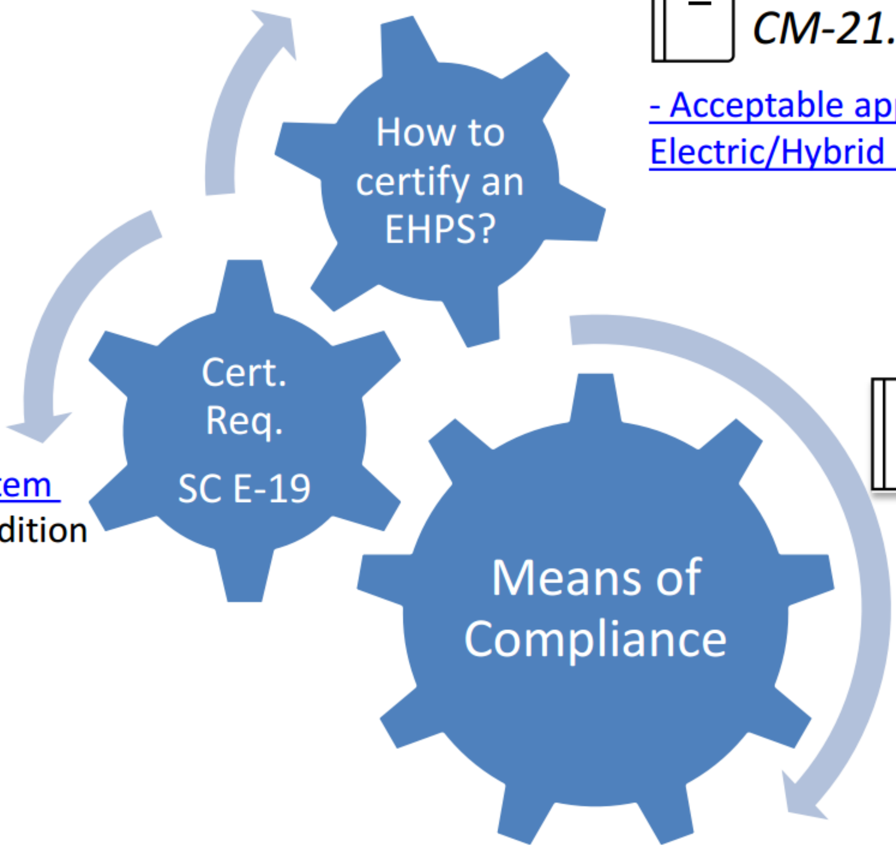
- EUROCAE WG113 Hybrid electrical propulsion
- EUROCAE WG116 High Voltage Systems and Components in Aviation
- SAE E-40 Electrified Propulsion

EHPS certification

Proposed:

CM-21. A-004 Issue 01

- Acceptable approaches for the certification of Electric/Hybrid Propulsion Systems"



Final:

SC E-19 Issue 01

- Electric / Hybrid Propulsion System
- Performance Based Special Condition

Under preparation:

See next slides

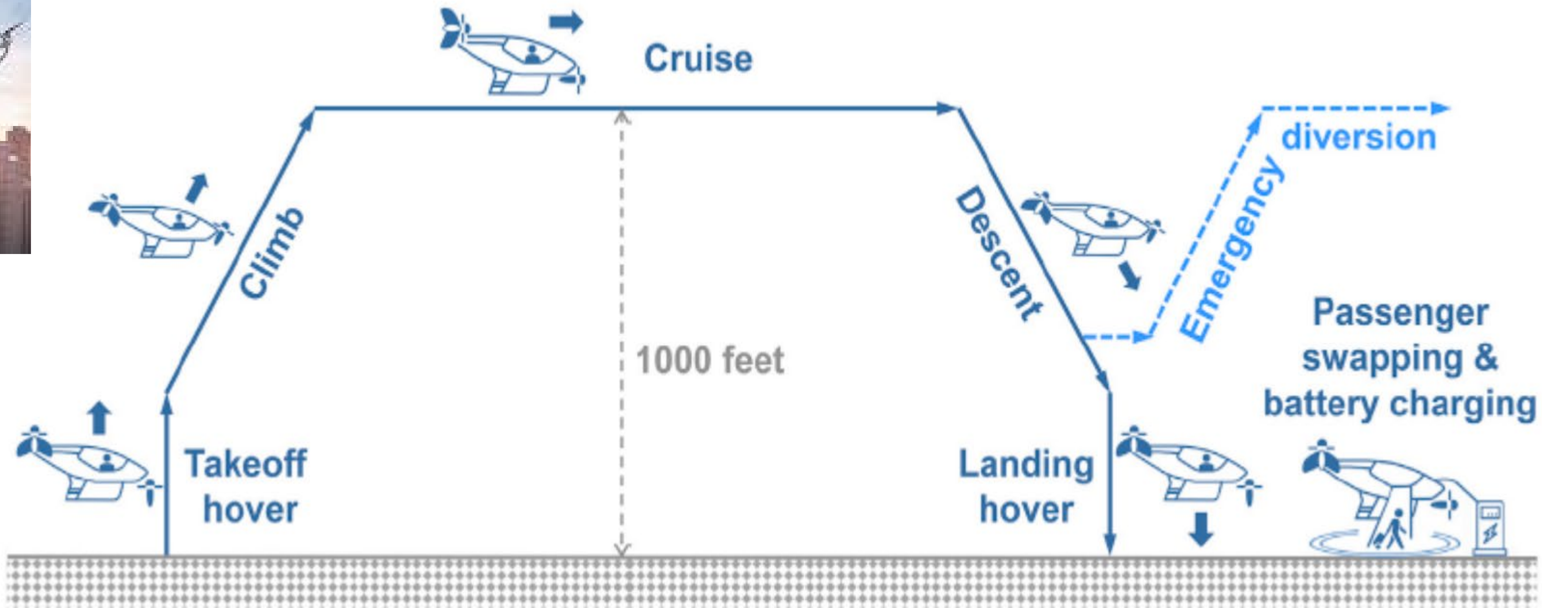
- Detail guidance provided in the MoCs.

EASA

ACTUAL REQUIREMENTS TO DESIGN A PROPULSION BATTERY for EHPS

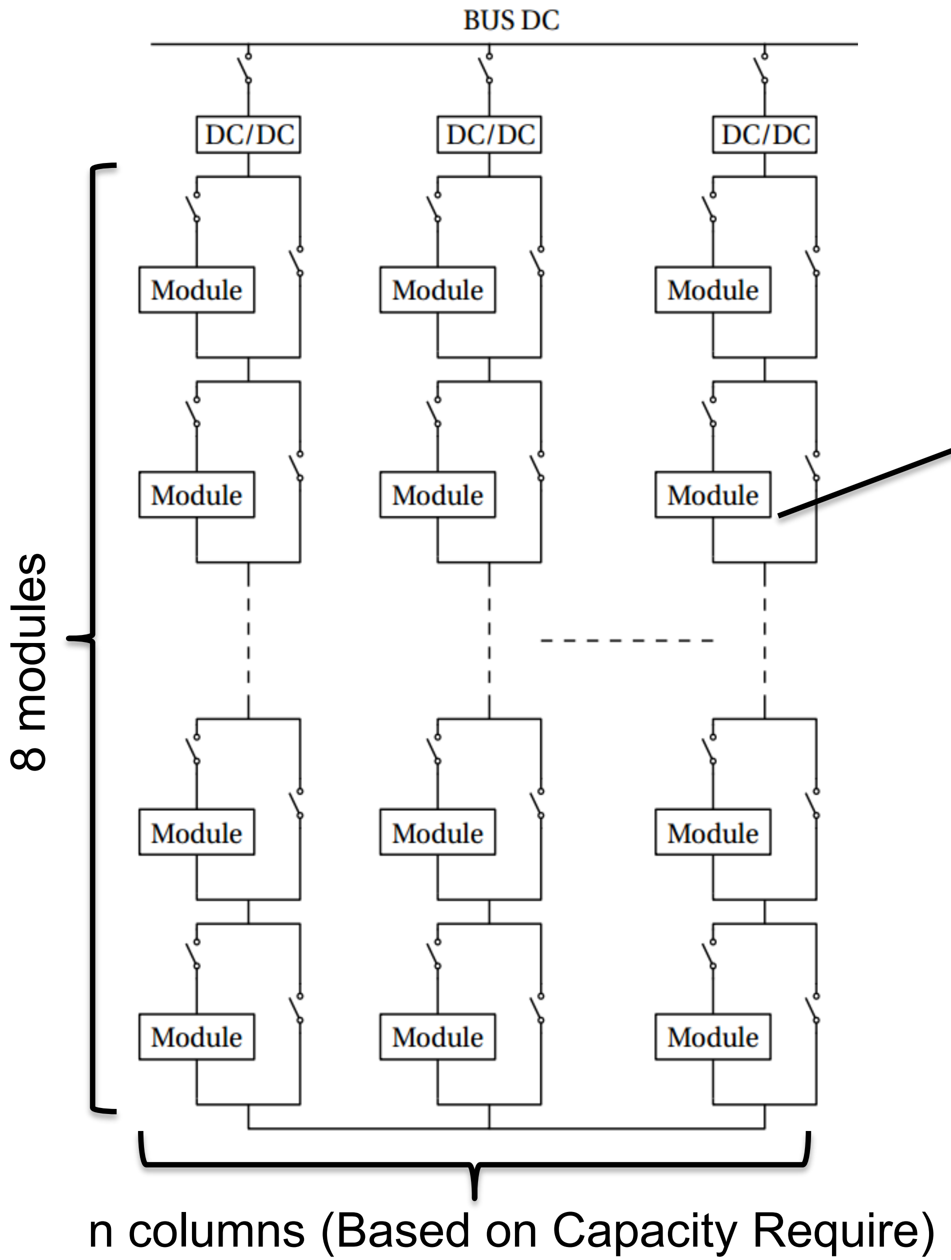
TOPIC	*CHECKLIST*	*REFERENCE(SECTION)*
Cell Balancing	Cell balancing to minimize the occurrence of cell overvoltage, cell undervoltage or cell reversal.	RTCA DO-311A(2.1.10.2)
Energy and Power	Design of propulsion battery to safety ensure energy as required for the engine, under any normal operating conditions.	SC-LSA-F2480-01
	Take-off power, maximum continuous power and emergency ratings must be established.	SC E-19 (EHPS.40(c))
	Maximum permitted duration for the use of ratings other than maximum continuous power must be established.	SC E-19 (EHPS.40(d))
	Power generation, energy storage, distribution and wirings designed to supply the power required during all operating conditions.	SC E-19 (EHPS.370)
Emergency Ratings	Safety compromised if battery system not properly sized to provide emergency power for any aircraft system.	RTCA DO-311A(2.1.4)
	Emergency ratings must be established separately from the other ratings and failures associated with each emergency defined.	SC E-19 (EHPS.40(f))
	The remaining energy reserve following a failure condition should be no less than the sufficient accepted for compliance.	MOC SC-VTOL Issue 2 (MOC SC-VTOL.2000(2))
Thermal Runaway	Design of battery cells and other subcomponents of the system in order to mitigate the effort of thermal runaway or fire.	SC-LSA-F2480-01
	At least 20% of the cells in the battery system achieved thermal runaway in DO-311A section 2.4.5.5 Battery Thermal Runaway Containment test (1st approach).	MOC-3 SC-VTOL Issue 2 (MOC VTOL.2440(5))
	Thermal Runaway in at least 20% of the cells, caused by the worst-cases of test conditions, ensuring Continued Safe Flight and Landing (2nd approach).	MOC-3 SC-VTOL Issue 2 (MOC VTOL.2440(7.b))
Modularity and Indipendence	The applicant may propose a modularized battery system composed out of battery modules to comply with any test approach.	MOC-3 SC-VTOL Issue 2 (Note 2)
	Indipendence between multiple energy storage and supply systems to isolate failures.	SC-VTOL-02 Issue 2 (VTOL.2430(a))
Weight	Maximum certified take-off mass of 5700kg, leaving the maximum passengers seating configuration of 9 unchanged.	SC-VTOL-02 Issue 2 (VTOL.2430(a))
Wiring	Electrical wiring interconnection system must be considered an integral part of the system and must be considered in compliance.	SC-VTOL-02 Issue 2 (VTOL.2430(a))

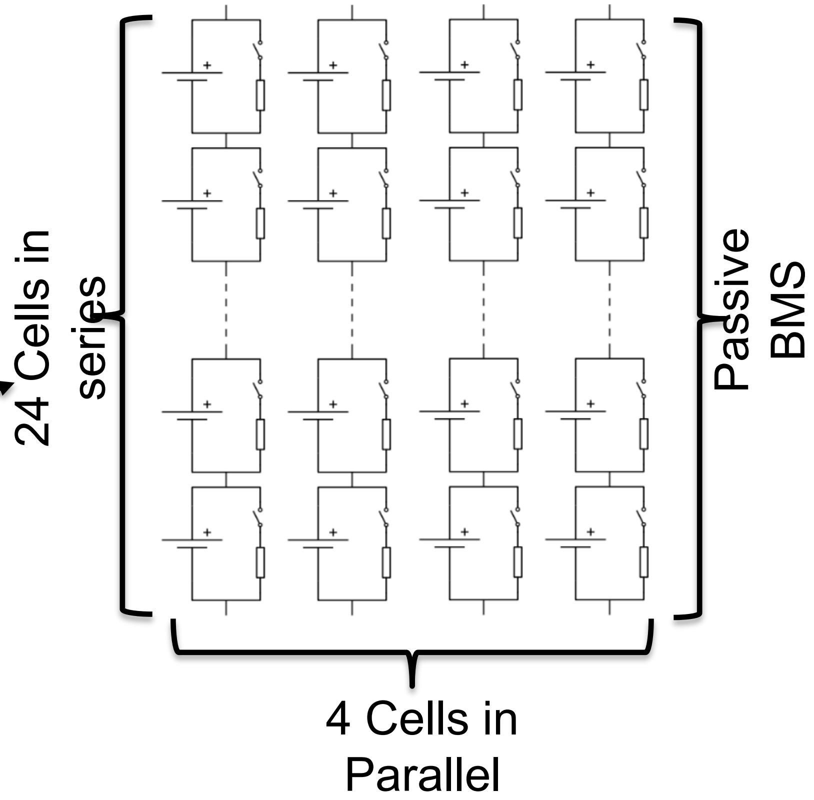
BATTERY PACK DIMENSIONING FOR AN EXAMPLE OF TEST FOR eVTOL MISSION



Nominal mission	Taxi roll	Take off	Climb	Cruise	Descent	Approach	Landing	Taxi in
Duration (min)	5,0	3,0	2,7	11,9	4,7	2,8	2,9	5,0
Output power (kW)	15,0	250,0	0	0	0	0	54,0	15,0
Efficiency (%)	82	94	80	80	80	80	88	82
Input power (kW)	18,3	266	0	0	0	0	61,6	18,3
Energy (kWh)	1,5	13,3	0	0	0	0	3,0	1,5
Voltage range (V)	600÷800	670÷800	600÷800	600÷800	600÷800	600÷800	600÷800	600÷800

BATTERY PACK ARCHITECTURE FOR eVTOL MISSION



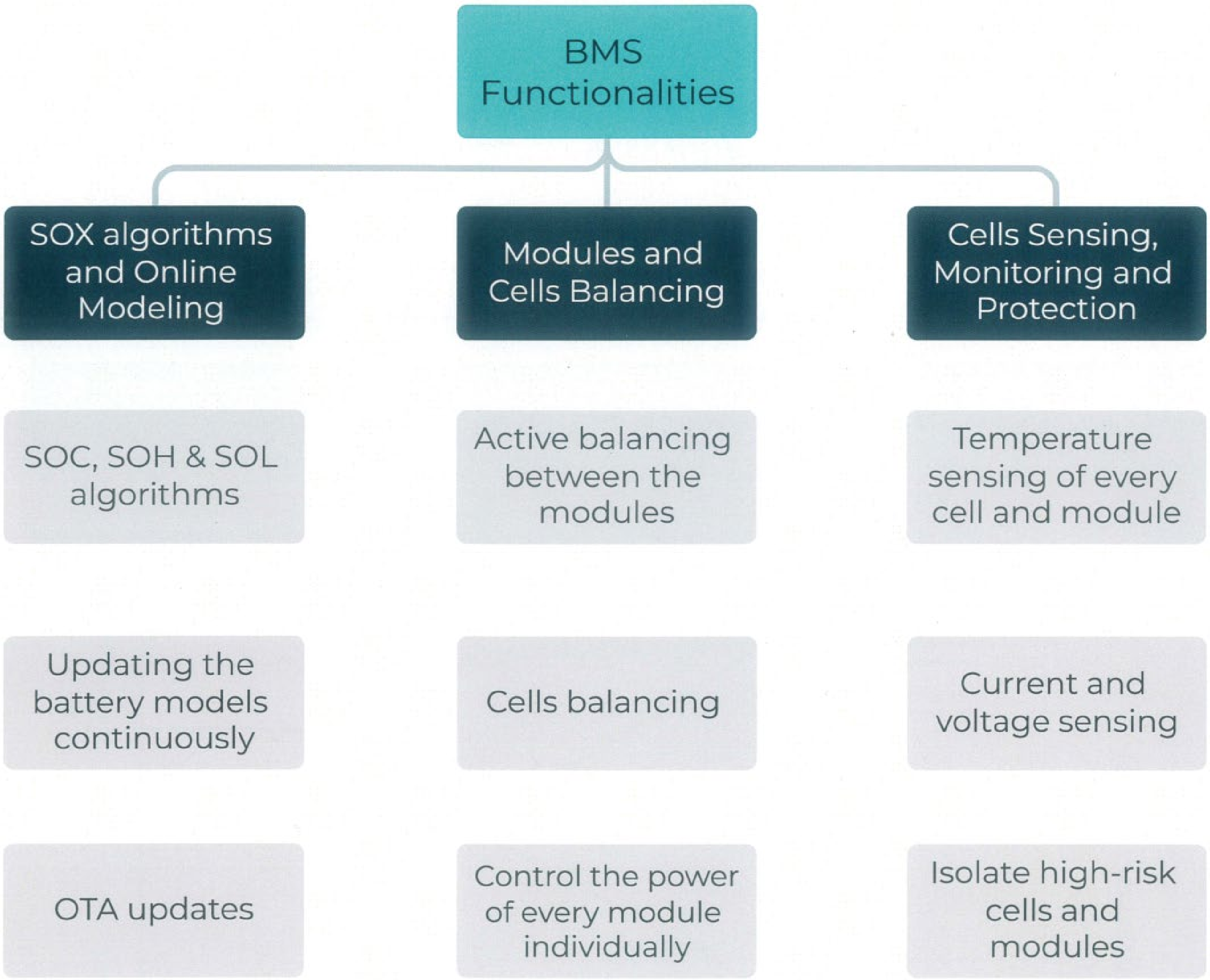


$$C_{battery} = C_{cell} \cdot N_{columns}$$

$$E_{module} = N_{cells\,module} \cdot E_{cell}$$

$$E_{battery} = N_{total\,modules} \cdot E_{module}$$

BMS FUNCTIONALITIES for CMD AVIO BATTERY

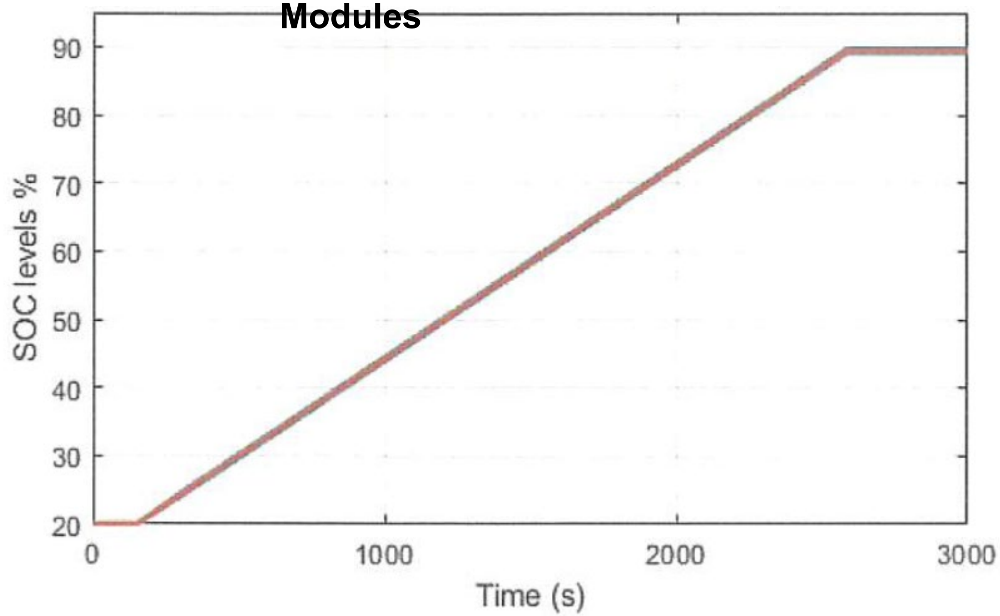


CMD’s BMS IMPACT on BATTERY

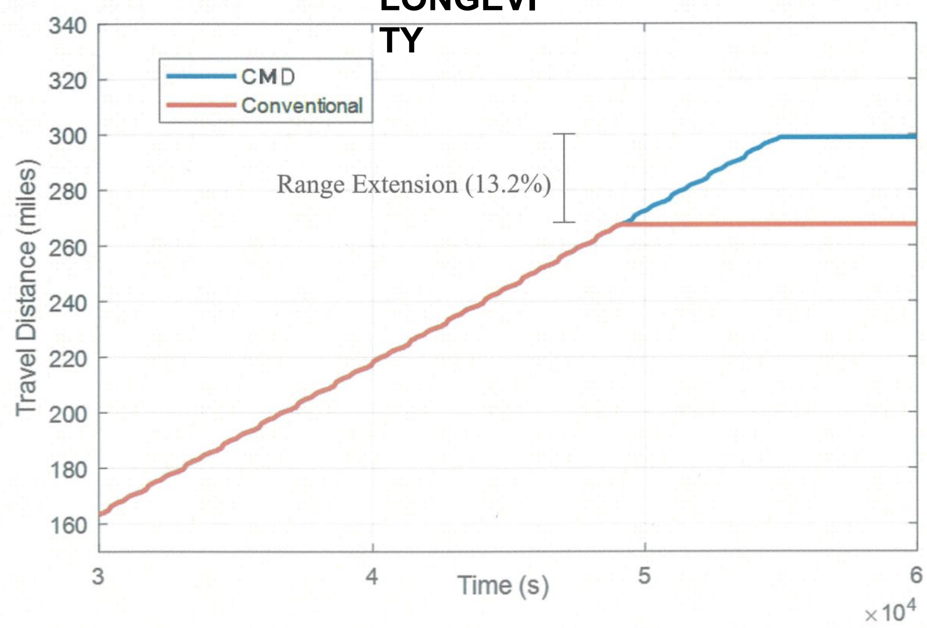
FULL CAPACITY & FAST CHARGING

- **Conventional** Powertrain ARCHITECTURES suffer from UNBALANCED charging across the battery cells and modules. This leads to suboptimal charging by ending the charging cycle without fully charging all the modules or longer charging time to allow the slowest modules to charge fully.
- Due to the uniform SOC balancing of all the modules in **CMD**’s Battery, all the modules reach their maximum SOC levels in the shortest time possible.

SOC levels of CMD Battery Modules

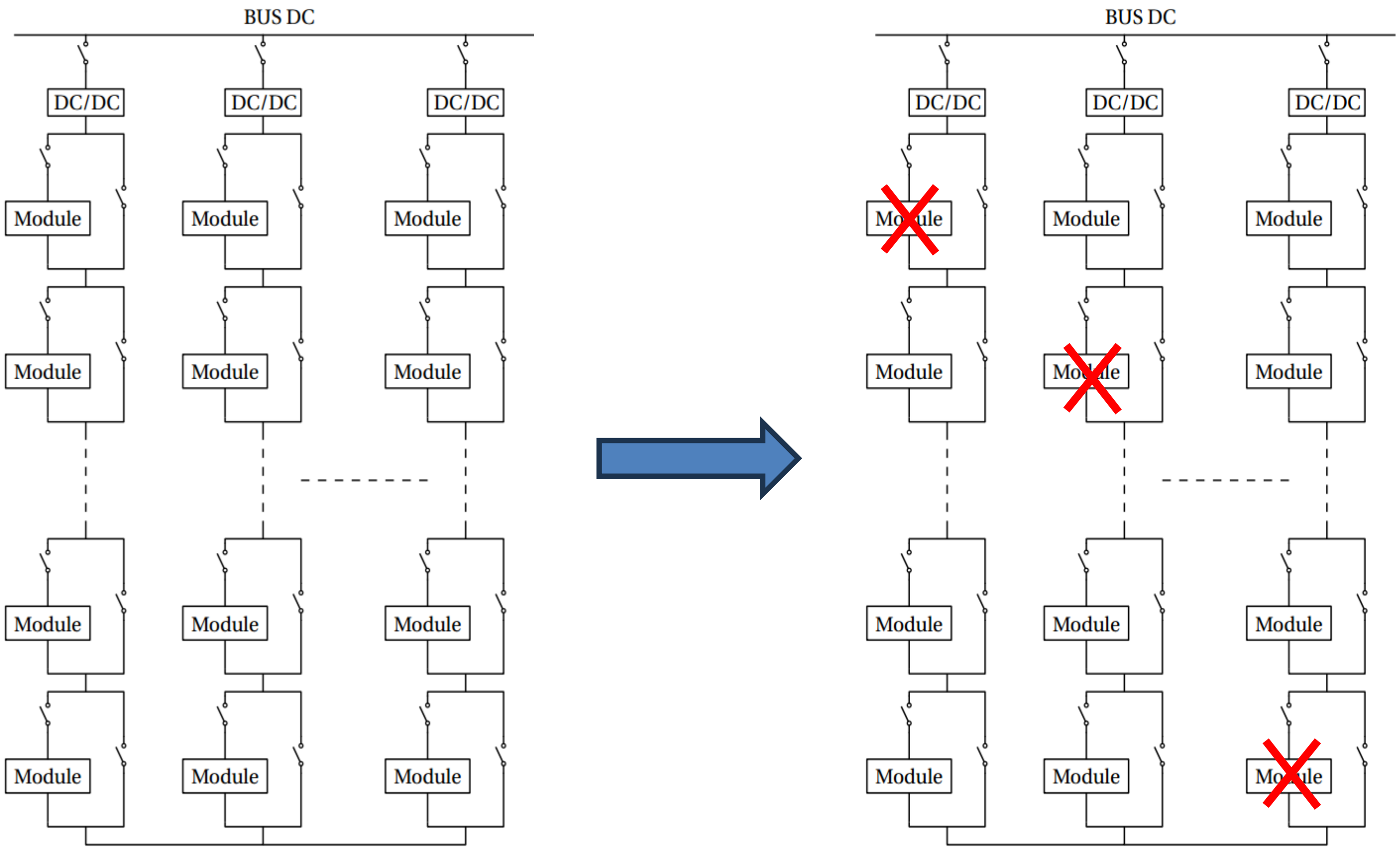


LONGEVITY



RELIABILITY of CMD's BATTERY

- The fully distributed ARCHITECTURE eliminates every Single Point of Failure in the system. This make the CMD's System compliant with SAFETY STANDARDS in AIRBORNE applications.
- The System can isolate the faulty module and still work properly with reduced capacity as showed in the figure below.



General Functions of CMD BMS.

1) ***Sensing and High-Voltage Control***.
   - ✓ Voltage, Current and Temperature measurements.
   - ✓ Pre-Charger Control.
   - ✓ Ground-Fault Detection.
   - ✓ Thermal Management.

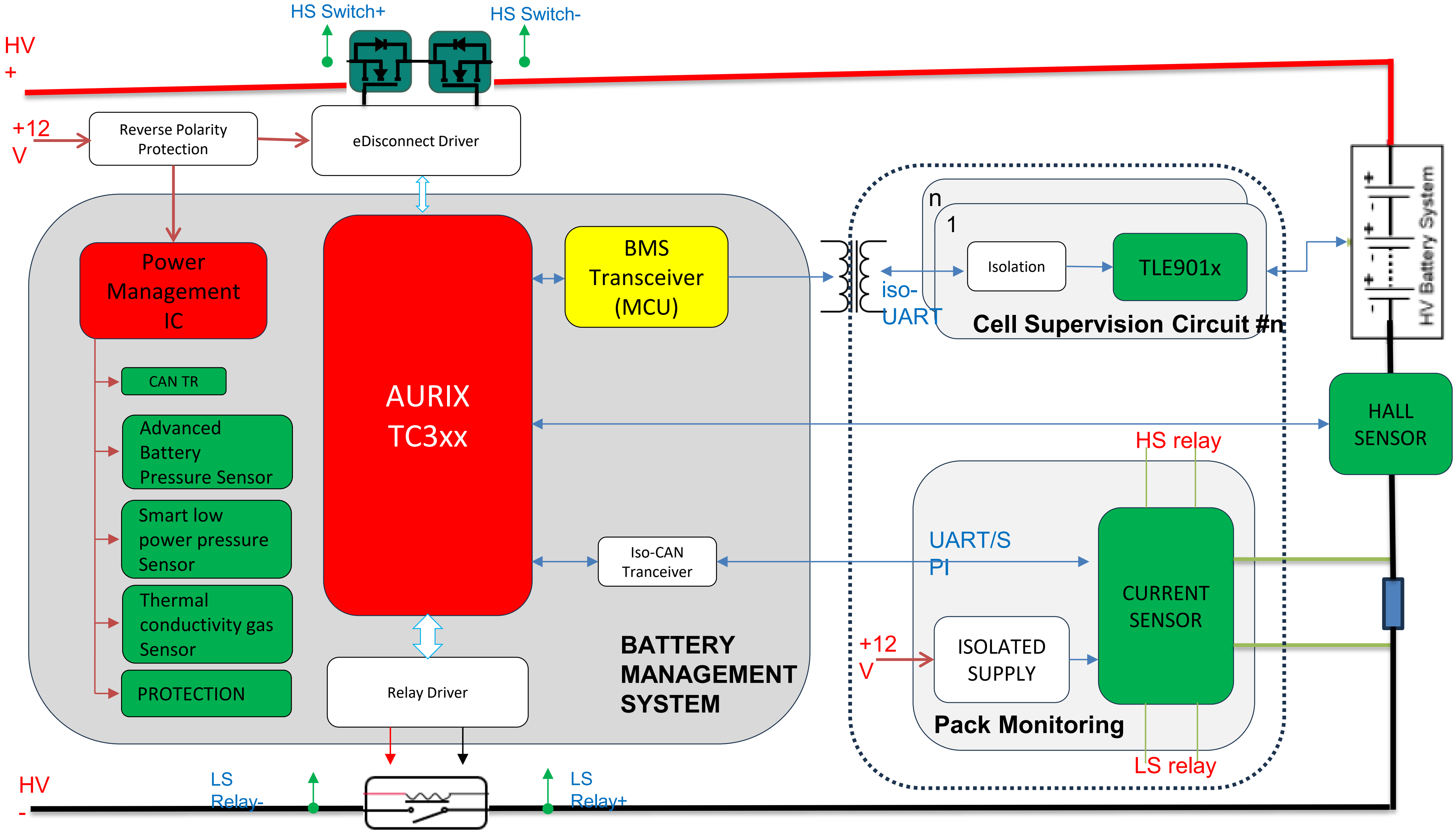
2) ***Protection.***
   - ✓ Contactors Control.
   - ✓ Over Charge, Over Discharge, Over-Current (Short Circuit).
   - ✓ Extreme Temperatures.

3) ***Interface.***
   - ✓ Range Estimation.
   - ✓ Communications.
   - ✓ Reporting.

4) ***Performance Management.***
   - ✓ State of Charge (SOC) Estimation.
   - ✓ Power Limit Computation.
   - ✓ Balance and Equalize Cells.

5) ***Diagnostics***
   - ✓ Abuse Detection
   - ✓ State of Health (SOH) Estimation and State of Life (SOL) Estimation.

BLOCK DIAGRAM of CMD BMS.



CMD BMS TOPOLOGY : DISTRIBUTED (Single String Example)

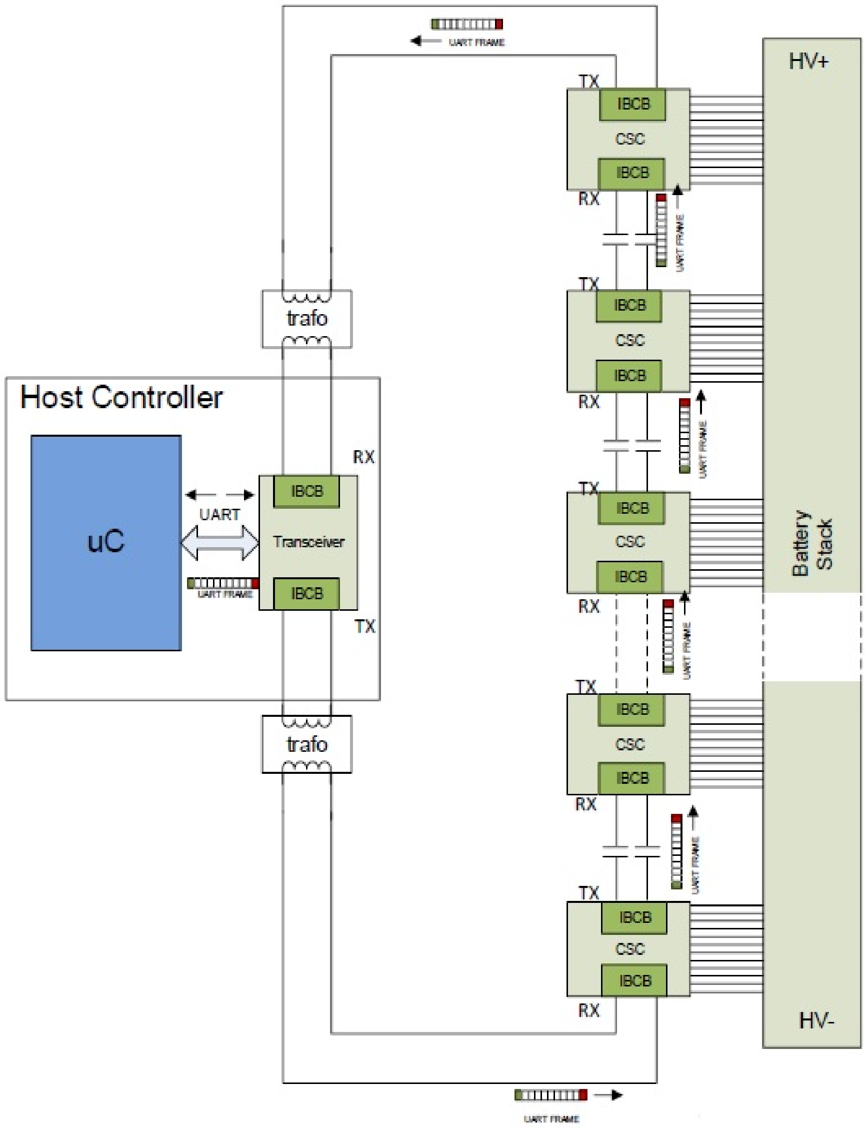
- Each battery cell or small group of cells has its own dedicated management circuit (CSC).

BMS **Slave Role**:

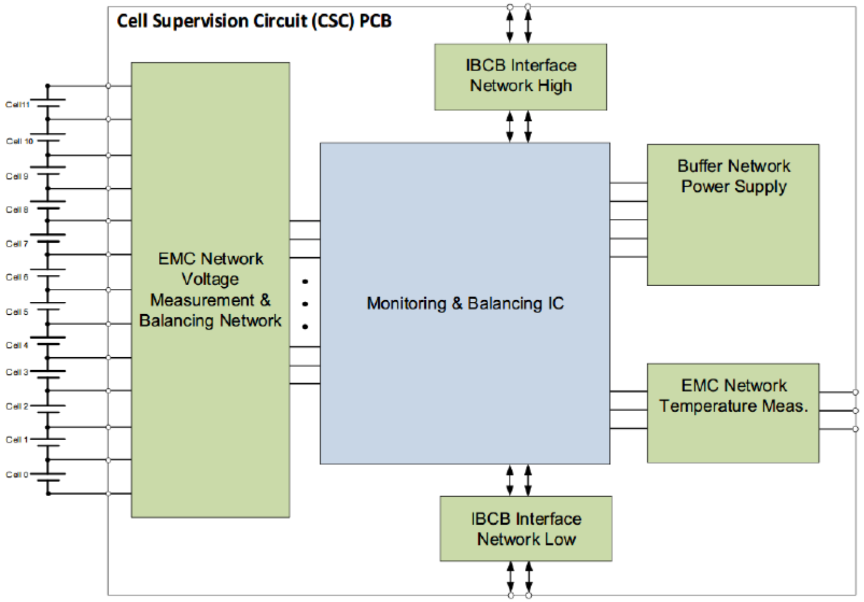
- Measure Voltage of every Cell within the module.
- Measure Temperature.
- Balance the energy stored in every cell within the module.
- Communicate this information to the Master.

BMS **Master Role**:

- Control contactors that connect and disconnect battery to load.
- Monitor pack current and isolation.
- Communicates with BMS slavers.
- Control Thermal-Management.
- Communicate with host application controller.



CELL SUPERVISION CIRCUIT (CSC)



The ***SLAVE MODULE*** is composed by an Infineon Li-ion battery monitoring and balancing IC .

This Device have the follow characteristic:

- Voltage monitoring of up to 16/18 battery cells connected in series.
- Dedicated 16-bit high precision delta-sigma ADC for each cell.
- Integrated balancing switch allows up to 200/300 mA balancing current.
- Temperature measurement channels for external NTC elements
- ISO 26262 Safety Element out of Context for safety requirements up to ASIL D.

Microcontroller Characteristics.

BMS Mother Board HW is based on the Infineon TC3xx microcontroller of the Aurix family

<u>Main HW features</u>:

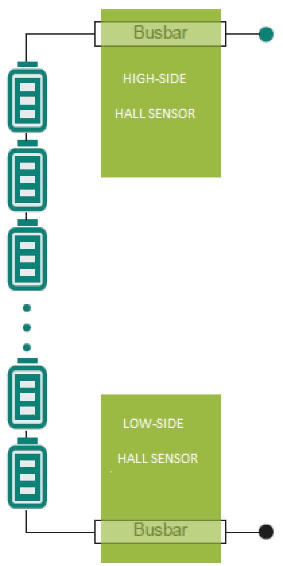
- 4 independent CAN nodes.
- 16 Digital inputs.
- 16 Analog inputs.
- Up to 16 Open Drain Outputs.

The Infineon HW/SW **Aurix** Platform is ideal for safety critical embedded application that require compliance to the reference standards:

- DO-178C/DO-254
- ISO 26262
- IEC 61508
- EN 62304

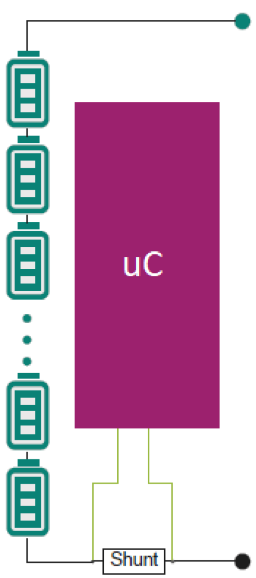
Current sensing methods and topologies.

There are three different ways to obtain an accurate current measurement:



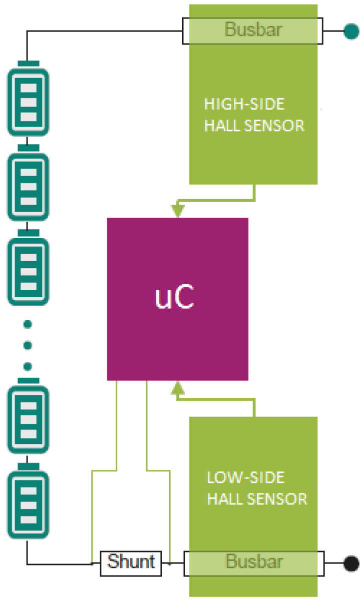
Hall-Based Pack Current Sensing:

- More reliable for overcurrent detection.
- No require extra isolation.
- Easy to mount.



Shunt-Based Pack Current Sensing:

- Shunt could offer higher accuracy than Hall based solutions.
- Single or double shunt is typical for applications up to ASIL-C.



Hybrid Hall- and Shunt-Based Current Sensing:

- The Hybrid solution offers the best of the shunt and hall solutions.
- This solution offer more reliable measurement redundancy.
- Typically used for applications up to ASIL-D.

Thermal Runaway challenge Solutions.

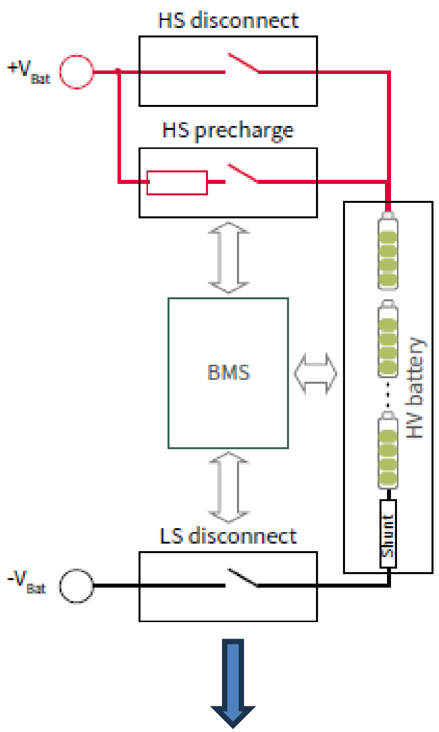
To prevent or give the aircraft time to land the challenge is to manage the Thermal Runway, this problem requires some measures:

- **Thermal conductivity gas sensor**
  - AEC-Q100 up to 105°C.
  - Fast response time <100 ms.
  - Ultra low power consumption.

- **Smart low power pressure sensor.**
  - Autonomous low-power monitoring modes.
  - High Accuracy & Reliability.
  - Advanced diagnostic functions.

- **Advanced Battery pressure senso**
  - Shock sensor integrated.
  - Flexible low power monitoring features.
  - Settings/algorithms adjustable in field.

Battery disconnect units.



Battery disconnect unit is responsible for disconnecting and connecting the DC bus of the high voltage (HV) battery:

- The precharge, which manages the turn-on inrush currents.
- The low side and the high side connects/disconnects the negative/positive pole of the HV battery pack.
- Detecting the aging and arcing of the mechanical disconnects.

SOLID STATE DISCONNECT

- Functional Safety according to ASIL C.
- Selective, arcing free switch off in case of failure.

MECHANICAL DISCONNECT

- Cost-efficient way to manage disconnects in a junction box.
- Most common topology in high voltage battery junction boxes.

BMS will be developed according to General Aviation standards:

- **RTCA-DO-178C** (*software*) with safety level up to DAL B (Design Assurance Level).
- **RTCA-DO-254** (*hardware*).
- Certified for *environmental conditions* according to General Aviation standard **RTCA-DO-160G**.

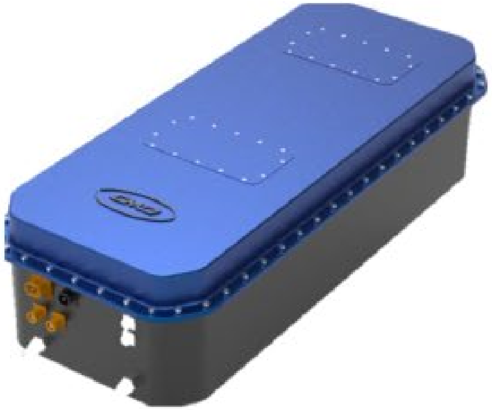
SECTION	4.0	5.0	6.0	7.0	8.0		9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0		21.0	22.0			23.0	24.0	25.0	26.0
CATEGORY	B2	B	A	B	S, curve M and L	U2, curve F & F1	X (N.A.)	R	X (N.A.)	X (N.A.)	X (N.A.)	X (N.A.)	A	B	A	B	ZC-X	W	W	L	A3 (pins)	C3 (bundle)	X	X	X	A	X

Energy Storage Systems

From prototyping beginnings to battery pack technology provider

Prototyping:

Battery Module Technology:



Superior Performance, safety and modularity at competitive cost

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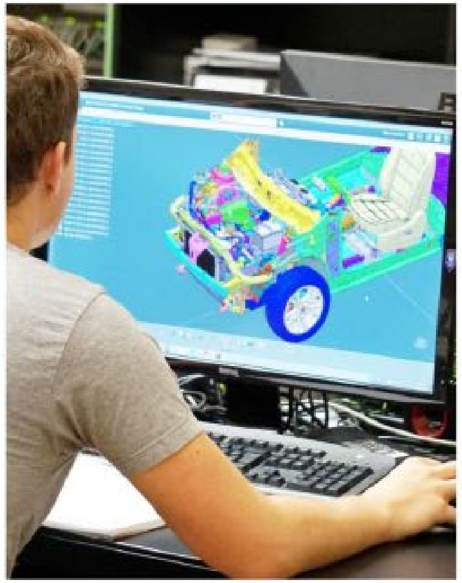
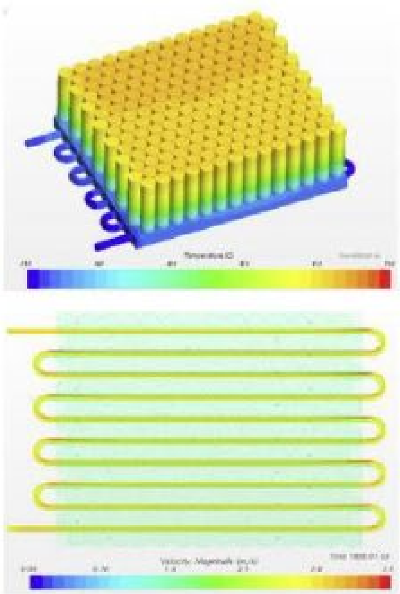
Focus on in-house research & development, validation and assembly

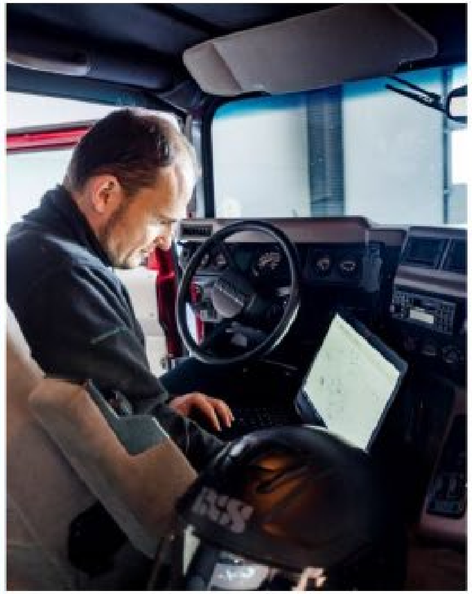
Engineering:



Simulation:



Software Dev:



Production:

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Main Challenges in design Battery Module for Aviation:

1 Weight and packaging

- Gravimetric Density
- Volumetric Density

2 Performance

- 10C+ continuous power
- Thermal Management

3 Security and Safety

- Thermal Runaway
- Crash Protection
- Short Circuit Protection

How we addressed ?

Immersion Cooling Technology

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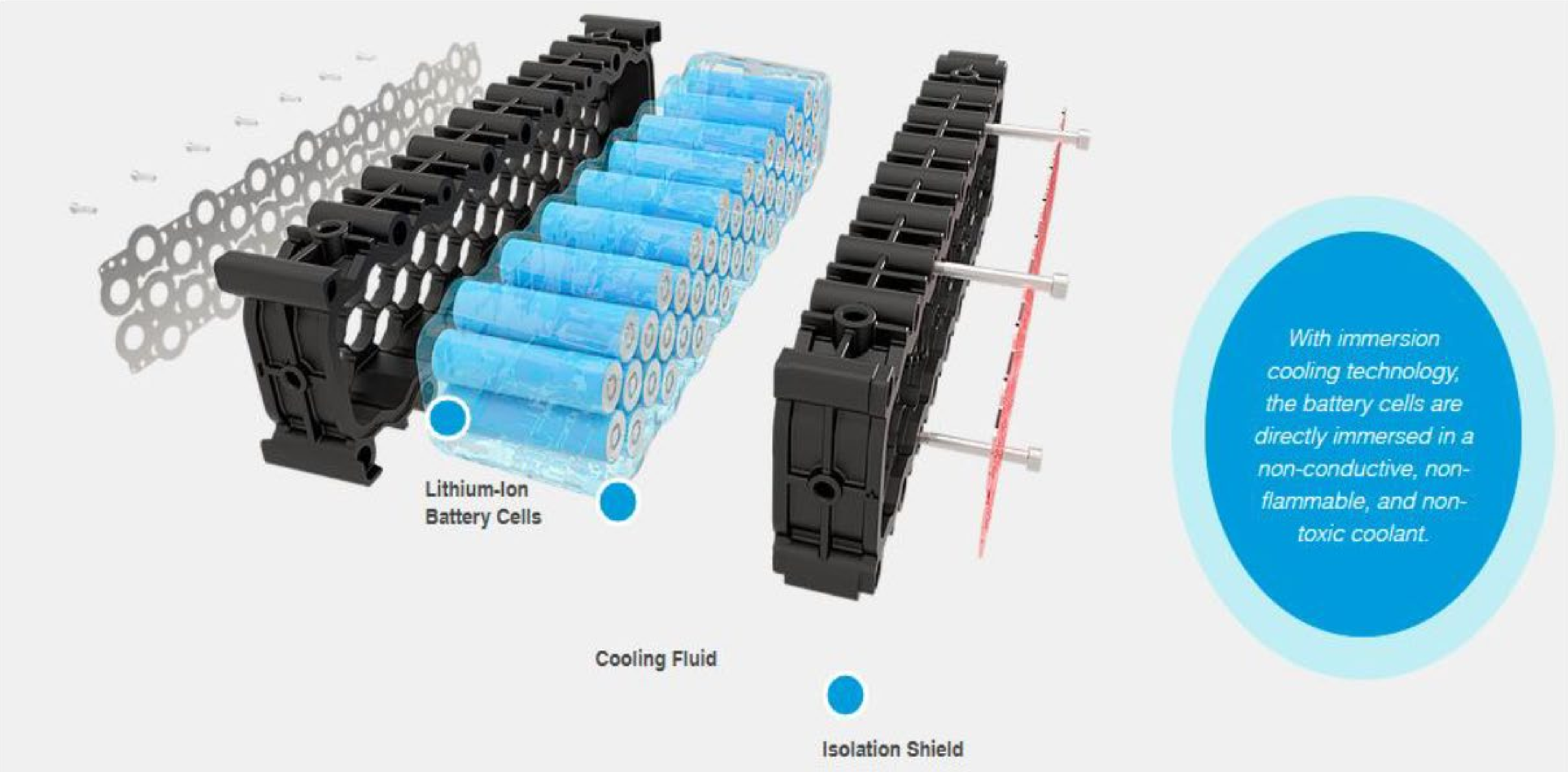
Proprietary Immersion Cooling Technology



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High Power Battery Module for aviation

- Designed for eVTOL requirements from the ground-up
- Up to 10C continuous discharge rate
- Multiple energy and power configurations available
- Modular designs for use in a variety of aircraft types
- Architecture that supports regular cell upgrades

Designed to stop propagation of thermal runaway :

- DO 311A, Category B requirements
  - Module Level Containment Protection
  - Thermal Runaway
  - Venting
- DO 160g Environmental
  - CAT R1, L, M shock and Vibe
  - -40 C to 60 C normal operating temperature

ACTIVE Battery Management System:

- Increasing life cycle of cells
- Real Time cell internal temperature estimation
- Fast real time diagnostic
- DO-178 for Battery Management software
- DO-254 for BMS Hardware

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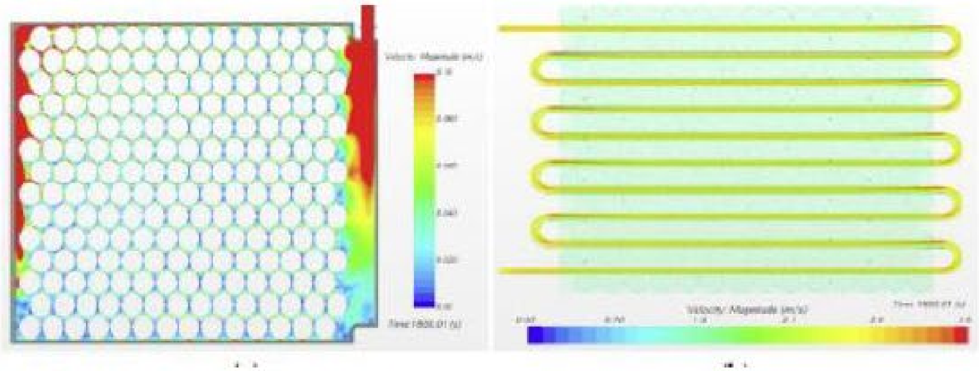
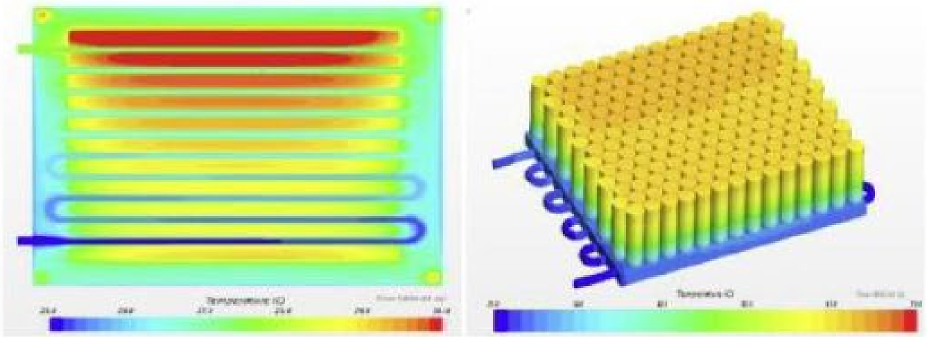
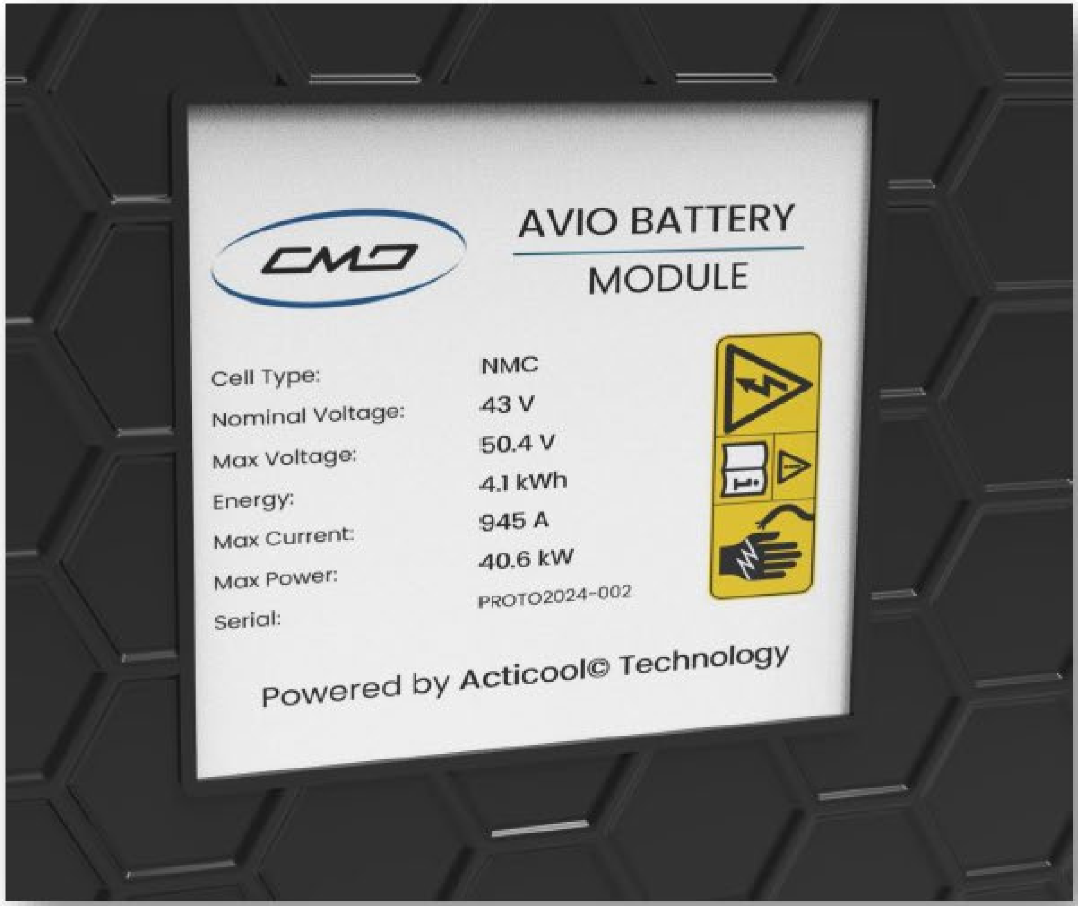
CMD AVIO Battery Module (Acticool)



Analisi termica Smart e-Module ACTICOOL



Analisi termica pacco batteria tradizionale



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Thank You