ONERA
THE FRENCH AEROSPACE LAB

# DESIGN AND MANUFACTURING OF A HIGH-POWER DENSITY EMOTOR

## TECHNICAL NEED SPECIFICATION

| | Prepared by | Reviewed by | | Approved by |
|---|---|---|---|---|
| Function | Project Manager | Head of Specific Devices & Models Unit | Deputy in charge of Electronic Laboratory | Head of Windtunnels Engineering and Models Department |
| Nom | A.Trollé | F.Ternoy | E. Eglinger | Y.Vernat |
| Visa | | | | |

GEN-F172-1 (GEN-SCI-003)




ONERA
THE FRENCH AEROSPACE LAB

## HISTORY

| Version Revision | Effective date | Description of change |
|---|---|---|
| 1.4 | 16/02/2026 | 5th draft |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**SOMMAIRE**

## 1 PURPOSE OF THE DOCUMENT

This document describes the technical specifications for designing and manufacturing an electric powertrain inside large wind tunnel aircraft models.

## 2 SCOPE

The electric powertrain will be installed in a complete aircraft scaled model. This model is an onsite facility that will run experimental tests at ONERA F1 Wind Tunnel in Fauga-Mauzac, France and at ONERA S1MA Wind Tunnel in Modane-Avrieux, France.

Such models are developed as high accuracy metrological equipment to test and analyze aerodynamic surfaces. In this context, it is mandatory to perform thrust simulation of turbofan or turboprop engine with high standards on aerodynamic similitude.

## 3 RELATED DOCUMENTS

**Applicable documents:**

These are the documents which must be applied.

[DA1] ISO 21940-11:2016 – BALANCING STANDARD
[DA2] 2014/35/UE, 2014/30/UE, 2006/42/CE - MACHINE STANDARDS
[DA3] DS-SCI-0409-2.1 – RULES FOR THE DESIGN OF WIND-TUNNEL MODELS, SET-UPS AND TEST RIGS

**Reference documents:**

These are documents which can be used as support, bibliography, etc.

[DR1] Preliminary volume

## 4 DEFINITIONS AND ACRONYMS

Each specification is made of two acronyms:
- One requirement or constraint [FR, IR, OR, EC, DC, LC],
- One level of expectation [Flexible or Primary].

The criteria are listed below:

| | |
|---|---|
| **FR** | Functional Requirements |
| **IR** | Interface Requirements |
| **OR** | Operational Requirements |
| **EC** | Environmental Constraints |
| **DC** | Design Constraints |
| **LC** | Logistic Constraints |
| **(Flexible)** | Flexible level, non-essential function |
| **(Primary)** | Primary level, essential and non-negotiable function |

The first term defines the nature of the specification:

- A constraint,
  - It is a limitation or a restriction imposed to the system;

- It can be technical, legal or environmental.

- A requirement,
  - It is a specific criterion or capability of the system that it must fulfil to consider the service as successful;
  - It describes what the system must reach to satisfy the need.

# 5 PRODUCT OVERVIEW

## 5.1 GENERAL DESCRIPTION

The electric powertrain is an assembly integrated inside a wind tunnel model. **The matter here is to design and manufacture a motor powerful enough** to fit the demanding environment of Wind Tunnel Testing.

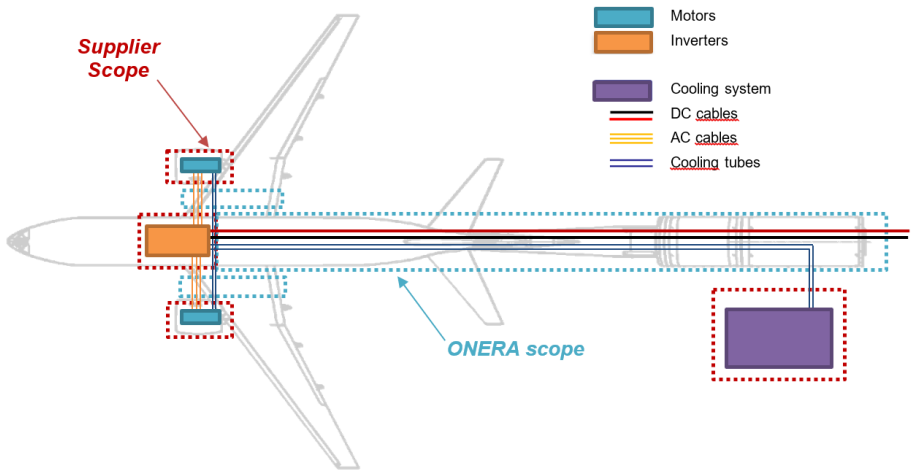


*Fig.1 – General description of a motorised scaled model*

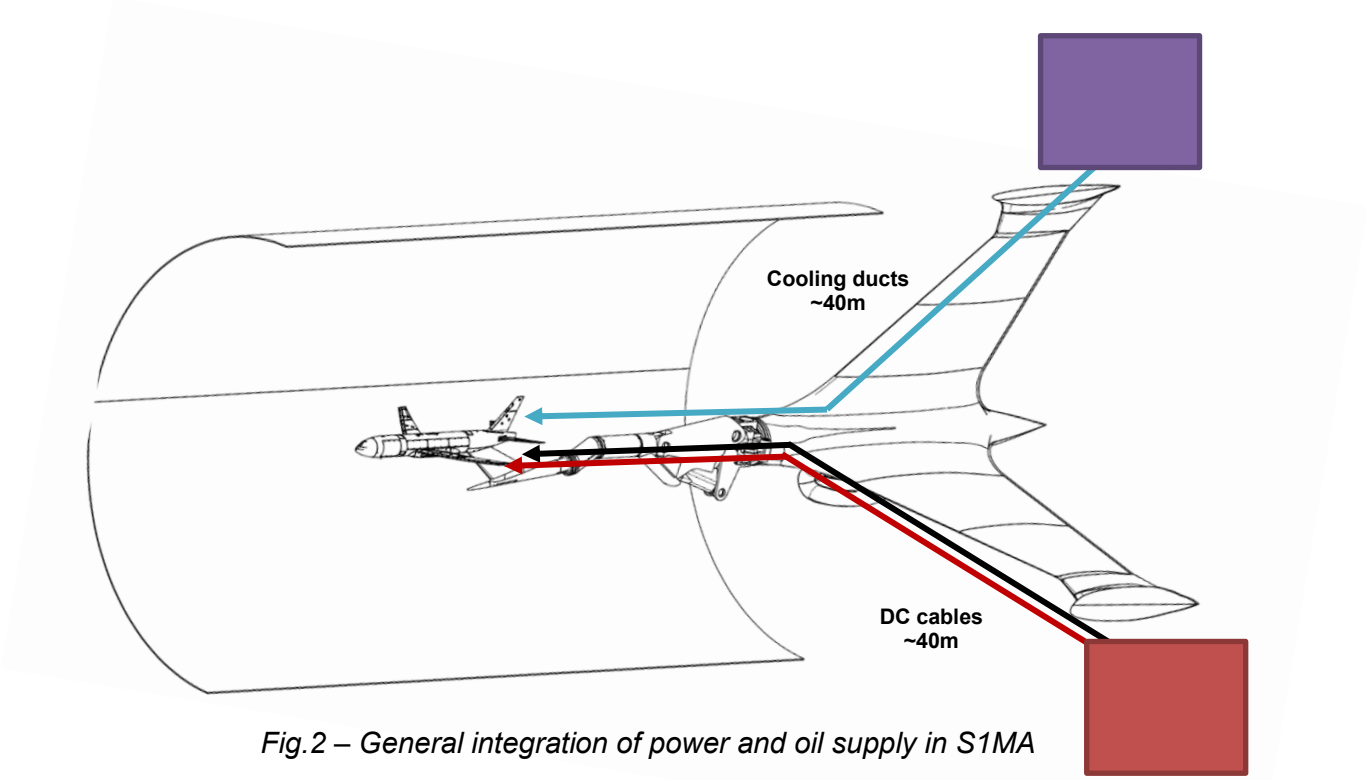


*Fig.2 – General integration of power and oil supply in S1MA*

The supplier will handle the design and manufacturing of the electric motors, the supply of inverters and controllers and the supply of the cooling station.

ONERA will handle the supply and integration of the components inside the aircraft model and the wind tunnel, this includes the electrical wiring, the cooling tubing and the DC power supply.

The interfaces in between and the complete system scheme (electrical harness and cooling circuit) will be discussed continuously between the supplier and ONERA to reach together the best possible overall solution at the PDR milestone (e.g. connectors, cable gauges, length...).

## 5.2 DELIVERABLES

**[DF_01] High power density electric motor**

The supplier must develop a specific electric motor to meet with the requirements and constraints. The integration of this design will be performed in collaboration with ONERA to ensure the best fitting possible inside the restricted volume. A rotational speed sensor shall be mounted on the motor and 1 spare sensor shall be provided for the 4 motors.

**Quantity:**
- **4 motors**

**[DF_02] Inverter and controller selection**

The supplier must supply two inverters (within the same casing would be appreciated) to drive the designed motors and that meet with the requirements and constraints.

**Quantity:**
- **2 single inverters**
  **or 1 double inverter**

**[DF_03] Cooling station supply**

The supplier must supply the cooling system that will be installed inside the wind tunnel facility.

**Quantity:**
- **1 cooling station**

**[DF_04] Testing**

The supplier must provide:

- Prototype testing inside its facility including:
  - Mechanical performance tests,
  - Control performance tests (including the RPM accuracy),
  - Thermal behavior tests,
  - EMC (Electromagnetic Compatibility); e.g. vicinity of some of ONERA's sensors must be tested to help identify the EM shielding needed.

The acceptance document that will be defined at PDR milestone will be checked during this testing phase.

**Quantity:**
- **1 prototype testing with acceptance review**

**[DF_05] Technical documentations**

At the end of the service, the supplier must provide an extensive documentation gathering at least:

- Acceptance document
- Simplified 3D model,
- Assembly and manufacturing drawings,
- End-user BOM (Bill of Materials) for maintenance and spare-parts,
- Campbell diagram,
- Maximum load envelop,
- Tightening calculation,
- Performance curves (nominal and peak) at 3 different cooling parameters along the rotational speed range (at least torque and temperature curves)
- Communication protocol definition,
- Control strategy description and justification (accuracy and stability),
- General drawings of the control circuits and the power circuits (in the supplier scope),
- General drawings of the cooling circuits (in the supplier scope),
- Short maintenance plan if any,
- Safety instructions if any,
- ROM cost for technical onsite support for installation inside the wind-tunnel (price for one day of support).

**Quantity:**

- **1 numerical copy of each document**

## 5.3 EXPECTED SCHEDULE

This project should start beginning of summer 2026 and shall be completed within 2026 if possible. The supplier and ONERA will follow the project every two weeks through online meetings.

Three Milestones are identified each with meeting minutes :

- PDR : Preliminary Design Review where the supplier and ONERA will agree on the interfaces, the redundancies in the system (safety, controlling and cooling) and the acceptance document content,
- CDR : Complete Design Review to validate calculations before manufacturing,
- FAT : Factory Acceptance Test to review the acceptance document defined in PDR.

The FAT will be perform directly on the supplier test rig location during [DF_04] with ONERA.

# 6 REQUIREMENTS

## 6.1 FUNCTIONNAL REQUIREMENTS

**[FR_01] Nominal operating point (Primary)**
The motor must at least reach the following performance with respect to [FR_02]:

**52 Nm at 32 000 rpm (~175 kW shaft power)**

ONERA is looking for the best power output possible inside the [IR_01] volume, a substantial part of the technical grade is on this requirement.

**[FR_02] Nominal duty cycle (Primary)**
The continuous duty cycle is defined as:

- At least 5min Power on at nominal operating point,
- At most 5min Power off.

This duty cycle can be repeated continuously with respect to [OR_01].

**[FR_03] Maximum rotational speed (Primary)**
The motor must be able to sustain small overspeed beyond 32 000rpm. The supplier shall define the maximum speed reachable without critical damage.

**[FR_04] Motor control (Primary)**
The supplier must design a control strategy to drive the engine with an accuracy of +/- 2 rpm or better. The supplier must design or benchmark the software of the inverter.

**[FR_05] Peak operation (Flexible)**
The motor shall at least reach the following performance in peak operations:

**64 Nm at 32 000 rpm (~215 kW shaft power)**

The supplier must define the maximum peak power reachable and its peak cycle defined as:

- More than 15s peak power at 32 000 rpm,
- Unlimited power off for cooling.

As a result, the supplier should provide the total duration of this duty cycle.

ONERA is looking for the best power output possible inside the [IR_01] volume, a substantial part of the technical grade is on this requirement.

**[FR_06] Inverter (Primary)**
The inverter must not limit the motor functional requirements [FR_01] and [FR_02]. This means continuous and peak powers must be motor-limited.

## 6.2 OPERATIONAL REQUIREMENTS

**[OR_01] Lifetime (Flexible)**
The minimal lifetime before maintenance must be 700 hours at Nominal duty cycle [FR_01] and [FR_02].

**[OR_02] CE marking (Primary)**
The motor and the inverter must demonstrate its conformity to the low voltage, EMC and machine EU standards [DA2] with a CE marking (UKCA may be accepted).

**[OR_03] Recovery (Flexible)**
During wind-milling testing, the wind-tunnel airflow leads to an induced rotation of the fan. The motor and the inverter must at least sustain ~30% power recovery for 5 minutes to allow such tests.

**[OR_04] Direction of rotation (Primary)**
It must be possible for the motor to rotate clockwise and anti-clockwise.

## 6.3 INTERFACE REQUIREMENTS

**[IR_01] Preliminary volume allowance for the electric motor (Primary)**
The motor, its cooling jacket, its mounting and all of its connectors must fit inside the volume [DR1] (around ø90x275 mm).

This volume will be opened for small millimeter-scale modifications in accordance with ONERA before the PDR milestone to find the best integration.

**[IR_02] Preliminary volume allowance for the inverter (Primary)**
Both inverters, their cooling jacket/heatsink, their mountings and all of their connectors must fit inside the following volume:

- Smaller diameter as possible and no greater than Ø260 mm,
- Smaller length as possible and no greater than 500 mm.

**[IR_03] Mounting (Primary)**
The motor shall be fixed with repeatable, precise and calculated mountings such as screws, pins and centering [DA3].

It is necessary to have a spline shaft coupling. ONERA and the supplier will collaborate to find the best spline geometry before PDR milestone. The supplier must manufacture the shaft.

**[IR_04] Communication protocol (Primary)**
The supplier must define a communication protocol so that the Wind Tunnel can use the data of the different sensors for real time calculation and control.

# 7 CONSTRAINTS

## 7.1 ENVIRONMENT

**[EC_01] Cooling system (Primary)**
The motor and the inverter must be cooled, the design must consider:

- Temperature sensor for the inlet flow of each part,
- Temperature sensor for the outlet flow of each part,
- Flowmeter and pressure sensor of the outlet of the cooling station,
- Lockable sealed connectors.

The redundancy and the specification of the sensors shall be discussed and defined by the supplier and ONERA before the PDR milestone.

**[EC_02] Power circuit (Primary)**
The components and control strategy must allow:

- an overheating protection of the motor,
- a surge protection,
- an overload protection.

These protection strategies shall be discussed and defined by the supplier and ONERA before the PDR milestone.

**[EC_03] Temperature (Primary)**
The wind tunnel temperature is usually between 0 to 60°C. The motor and the inverter must proper run within this range of temperature.

**[EC_04] Pressure (Flexible)**
The wind tunnel static pressure is usually between 0.89 to 3.85 bars. The motor and the inverter must proper run within this range of pressure.

## 7.2 DESIGN AND PRODUCTION CONSTRAINTS

**[DC_01] Rotational speed monitoring (Primary)**
The shaft rotational speed must be monitored directly by a sensor with an accuracy sufficient for controlling the motor with respect to [FR_05].

The accuracy shall be demonstrated during the FAT milestone.

The inverter data and control system shall not be used for this purpose. The inverter data shall be considered as a redundant input for real time cross-checking.

**[DC_02] Balancing (Primary)**
The delivered rotating parts must be balanced at G2.5 class based on [DA1] standard at nominal speed [FR_01].

**[DC_03] Loads on the shaft (Primary)**
ONERA will provide loads as inputs for the shaft and bearings design before PDR milestone. The supplier must provide a first estimation of the maximum load on the shaft.

**[DC_04] Dynamic behavior of the motor (Primary)**
A Campbell diagram is required to define the dynamic behavior of the rotating parts. ONERA will provide the fan inertia matrix.

**[DC_05] Marking (Primary)**
All parts delivered must be marked with at least part numbers.

## 7.3 LOGISTICS AND IMPLEMENTATION

**[LC_01] Handling (Primary)**
For all parts weighting more than 15kg, a handling method must be defined with lifting eyes or equivalent.

**[LC_02] Rooting (Primary)**
ONERA requests a hollow shaft.

**[LC_03] Shipping (Primary)**
All the supplied components shall be shipped within dedicated and re-usable wooden boxes or flight cases (all cases provided by the supplier).