Clean Sky Joint Undertaking
Call SP1-JTI-CS-2011-01

European Commission
Research Directorates

# Call for Proposals:

## CLEAN SKY
## RESEARCH and TECHNOLOGY DEVELOPMENT PROJECTS
(CS-RTD Projects):

# Call Text

| Call Identifier |
|---|
| **SP1-JTI-CS-2011-01** |

**Part A – ECO, GRA and GRC**

Index

# Document track changes

| *Page/topic* | *Original* | *Correction or modification* |
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# Specialised and technical assistance:

CORDIS help desk http://cordis.europa.eu/guidance/helpdesk/home_en.html

EPSS Help desk support@epss-fp7.org

IPR help desk http://www.ipr-helpdesk.org

# Introduction

Via the Calls for Proposal, Clean Sky aims to incorporate Partners to address very specific tasks which fit into the overall technical Work Programme and time schedule.

Due to the nature of these tasks, the Call is not set up using a set of themes, but it is conceived as a collection of very detailed Topics. The Call text therefore consists of a set of topic fiches, attached here.

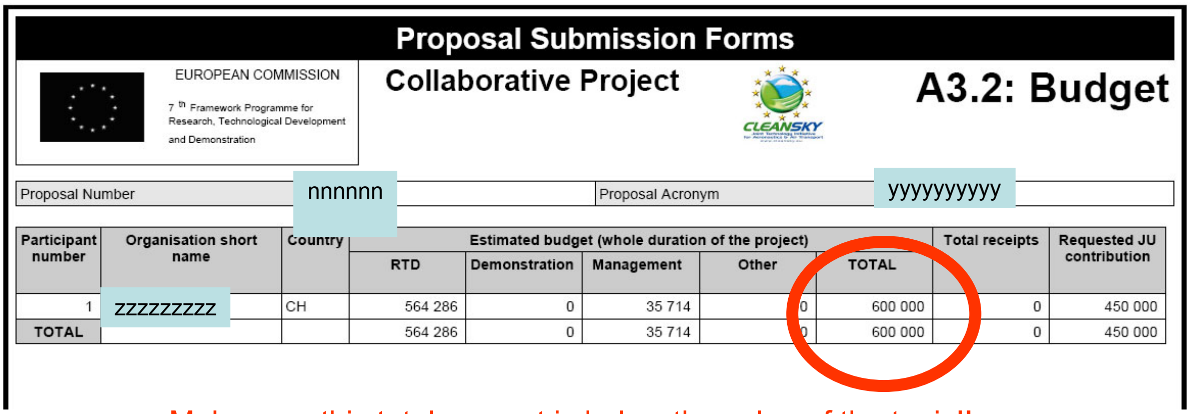
Each Topic fiche addresses the following points:

- Topic manager (not to be published)
- Indicative start and Indicative End Dates of the activity
- Description of the task
- Indicative length of the proposal (where applicable)
- Specific skills required from the applicant
- Major deliverables and schedule
- Maximum Topic Budget value
- Remarks (where applicable)

**The maximum allowed Topic budget relates to the total scope of work. A Maximum funding is also indicated.**

Depending on the nature of the participant, the funding will be between 50% and 75% of the Topic maximum budget indicated. It has to be noted that the Topic budget excludes VAT, as this is not eligible within the frame of Clean Sky.

**Recommendation to applicants:**



Proposal Submission Forms

EUROPEAN COMMISSION
7 th Framework Programme for Research, Technological Development and Demonstration

Collaborative Project

A3.2: Budget

Proposal Number: nnnnnn
Proposal Acronym: yyyyyyyyyy

| Participant number | Organisation short name | Country | Estimated budget (whole duration of the project) RTD | Demonstration | Management | Other | TOTAL | Total receipts | Requested JU contribution |
|---|---|---|---|---|---|---|---|---|---|
| 1 | zzzzzzzzz | CH | 564 286 | 0 | 35 714 | 0 | 600 000 | 0 | 450 000 |
| TOTAL | | | 564 286 | 0 | 35 714 | 0 | 600 000 | 0 | 450 000 |

Make sure this total amount is below the value of the topic!!
Better, keep at least 5% margin.
Final amount is to be discussed in the negotiation.

**Eligibility criteria**

All applicants are requested to verify their actual status of "**affiliate**" with respect to the members of the relevant ITD for whose topic(s) they wish to submit a proposal. Applicants who are affiliated to any leader or associate of an ITD will be declared not eligible for the topics of that ITD.
Refer to art.12 of the Statute (*Council Regulation (EC) No 71/2007 of 20 December 2007 setting up the Clean Sky Joint Undertaking*) and to page 8 of the Guidelines.

**Thresholds:**

As indicated in section 4.6 of the *"Rules for Participation and Rules for Submission of Proposals and the related Evaluation, Selection and Award Procedures"*, each proposal will be evaluated on 6 criteria.

For a Proposal to be considered for funding, it needs to pass the following thresholds:

- **Minimum 3/5** score for each of the 6 criteria,
  **AND**
- **Minimum 20/30 total score**

**Only one Grant Agreement (GA) shall be awarded per Topic.**

**Calendar of events:**

- **Call Launch: 10 February 2011**
- **Call close: 3 May 2011, 17:00**

- Evaluations (indicative): 23-27 May 2011

- Start of negotiations (indicative): 01 July 2011
- Final date for signature of GA by Partner: 31 August 2011
- Final date for signature of GA by Clean Sky JU: 15 September 2011

**Recommendation**

The applicant is encouraged to apply for a PIC (Participant Identity Code) and to launch the process of validation as early as possible; this will speed up the process of negotiation in the event that your proposal is successful (see http://ec.europa.eu/research/participants/portal/appmanager/participants/portal)

**Contacts:**
All questions regarding the topics published in this Call can be addressed to:

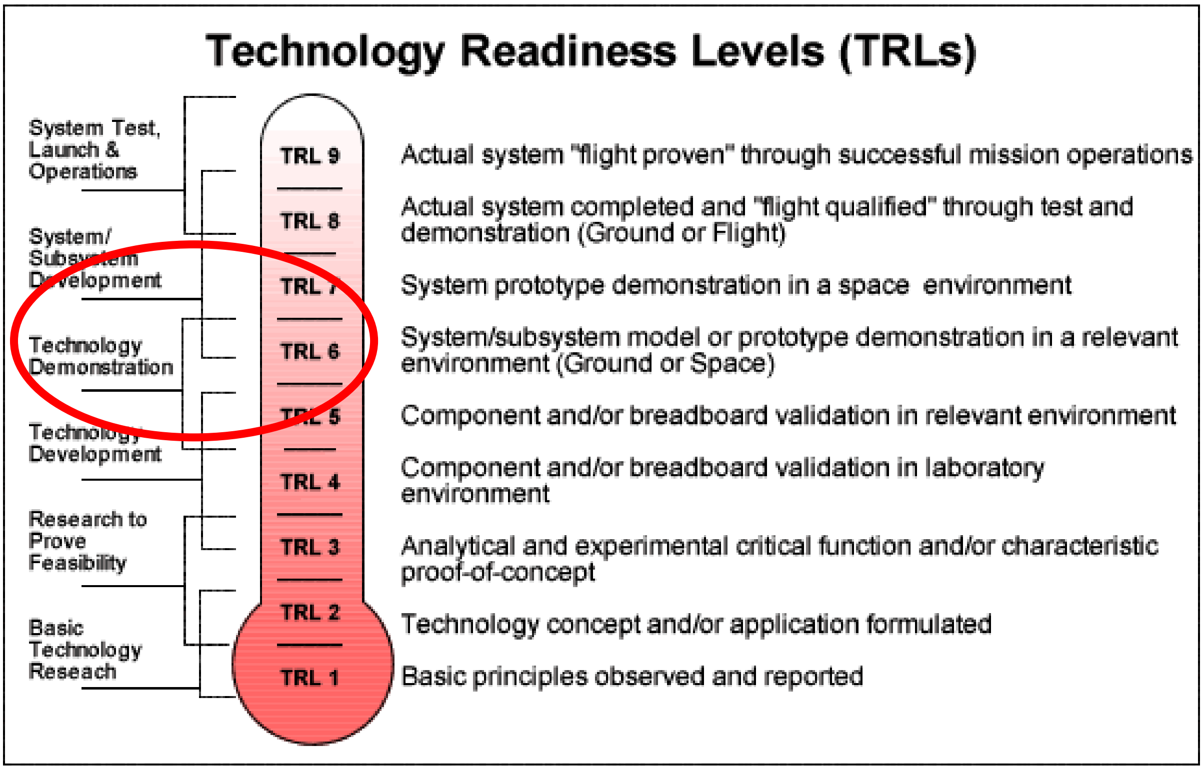
**info-call-2011-01@cleansky.eu**

Questions received until **25 March 2011** will be considered.

Questions having a general value, either on procedural aspects or specific technical clarifications concerning the call topics, when judged worth being disseminated, will be published in a specific section of the web site (www.cleansky.eu), together with the answers provided by the topic managers.

All interested applicants are suggested to consult periodically this section, to be updated on explanations being provided on the call content.

**Reference to TRL:**
When applicable or quoted in the text of topics, the applicants should be aware of the definition of Technology Readiness Levels, as per following chart, being TRL 6 the target for Clean Sky for all applicable technologies:



| Identification | ITD - AREA - TOPIC | topics | VALUE | MAX FUND |
|---|---|---|---|---|
| **JTI-CS-ECO** | **Clean Sky - EcoDesign** | **12** | **6.410.000** | **4.807.500** |
| *JTI-CS-ECO-01* | *Area-01 - EDA (Eco-Design for Airframe)* | | 2.050.000 | |
| JTI-CS-2011-1-ECO-01-018 | Environmental Data Models and Interface development | | 720.000 | |
| JTI-CS-2011-1-ECO-01-019 | Borate-free cleaners used in anodizing processes | | 100.000 | |
| JTI-CS-2011-1-ECO-01-020 | Chromate-free sealing of TSA | | 100.000 | |
| JTI-CS-2011-1-ECO-01-021 | Industrialisation Set-Up of Thermoplastics «In situ » Consolidation Process | | 290.000 | |
| JTI-CS-2011-1-ECO-01-022 | Development of flexible inductive thin sheet heating device for FRP repair applications | | 200.000 | |
| JTI-CS-2011-1-ECO-01-023 | To develop recycling technologies of aeronautical composite materials through mechano-physical approaches | | 140.000 | |
| JTI-CS-2011-1-ECO-01-024 | Simplified LCA Tool development | | 250.000 | |
| JTI-CS-2011-1-ECO-01-025 | Production of yarns and fabrics based on recycled carbon fibres (CFs) | | 250.000 | |
| *JTI-CS-ECO-02* | *Area-02 - EDS (Eco-Design for Systems)* | | 4.360.000 | |
| JTI-CS-2011-1-ECO-02-008 | Electrical Model of Generic Architecture Electrical Power Distribution | | 300.000 | |
| JTI-CS-2011-1-ECO-02-009 | Alternator with active power rectification and health monitoring | | 1.700.000 | |
| JTI-CS-2011-1-ECO-02-010 | Development, Construction and Integration of Systems for Ground Thermal Test Bench | | 2.000.000 | |
| JTI-CS-2011-1-ECO-02-011 | Heat pipe for critical applications | | 360.000 | |
| **JTI-CS-GRA** | **Clean Sky - Green Regional Aircraft** | **6** | **1.330.000** | **997.500** |
| *JTI-CS-GRA-01* | *Area-01 - Low weight configurations* | | 770.000 | |
| JTI-CS-2011-1-GRA-01-035 | Smart maintenance technologies | | 220.000 | |
| JTI-CS-2011-1-GRA-01-036 | Development of methodology for selection and integration of sensors in fuselage stiffened panels. Testing scheme, | | 100.000 | |
| JTI-CS-2011-1-GRA-01-037 | Advanced fuselage and wing structure based on innovative alumiunium lithium alloy - numerical trade off study and | | 450.000 | |
| *JTI-CS-GRA-02* | *Area-02 - Low noise configurations* | | 460.000 | |
| JTI-CS-2011-1-GRA-02-015 | Advanced concepts for trailing edge morphing wings - Design and Manufacturing of test rig and test samples - Test | | 210.000 | |
| JTI-CS-2011-1-GRA-02-016 | Novel nose wheel evolution for noise reduction | | 250.000 | |
| *JTI-CS-GRA-03* | *Area-03 - All electric aircraft* | | | |
| *JTI-CS-GRA-04* | *Area-04 - Mission and trajectory Management* | | | |
| *JTI-CS-GRA-05* | *Area-05 - New configurations* | | 100.000 | |
| JTI-CS-2011-1-GRA-05-006 | Updated Regional traffic scenario to upgrade Requirements for "Future Regional Aircraft". | | 100.000 | |
| **JTI-CS-GRC** | **Clean Sky - Green Rotorcraft** | **5** | **3.150.000** | **2.362.500** |
| *JTI-CS-GRC-01* | *Area-01 - Innovative Rotor Blades* | | | |
| *JTI-CS-GRC-02* | *Area-02 - Reduced Drag of rotorcraft* | | | |
| *JTI-CS-GRC-03* | *Area-03 - Integration of innovative electrical systems* | | 2.150.000 | |
| JTI-CS-2011-1-GRC-03-006 | EMA for utility consumer systems: EMA for Landing Gear | | 1.000.000 | |
| JTI-CS-2011-1-GRC-03-007 | Innovative Dynamic Rotor Brake | | 700.000 | |
| JTI-CS-2011-1-GRC-03-008 | Innovative High Voltage Energy Storage System for Advanced Rotorcraft Integration. | | 450.000 | |
| *JTI-CS-GRC-04* | *Area-04 - Installation of diesel engines on light helicopters* | | | |
| *JTI-CS-GRC-05* | *Area-05 - Environmentally friendly flight paths* | | 800.000 | |
| JTI-CS-2011-1-GRC-05-005 | Integrated ATC/tiltrotor simulation of low-noise procedures and evaluation of the impact on operators | | 800.000 | |
| *JTI-CS-GRC-06* | *Area-06 - Eco Design for Rotorcraft* | | 200.000 | |
| JTI-CS-2011-1-GRC-06-003 | Dismantling and recycling of ecodesigned helicopter demonstrators | | 200.000 | |
| **JTI-CS-SAGE** | **Clean Sky - Sustainable and Green Engines** | **18** | **20.000.000** | **15.000.000** |
| *JTI-CS-SAGE-01* | *Area-01 - Geared Open Rotor* | | 1.000.000 | |
| JTI-CS-2011-1-SAGE-01-001 | Lean Burn Control System Verification Rig | | 1.000.000 | |
| *JTI-CS-SAGE-02* | *Area-02 - Direct Drive Open Rotor* | | 4.500.000 | |
| JTI-CS-2011-1-SAGE-02-006 | Pitch Change Mechanism key technologies maturation | | 2.000.000 | |
| JTI-CS-2011-1-SAGE-02-007 | PCM kinematic demonstration | | 2.200.000 | |
| JTI-CS-2011-1-SAGE-02-008 | Propellers electrical de-icing system: reliability assessment of key technologies for high temperature electrical machines | | 300.000 | |
| *JTI-CS-SAGE-03* | *Area-03 - Large 3-shaft turbofan* | | 6.900.000 | |
| JTI-CS-2011-1-SAGE-03-007 | Large 3-shaft Demonstrator – Core Turbomachinery – High Temperature Flexible PCB | | 600.000 | |
| JTI-CS-2011-1-SAGE-03-009 | Large 3-shaft Demonstrator – Aeroengine intake acoustic liner technology development | | 5.000.000 | |
| JTI-CS-2011-1-SAGE-03-010 | Steel casting process advancement | | 800.000 | |
| JTI-CS-2011-1-SAGE-03-011 | Advanced press forming and hardening of high strength steels | | 500.000 | |
| *JTI-CS-SAGE-04* | *Area-04 - Geared Turbofan* | | 5.300.000 | |
| JTI-CS-2011-1-SAGE-04-008 | Casting process optimization and validation of hollow multivane clusters with thin walls and trailing edges | | 600.000 | |
| JTI-CS-2011-1-SAGE-04-009 | Integrating forging- and process-simulation into SAGE4 GTF LPT rotor design | | 400.000 | |
| JTI-CS-2011-1-SAGE-04-010 | Total Measurement System for Geometry and Surface Inspection of bladed Disks (TOMMI) | | 1.300.000 | |
| JTI-CS-2011-1-SAGE-04-011 | Implementation of Carbon-Nanotube Rein-forced Aluminum for Aerospace Heat Ex-changer Applications | | 1.000.000 | |
| JTI-CS-2011-1-SAGE-04-012 | Electric Smart Engine Actuator | | 1.000.000 | |
| JTI-CS-2011-1-SAGE-04-013 | High temperature Ni-based alloy forging process advancement | | 500.000 | |
| JTI-CS-2011-1-SAGE-04-014 | High temperature Ni-based super alloy casting process advancement | | 500.000 | |
| *JTI-CS-SAGE-05* | *Area-05 - Turboshaft* | | 2.300.000 | |
| JTI-CS-2011-1-SAGE-05-013 | Feasibility study and prototypes manufacturing of oil tank in thermoplastic for Helicopter Engine | | 450.000 | |
| JTI-CS-2011-1-SAGE-05-014 | Hot environment unsteady pressure sensors | | 750.000 | |
| JTI-CS-2011-1-SAGE-05-015 | Development of Quiet exhaust noise attenuation technologies | | 1.100.000 | |
| **JTI-CS-SFWA** | **Clean Sky - Smart Fixed Wing Aircraft** | **12** | **9.900.000** | **7.425.000** |
| *JTI-CS-SFWA-01* | *Area01 – Smart Wing Technology* | | 2.100.000 | |
| JTI-CS-2011-01-SFWA-01-034 | Analysis of sensitivity/robustness of distributed micron-sized roughness elements (MSR) for transition delay | | 500.000 | |
| JTI-CS-2011-01-SFWA-01-035 | Grooved paint surface manufacturing and aerodynamic testing | | 350.000 | |
| JTI-CS-2011-01-SFWA-01-036 | Automated riblet application on relevant aircraft parts | | 550.000 | |
| JTI-CS-2011-01-SFWA-01-037 | Basic wind tunnel investigation to explore the use of Active Flow Control technology for aerodynamic load control | | 250.000 | |
| JTI-CS-2011-01-SFWA-01-038 | High Voltage amplifier for MEMS-based Active Flow Control (AFC) actuators | | 450.000 | |
| *JTI-CS-SFWA-02* | *Area02 – New Configuration* | | 3.150.000 | |
| JTI-CS-2011-01-SFWA-02-012 | Design and manufacturing of an innovative shield - A | | 70.000 | |
| JTI-CS-2011-01-SFWA-02-013 | Design and manufacturing of an innovative shield - B | | 90.000 | |
| JTI-CS-2011-01-SFWA-02-014 | Design and manufacturing of an innovative shield - C | | 90.000 | |
| JTI-CS-2011-01-SFWA-02-015 | Ground Based Structural and Systems Demonstrator Phase 3 – Component and sub-system manufacture | | 2.900.000 | |
| *JTI-CS-SFWA-03* | *Area03 – Flight Demonstrators* | | 4.650.000 | |
| JTI-CS-2011-1-SFWA-03-006 | Outer wing assembly for tooling manufacturing | | 3.000.000 | |
| JTI-CS-2011-1-SFWA-03-007 | Low drag wing foam cover for flight test | | 900.000 | |
| JTI-CS-2011-1-SFWA-03-008 | Acoustic Inlet Lip panel large scale endurance demonstrator | | 750.000 | |
| **JTI-CS-SGO** | **Clean Sky - Systems for Green Operations** | **5** | **1.700.000** | **1.275.000** |
| *JTI-CS-SGO-01* | *Area-01 - Definition of Aircraft Solutions and explotation strategies* | | | |
| *JTI-CS-SGO-02* | *Area-02 - Management of Aircraft Energy* | | 1.450.000 | |
| JTI-CS-2011-1-SGO-02-014 | Construction of evaluation Power Modules to a given design | | 250.000 | |
| JTI-CS-2011-1-SGO-02-026 | Modelica Model Library Development Part I | | 300.000 | |
| JTI-CS-2011-1-SGO-02-032 | Current return simulation (methodology & tool) | | 400.000 | |
| JTI-CS-2011-1-SGO-02-033 | Optimisation of coating for low pressure operation of power electronics and identification of pass and fail criteria for r | | 500.000 | |
| *JTI-CS-SGO-03* | *Area-03 - Management of Trajectory and Mission* | | 250.000 | |
| JTI-CS-2011-1-SGO-03-011 | Flight operations for novel Continous Descent Operations | | 250.000 | |
| *JTI-CS-SGO-04* | *Area-04 - Aircraft Demonstrators* | | | |
| *JTI-CS-SGO-05* | *Area-05 - Aircraft-level assessment and exploitation* | | | |
| **JTI-CS-TEV** | **Clean Sky - Technology Evaluator** | **0** | | |
| | | topics | VALUE | FUND |
| | totals (€) | 58 | 42.490.000 | 31.867.500 |

# Clean Sky – EcoDesign

| | | | |
|---|---|---|---|
| **JTI-CS-ECO** | **Clean Sky - EcoDesign** | **12** | **6.410.000** |
| *JTI-CS-ECO-01* | *Area-01 - EDA (Eco-Design for Airframe)* | | **2.050.000** |
| JTI-CS-2011-1-ECO-01-018 | Environmental Data Models and Interface development | | 720.000 |
| JTI-CS-2011-1-ECO-01-019 | Borate-free cleaners used in anodizing processes | | 100.000 |
| JTI-CS-2011-1-ECO-01-020 | Chromate-free sealing of TSA | | 100.000 |
| JTI-CS-2011-1-ECO-01-021 | Industrialisation Set-Up of Thermoplastics «In situ » Consolidation Process | | 290.000 |
| JTI-CS-2011-1-ECO-01-022 | Development of flexible inductive thin sheet heating device for FRP repair applications | | 200.000 |
| JTI-CS-2011-1-ECO-01-023 | To develop recycling technologies of aeronautical composite materials | | 140.000 |
| JTI-CS-2011-1-ECO-01-024 | Simplified LCA Tool development | | 250.000 |
| JTI-CS-2011-1-ECO-01-025 | Production of yarns and fabrics based on recycled carbon fibres (CFs) | | 250.000 |
| *JTI-CS-ECO-02* | *Area-02 - EDS (Eco-Design for Systems)* | | **4.360.000** |
| JTI-CS-2011-1-ECO-02-008 | Electrical Model of Generic Architecture Electrical Power Distribution | | 300.000 |
| JTI-CS-2011-1-ECO-02-009 | Alternator with active power rectification and health monitoring | | 1.700.000 |
| JTI-CS-2011-1-ECO-02-010 | Development, Construction and Integration of Systems for Ground Thermal Test Bench | | 2.000.000 |
| JTI-CS-2011-1-ECO-02-011 | Heat pipe for critical applications | | 360.000 |

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-018 | **Environmental Data Models and Interface Development** | **End date** | *T0 + 32 months* |
| | | **Start date** | *T0* |

## 1. Topic Description

The content of this call is directly following up work carried out within the Clean Sky Eco-Design following the outlines in [1].

Based on the current status of the Clean Sky EDA project consortium knowledge and the outcomes of the Clean Sky Eco-Design work outlined in [1], a Life Cycle Assessment (LCA) model shall be defined for a set of reference aircrafts. This includes identification of major components/parts, allocation of materials selection, and analysis of current processes for production, maintenance, and recycling/disposal. This analysis explicitly should cover the use of ILCD 1.1 (International Reference Life Cycle Data System) data format and data readily available.

The topics and activities in this call contain:

- A model that shall be transformable into a future reference aircraft, taking into account the progress in materials, processes, life time prediction, and recycling steps from the Clean Sky EDA project as well as from other sources which might be applicable.
- LCA modelling for the most relevant materials and processes for environmental friendly aircraft production, maintenance, and disposal
- identification of the most relevant processes in terms of environmental effects
- set up a parameterized model for the reference aircraft
- perform impact analysis and sensitivity analysis for environmental impacts of the reference and future aircraft
- provision of a scale-up option of the single reference aircraft results to a fleet level, and a benchmarking option on this level
- delivery of a workplan taking into account the easy-to-use interface for the standard LCA tool (API: Application programming interface) and a harmonization of the software interface with the EDA LCA tool
- the applicant shall propose a method and project plan of cooperation with the CS EDA partners involved
- delivery of a milestone plan for a comprehensive documentation of the LCA models, of the current and future aircrafts, of the method and the contents as well as of the key findings has to be provided
- guarantee a cooperation with the CLEAN SKY Eco-Design project related to a call work element described in [1]
- establish an ongoing exchange, coordination and adaptation process between the applicant and the Topic Manager.

The LCA models and methods developed have to be applicable, flexible and customized for the aeronautics industry. Modeling has to be done in the standard LCA software tool GaBi (Ganzheitliche Bilanzierung) for verification.

Due to the complex structure of aircrafts, a function allowing to import Bills of Material into the software should be available, in order to reduce time required to model reference and future aircraft. A general methodological framework of Life Cycle Assessment in the aviation industry has to be developed.

## 2. Special skills, certification or equipment expected from the applicant

The expected maximum total proposal length is 25 pages.

The applicant has to show a multi-year track record of work in the field of LCA, and has to show that he already has worked in the aeronautics field in European publicly funded projects.

The work shall be carried out using the GaBi LCA tool to capitalize synergy effects from the CLEAN SKY Eco-Design funded project resting on the outlines [1] in order to reduce cost and workload and to ensure full compatibility of database, data sets and modells from the CLEAN SKY Eco-Design funded project related to the outlines [1].

Proven network in LCA community, materials suppliers sector and in professional knowledge of data acquisition in various sectors is required.

Access to the GaBi LCA software tool for source code modification is necessary to fully meet the specifications of this CfP in order to provide an adequate API for a maximum of automation. The LCA software tool must include functionality for a parametrized and flexible modeling of complex processes, especially in the aeronautic industry. Moreover, it must be guaranteed that the ILCD 1.1 support of the LCA software tool is available at project start.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | KOM MoM | Kickoff Meeting Minutes: shall provide a common basis of goal and scope of work | T0+4 |
| D2.1 | Progress Report 1 and presentation | progress report including methodology, assumptions, and detailed work plan | T0+10 |
| D2.2 | Progress Report 2 | annual progress report | T0+16 |
| D2.3 | Progress Report 3 | annual progress report | T0+28 |
| D3 | Reference a/c definition | basis for LCA work | T0+10 |
| D4 | Key findings Presentation | | T0+28 |
| D5 | Comprehensive Documentation | | T0+32 |
| D6 | ILCD Data base | | T0+32 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 720.000**

**[seven hundred twenty thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*Internal reference: This CfP addresses the WP2.1.4, 2.2.3, 3.1 and 3.3 of the CS EDA project*

**References**

[1] Related ECO Design Airframe work element

Title: LCA Databases Improvement

The content of this call was improvement of Life Cycle Assessment database, application and customisation for aerospace sector:

- Requirements and acquisition of LCA background data and datasets according to the specific needs of the aerospace sector e.g. from materials suppliers
- Harmonisation of Eco-Design activities with the ELCD system of the EC
- Life Cycle Assessment (LCA) of current and future system as benchmark (Life Cycle Inventory and Life Cycle Impact Assessment)
- raw material supply
- production and manufacturing
- identification of ecological weak-points
- sensitivity analyses on ecological impacts
- quantification of ecological improvements
- Modelling and calculation of selected parts for the current eco statement in the standard GaBi (Ganzheitliche Bilanzierung) LCA software for verification of data sets
- use of harmonised nomenclature of flows and accounting methods for flows like GaBi which will be clarified for the proposing partner

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| *JTI-CS-2011-1-ECO-01-019* | **Borate-free cleaners used in anodizing processes** | End date | *31/12/2011* |
| | | Start date | *01/01/2011* |

## 1. Topic Description

The subject of this CfP is to evaluate the process window for the borate free alkaline cleaning of aluminium alloys used typically in aerospace industry.

Todays commonly used bath cleaning processes are using borate containing alkaline cleaning agents. Bath processes are used for the cleaning of aluminium parts before they will enter pre-tratment processes like pickling, etching or anodising.

Major aim of this projekt is to evaluate the process window for borate free alkaline cleaning processes. For the evaluation of the process window the influence of the temperature and the immersion time to different properties of the new cleaning agents shall be identified. The process window influence to the cleaning effect shall be shown by wettingb tests and surface analysis like XPS or ESCA to show rest contamination after cleaning. Also the mechanical influence of the cleaning agent shall be evaluated by end grain pitting tests and micrisections.

After the evaluation of the process parameters the workability of the new cleaning agent shall be shown by some small and midsize laboratory tests where cleaned parts will enter AIRBUS standard pre-treatment tests. Cleaned parts will enter the process chain at the laboratory galvanic in Bremen.

After anodisation the parts shall be checked for thier properties by corrosion tests and microscopic analysis of the anodisation layer.

A final report shall give detailed information of the performed tests and summarize all results in expected 80 pages.

## 2. Special skills, certification or equipment expected from the applicant

*Experience in: Cleaning and Surface technologie, mechanical testing and pre-treatmet processes*

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Test program | In the test program detailed information shall be given which tests shall be performed. | 28/01/2011 |
| D2 | Midterm report | Midterm report shall give first results and information if an adjustment of the test program is needed. | 15/07/2011 |
| D3 | Final report | Final report shall give detailed information of the performed tests and summarize all results in minimum 80 pages. | 09/12/2011 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 100.000**

**[one hundred thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*None*

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-020 | **Chromate free and energy efficient sealing of TSA anodic films for corrosion protection.** | **End date** | *31/12/2011* |
| | | **Start date** | *01/01/2011* |

## 1. Topic Description

In the frame of chromate replacement TSA Tartaric Sulphuric Acid Anodising was introduced at Airbus and subcontractors as a replacement for the CrVI based Chromic Acid Anodising process. The TSA process is used as pretreatmentment before paint application. For corrosion protection of unpainted parts the pores of the film has to be sealed to provide sufficient resistance to corrosive environment. Actually the sealing process has to be carried out in chromate containing boiling water, or a CrVI based conversion coating process. In the frame of chromate replacement and also for REACH compliance, both sealing options has to be replaced by environmental friendly processes and products.

The following six tasks shall be considered:

1. Standard hot water sealing shall be used as reference for alternative options.

2. Hot water sealing process supported by REACH compliant sealing additives

3. Investigation of alternative sealing via chromate free conversions coatings, eg. CrIII, Silanes etc.

4. Adaption of the electrical TSA cycle for improved corrosion resistance for unpainted parts without negative impacts on the fatigue cycle.

5. Local sealing of partial painted parts based on Task 3 procedures (Silane or CCC).

6. Combination of indiviual measures with the aim to provide a maximum of achievable corrosion protection.

The six task are chosen in that way, because it shall be ensured the in any case the requirements for corrosion protection were met. A main focus will be put on the investigation and understanding of cold sealed anodic films via CCC on Silanes systems with strongly reduced energy consumption.

As mitigation, but also to provide a process with a maximum of corrosion protection the sixth task shall combine different separate measures. So it shall be considered, the combination of e.g. optimised hot water sealing followed by a conversion coating for extra protection, and e.g. adapted TSA plus hot water seal or CCC. Aim is to meet the performance of the CAA film in combination with dichromate hot water sealing, which is usually 500h salt spray test (SST) and more.

The assessment of the sealing options will be justified with the required standard salt spray test, but also with additional investigations like impedance spectroscopy (EIS), to get detailed information about the resistance of the generated films. Further aim is to correlate SST values and EIS data, so that EIS can be used as a additional very fast method for quality control of the sealed films in case of production problems.SEM shall be used to investigate the surface modification after the sealing process and as a pre-assessment for selection if sealed coatings were suitable for paint application as alternative option for the post local sealing procedure.

For application of the different processes that lab galvanic line at Airbus in Bremen will be available for the sample preparation studies, including the paint application.

The quality of achieved data shall be sufficient, so that the proposed process can be be specified. Finally it is intended, to provide a commonly accessible and available EN with the relevant TSA process parameters, including the sealing parameters.

## 2. Special skills, certification or equipment expected from the applicant

*Experience in: Cleaning and Surface technologie, mechanical testing and pre-treatmet processes*

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Test program | In the test program detailed information shall be given which tests shall be performed. | 28/01/2011 |
| D2 | Midterm report | Midterm report shall give first results of task 1 to 4 as baseline for process combinations. | 15/07/2011 |
| D3 | Final report | The final report covers the finished performance data of the combined processes and the local sealing performance. The second part of the report covers the process parameter set as baseline for specification, including a proposal for the EIS quality control. | 15/12/2011 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 120.000**

**[one hundred twenty thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*None*

# Clean Sky Joint Undertaking
## JTI-CS-2011-1-ECO-01-021

**Topic Description**

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-021 | **Industrialization set up of Thermoplastics *«In situ»* Consolidation Process** | **End date** | *T0 + 27 Months* |
| | | **Start date** | *T0* |

## 1. Topic Description

**Short description:** The subject of this CfP is to assess a new manufacturing process based on "In situ consolidation" (ISC) under industrial perspective. In this context, following the integration of the process into a machine head, appropriate manufacturing trials have to be performed progressively covering since basic design details up to a more complex structure enabling the integration of bidirectional stiffeners onto a curved panel. Manufacturing should take place with last generation of PEEK material or other thermoplastic with similar characteristics. Basic repairs derived from the necessity of restoring a prescribed quality have to be searched in parallel, providing rational for eco-statement.

**1.1 Introduction**

**1.1.1 Background:** The attractive characteristics of thermoplastics from the mechanical and environmental point of view have led to try to extend the use of composite thermoplastic materials as much as possible into aero-structures, (cabin floors, large curved panels, doors, etc.). The main drawback of thermoplastic composites is the higher cost of manufactured product in comparison with current thermoset material and process, generally associated with higher cycle temperature. The absence of an industrialized, automated and efficient manufacturing process and the limited reparability knowledge on this type of materials come to reinforce this situation.

In order to get advantage of the thermoplastic potential under an industrial perspective, a research based on "in situ" consolidation has been proposed to get profit of the foreseen intrinsic advantages associated to the process under both economic and ecological perspective induced the cancellation of autoclave use. Study of such energy balance should be part of the research. In addition, reversibility characteristic of the matrix should be primarily investigated to assess the capability to restore quality requirements associated to the manufacturing process (other alternatives might be proposed)

The whole activity must be oriented to enable in a longer term the production of a slight double curvature panel with longitudinal and transversal members being integrated through whichever process might be feasible including welding. Tooling aspects become an essential activity to be carefully assessed under industrial perspective. In essence, the practical demonstration must account for a method to fix first layer & a modular tooling to enable manufacturing since the flat panel with variable thickness until a double curved stiffened panel (not necessary accomplished within proposed time frame)

**1.1.2 Interfaces to ITD:** The information exchange will be materialized through deliverables to be established in the proposal that shall be accepted in the negotiation phase by ITD. Ordinary meetings will be held every two months and eventual meetings when the exceptional situation requires it.

**1.2 Reference documents**

Not applicable

**1.3 Scope of work:**
Assess a new thermoplastic manufacturing process based on "In situ consolidation" with respect to the standard one currently in use for this type of materials under industrial perspective through the production of a curved and variable thickness skin with integrated longitudinal and transversal reinforcements. The job will apply the knowledge available at the moment regarding "In situ consolidation" automated process to produce different trials with particular interest on preselected design details bearing in mind usage of:

- Material: -PEEK APC2-AS4 as reference. (Note: It is considered essential to establish an interactive relation with the material suppliers in order to continuously improve the material compatibility with the automation process.

- Modular Tooling:

Enabling different manufacturing details

With first layer fixing system/method

Surface treatment to increase adherence

Providing acceptable thermal gradients during consolidation

- Research on the way, method or process to restore the nominal quality of manufacturing associated to automated process being implemented in case of existence of unacceptable defects.

**1.4 Glossary of tasks**

1.- Identify "In-Situ" consolidation machine and material supplier

2.- Define and agree with the machine supplier and ITD the different manufacturing details and concepts to be proved in order to demonstrate the industrial feasibility of the ISC automatic process within the head machine (joggles, corners drop-off, assembly process, welding process, longitudinal and transversal stiffeners configuration, panel curvatures…)

3.- Agreement on detailed design of the structural element to be produced called "Demonstrator"

4.- Define the quality criteria to be controlled during manufacturing

5.- Propose repair alternatives to restore manufacturing quality - Design and manufacture required tooling and fixing system for first layer

6.- Identify the best alternative NDT inspection method for the layer being consolidated

7.- Optimize the process parameter for each manufacturing detail being produced.

8.- Manufacture all foreseen trials and "Demonstrator"

9.- Make destructive and non destructive inspection as required identifying areas to prove repair feasibility. Inspection test plan should be compiled in advance, being agreed by ITD. As much as possible, IPSS (In plane shear strength) and OHC (Open Hole Compression) laminate properties extracted from manufacturing trials should be checked to enlarge knowledge extracted from quality inspection program

10.- Repair trials to restore manufacturing quality

11.- Process assessment under industrial perspective

- Aspects of concern of process automatization into a head machine
- Tooling concerns
- Potential improvements of all the aspects involved in the automatization (i.e material, head machine, process, tooling etc)

12.- Repair assessment (specially under green perspective)

13.- Eco-statement vs current manufacturing technique of each structural item being produced.

*Information to be accounted for offer quotation:*

- *Flat specimens (30): 10 different detail config/geometry x 3 (for variability)*

  *Nominal thicknesses: 2mm, 4mm & 6mm*

  *Drop-off range: 1:10 & 1:20*

  *Lay-up´s: (45/-45)xS; (0/90)xS; (0/45/-45/90)xS or balanced combination of them*

  *Specimen span ratio: 200 mm x 400 mm*

- *Stiffened panel overall size: 400 mm x 400 mm*

  *Stringer; "C" shape 25x100x25; 3mm thickness; (45/-45)xS*

*The result of all this tasks will be echoed within the corresponding deliverables listed below.*

## 2. Special skills, certification or equipment expected from the applicant

- Experience on thermoplastic "In situ" consolidation process development
- Experience on Thermoplastic "In situ" consolidation process integration into a head machine
- Capability of design (CATIA 5 release 16 or higher)
- Experience in CFRP design
- Experience in manufacturing engineering
- Experience in manufacturing laminates both hand and automatic lay-ups is required
- Experience with thermoplastic autoclave process is required
- Abilities and capabilities for coupons preparation for destructive & NDI testing tis mandatory
- Experience and capabilities for coupons mechanical testing
- Both tooling and demonstrator must be delivered at ITD facilities once the deliverables have been finished

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | ISC Industrialization criteria and green requirements | Document | T0 + 03 |
| D2 | Demonstrator concept & Manufacturing details description (Including defects proposal) | Document | T0 + 05 |
| D3 | Demonstrator design & defects repair proposal | Document + CATIA | T0 + 07 |
| D4 | Tooling design | Document + CATIA | T0 + 09 |
| D5 | Tooling manufacturing | Tooling | T0 + 14 |
| D6 | "Details" manufacturing trials & quality report | Structural items + Document | T0 + 16 |
| D7 | Mechanical test results | Document | T0 + 18 |
| D8 | Preliminary demonstrator production (including inspection) | Element + NDI report | T0 + 20 |
| D9 | Repairs assessment | Document | T0 + 24 |
| D10 | Evaluation of the process including eco-statement | Document | T0 + 27 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 290.000**

**[two hundred ninety thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

The meetings for project monitoring will be held at ITD facilities in Getafe (Spain)

In average a meeting every two months will be required.

Tooling design and coupons tests must be organized using maximum communalities to optimize subsidiary costs and speed up testing for the whole set of specimens

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-022 | **Conductive thin skin heating (CSH) device for FRP repair applications** | **End date** | *To +24 Months* |
| | | **Start date** | *To* |

## 1. Topic Description

Introduction:

State-of-the-art heating and curing devices for FRP repairs are mainly based on electrical heat mats or on infrared radiatiors. The main disadvantages of electrical heat mats are the relatively long heating times and the energy consumption. Standard infrared radiators are faster, but the heat distribution over the repair area is non homogenious and difficult to control on multi curved surfaces (risk of heat spots).

Therefore new fast, low energy consuming heating techniques like medium frequency induction and near infrared are the subject of Task A.2.3.3-03. Alternatively to this two already selected heating devices a third heating method called CSH (conductive skin heating) should be developed and investigated within the new CfP A.2.3.3.03-04.

Objectives:

The advantages of CSH would be, that the voltage and the current could be very low compared to heat mats because of the very good efficiency of this middle frequency heating. This means that the CSH-mats could be cheaper and that electrical danger for the operators and any peripherical electronic devices is extremly reduced. This method allows heating of very thin foils which means, that the CSH-mats are very flexible and easy to adapt to 3D-geometries and can be integrated very easily into the vacuum device (directly under the vacuum foil). Additionally the handling of this thin and lightweight CSH-mats is very easy compared to the other heating systems used for FRP repair. Using laminar conductors makes laminar heating much more efficient and leads to very homogeneous heating. It also would be possible to define areas with higher and lower temperatures by modifying the geometry of the conductor foil.

Within the project a new generator type tailored for FRP repairs has to be developed together with a special software, which makes operating easy and failure safe. To get best results the best conductor materials and geometries and the best way to integrate the system into the repairing process has to be found out. Additionally an economic fabrication method of such a slotted foil and a robust contacting device, which allows positioning under the vacuum foil, have to be developed.

Requirements:

The flexible conductive heating devices have to be applicable for vacuum curing applications up to 150°C of FRP´s (mainly CFRP).

For GRP an additional succeptor layer, as already used for other inductive heating operations, will be necessary.

The flexible CSH heating foil has to be suitable for standard vacuum curing techniques. This means, the CSH foil will be preferable placed upon the bleeder layer, but below the vacuum foil. Therefore the thin CSH foil have to be compatible with standard auxiliary materials for vacuum repair applications (e.g peel plies, release films, bleeder and flexible vacuum foils).

Such a lay-up order of the auxiliary materials in the combination with the CSH foil will guarantee a tight contact and a defined distance of the heating device to the FRP surface, without the need of an additional pressure tool.

Furtheron, the flexible CSH device (control unit, connecting parts, inductive thin sheet,..) have to be designed as a “mobile light weight equipment” for the shop and specifically for field repair applications.

## 2. Special skills, certification or equipment expected from the applicant

The applicant must have the knowledge for the design of CSH heating devices and must have facilities to test and manufacture CSH heating equipment

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Selection of CSH foils and control unit and pre study of possible energy output and heat transfer on flat CFRP surfaces; development of a feasible contacting method. | | To + 6 Months |
| D2 | Optimisation of CSH heating device and development of suitable software. | | To + 12 Months |
| D3 | Application tests under vacuum repair conditions on flat CFRP laminates | | To + 16 Months |
| D4 | Application tests under vacuum repair conditions on curved CFRP structures | | To + 22 Months |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**200.000,- €**

**[two hundred thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

The flexible CSH heating device, is an absolutely new approach!

Patent compiled, but pending

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-023 | **To develop recycling technologies of aeronautical composite materials through mechano-physical approaches.** | End date | *To + 24* |
| | | Start date | *To* |

## 1. Topic Description

Thermoset and thermoplastic composite materials are currently used in a wide range of applications in the aerospace industry.

In fact, structural and non structural aircraft components are more and more realised in carbon fiber reinforced thermosetting plastics (CFRP) and high $T_g$ thermoplastic carbon fiber reinforced composites (TPC) in order to reduce weight and to optimise corrosion resistance and directional performances compared to the metallic solutions.

However, it is still disputed the fate of such materials in dismantling aircraft. Because the technological content of polymer based carbon fiber reinforced composites is very high, the recycling of such materials can lead to a significant improvement of the environmental impact and, also, to make high profit of the technology investment.

Objective of the call is to develop, through mechano-physical approaches, a new recycling methodology of thermoset and thermoplastic composites that doesn't provide the separation of the resin from the fibers.

The following tasks shall be performed by the selected partner:

**Task 1:** Selection of the preliminary machining technologies for grinding thermosetting as well as thermoplastic carbon fiber reinforced composite (including evaluation of the target final sizes suitable for the successive mechanical recycling);
**Task 2:** Definition and execution of the recycling process for the manufacturing of recycled specimens;
**Task 3:** Definition and execution of tests for a complete evaluation of the chemical, physical and mechanical characteristics of the obtained recycled materials. In particular, it is required to evaluate, at least in a semi-quantitative way, mode and state of interfacial adhesion between the chosen recycling matrix and CFRP fillers;
**Task 4:** Evaluation of the recycled composites performances by tests able to define their service behaviour in selected environmental conditions (combined moisture/temperature atmosphere).
**Task 5:** Manufacturing of and test on a reference part to use as demonstrator of the technology (a proper demonstrator should have dimension of at least 30 cm width and 50 cm length of different thicknesses).
**Task 6:** Based on the results of the above tasks, prepare and issue the Final Report that shall include a detailed proposal on how to optimise the materials in terms of process ability and fulfilment of the requirements.

## 2. Special skills, certification or equipment expected from the applicant

The applicant (single organization or a consortium) needs to have the following facilities and knowledge:

- Strong knowledge on thermoset and thermoplastic resin based composites;
- Wide activity on the synthesis of high performance epoxy matrices;
- Strong expertise on the curing process as well on the evaluation of curing kinetics;
- Strong knowledge of interfacial phenomena and equipments for assessing mode and state of interfacial adhesion in composites and blends (SEM, TEM, solid state NMR, Raman Spectroscopy are considered assets);
- Extensive experience and capabilities for manufacturing thermoplastic composites and experience in process optimisation (availability of processing equipments able to produce a demonstrator of the technology is considered an asset);

- Extensive experience and capabilities for characterizing thermoplastic composites ($T_g$, DSC, DMA, viscosity, etc);
- Extensive experience and capabilities to assess aging phenomena in polymer based composites, including experience in the analysis of degradation mechanisms.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Selection of conditions and technologies aimed to recycling of CFRP. | To perform a benchmarking to select proper machining and grinding technology for TSC and TPC. | T0 + 2 |
| D2 | Grinding and sorting of thermoplastic and thermoset aircraft composites. | To perform grinding and sorting according to size of CFRP and TPC suitable for the successive mechanical recycling and give results and conclusions. | T0 + 6 |
| D3 | Definition and development of the process for manufacturing composites based on recycled CFRP and TPC. | Selection of thermoplastic polymer matrices and evaluation of processing technologies suitable to get recycled thermoplastic composites. Blending of matrix with the granulated CFRP and TPC. | T0 + 10 |
| D4 | Characterization of specimen morphology and analysis of the interfacial adhesion between the selected recycling matrix and CFRP fillers. | Morphological characterization of specimens through SEM analysis. To give results and to compare with specimens obtained by conventional processing technologies. | T0 + 12 |
| D5 | Characterization of thermal and mechanical properties of the recycled thermoplastic composites. | Evaluation of thermal stability and glass transition temperature of the specimens. Characterization of interfacial adhesion in composites and blends by spectroscopic means (solid state NMR, Raman microscopy). Evaluation of dynamic-mechanical, impact and flexural properties. To give results and to compare with specimens obtained through conventional processing technologies | T0 + 14 |
| D6 | To study the effect of combined high temperature/moisture atmosphere on the material properties. | Evaluation of the composite mechanical performances to assess their service behaviour in selected environmental conditions. | T0 + 17 |
| D7 | Manufacturing of reference part as technology demonstrator | At least two demonstrators will be produced differing in shape and/or dimension to be compared to existing reference industrial items. | T0 + 20 |
| D8 | Evaluation, by test, of performances of technology demonstrators. | Evaluation of technological performances of the demonstrators (dimensional stability, creep and fatigue tests, impact and flexural properties, flame resistance). | T0 + 23 |
| D9 | Final report | | T0 + 24 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 140.000**

**[one hundred forty thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

Legend of abbreviations:

Carbon Fiber Reinforced Plastics (CFRP)
Thermoset Composites (TSC)
Transmission Electron Microscopy (TEM)
Glass transition Temperature ($T_g$)
Dynamic Mechanical Analysis (DMA)
Thermoplastic Composites (TPC)
Scanning Electron Microscopy (SEM)
Nuclear Magnetic Resonance (NMR)
Differential Scanning Calorimetry (DSC)

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-024 | **Simplified LCA (Life cycle assessment) Tool** | End date | *To + 18 Months* |
| | | Start date | *To +* |

## 1. Topic Description

The content of this call is directly following up work carried out within the Clean Sky Eco-Design.

The principal aim of this call is to develop a tool (software application) based on a simplifed life cycle assessment methodology defined by Airbus to perform Simplifed Eco-Statement for aerospace industries, and in particular for aerospace technologies developed in the Airframe Eco-Design ITD.

The main objectives are defined as follows:

- Development of an application according to simplified methodology
- Study of the compatibility and integration with the user friendly interface to be developped during Eco-Design project
- Development of an exportation module from ELCD/ ILCD 1.1 (International Reference Life Cycle Data System) database to the customised database exploited by the above tool.

In order to support the activities to be carried out as part of the call, the following information will be available :

- Description of the simplifed methodology and basic tool (based on Excel® visualbasic) on which the application should be built. One key characteristic of the current methodology is the ability to manage quantitative and qualitative data to compile a range of environmental indicators reflecting environmental profile of reference and future technologies.
- Project specific environmental database in ELCD format

**Application Development**

Three options have to be examined by the applicant to determine the best one to be implemented :

- Option 1: Development of a wrapper between the current tool (tool based on Excel® visualbasic) and the user interface to be developped by topic manager (development should be under QT – Java). This option will include the upgrade of the current tool to ensure expected functionalities.
- Option 2: Re-development of current tool in Stand alone application to meet wider industry user requirements and support upgraded functionalities
- Option 3: Collaboration with topic manager to integrate current tool functionalites directly into the user interface.

Any application development will be usable and accessible to members of Airframe Eco-Design ITD contributing in eco-statement workpackage (WP31) either as stand alone tool or via other ecodesign project LCA tool interface. The topic manager will have appropriate access to application code and relevant information to enable future upgrade to be performed in an independent manner for private company usage.

The applicant shall :

- propose a project plan including key milestones.
- guarantee a cooperation with the CLEAN SKY Eco-Design project.
- establish an ongoing exchange, coordination and adaptation process between the applicant and the Topic Manager.
- ensure the delivery of all documentation to ensure robusteness of the application to be developped.

## 2. Special skills, certification or equipment expected from the applicant

The expected maximum total proposal length is 25 pages.

The applicant has to show a multi-year track record of work in the field of IT application development (minimum Java, Java API for Microsoft documents, Visualbasic, XML development)

Knowledge and experience of Life Cyle assessment tools will also be a major advantage.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Option selection<br>Roadmap for completion | Full description of option selected.<br>Key project milestone and risk analysis | To + 3 Months |
| D2 | Description of the application | Description of the functionalities, Validation | To+ 6 |
| D3 | First application release | Validation of the functionalities | To+12 |
| D4 | Final application release | | To+18 |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**250.000 €**

[two hundreds fifty thousand euro]

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*This CfP addresses the 3.1 and 3.3 of the CS EDA project*

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-01-025 | Production of yarns and fabric based on recycled carbon fibres | **End date** | *To + 24 Months* |
| | | **Start date** | *1st April 2011* |

## 1. Topic Description

The rapid forecast growth in the carbon fibre (CF) composite market has focused attention on the need to find effective methods to re-use and recycle 'waste' CF materials. A high volume of CF waste is produced by a number of different sources in the composite manufacturing pipeline. These waste streams provide both discontinuous and continuous CF. Note that discontinuous CF may be derived from sources such as recovered woven fabric selvedge and multi-axial selvedge trim. Continuous waste CF is also available from CF tow remnants left over following manufacturing runs, although these materials are often in relatively short continuous lengths. CF waste is also becoming increasingly available via emerging technologies which recover fibre from uncured and cured parts through removal of the polymer matrix using different processing systems (solvent, thermal, fluidised bed and supercritical fluid).

Currently, the market for materials based on recycled CF is characterised by low performance and value, mainly consisting of milled fibres for injection applications and random mats based on short discontinuous fibres. The idea is to develop materials which exhibit significant performance enhancement and offer added value. The proposal is principally concerned with the reuse and recycling of waste CF from the available current waste sources to produce prepreg materials with discontinuous aligned long fibre as well as semi-continuous aligned fibre. Hence, it is essential to first develop a yarn or tape based on recycled carbon fibres which can be used in fabric structures such as unidirectional, non-crimp, 2D and 3D woven.

This proposal is to fill the gap in the production chain within Eco-Design Integrated Demonstrator Technology (ITD) project. A supplier of thermally recovered carbon fibres and several sources of waste CFs are already available. Additionally, the fabric impregnation with resin and the production of a demonstrator from the recycled materials will already be covered by the consortium. Potential applications include aircraft interiors and tooling.

This project would focus on thermoset resin–based prepregs. A high CF content is targeted within the yarn/tape. Additionally, any type of fabric structures (as listed above) is desired.

## 2. Special skills, certification or equipment expected from the applicant

- Yarn manufacture with high content of recycled discontinuous aligned long carbon fibres
- Yarn manufacture with high content of recycled continuous/semi-continuous aligned long carbon fibres
- Tape manufacture with high content of recycled discontinuous aligned long carbon fibres
- Unidirectional (UD) fabric manufacture
- 2D woven fabric manufacture
- Non-crimp fabric manufacture
- 3D woven fabric manufacture

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Supply of yarn from recycled discontinuous aligned long carbon fibres to be used with thermoset resins | | To + 18 Months |
| D2 | Supply of yarn from recycled continuous/semi-continuous aligned long carbon fibres to be used with thermoset resins | | To + 18 Months |
| D3 | Supply of tape from recycled discontinuous aligned long carbon fibres to be used with thermoset resins | | To + 18 Months |
| D4 | Supply of UD, non-crimp, 2D and 3D woven fabrics | | To + 24 Months |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 250,000**

**[two hundred fifty thousand euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*If applicable*

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-02-008 | Electrical Power Distribution System Model:* | End date | T0 + 16 Months |
| | | Start date | T0 |

*) Functional and scalable model of the EDS Generic Architecture Electrical Power Distribution System, simulating system level issues such as power control and management, load dispatching and shedding, regeneration and protection mechanisms of the electrical distribution network.

## 1. Topic Description

### INTRODUCTION

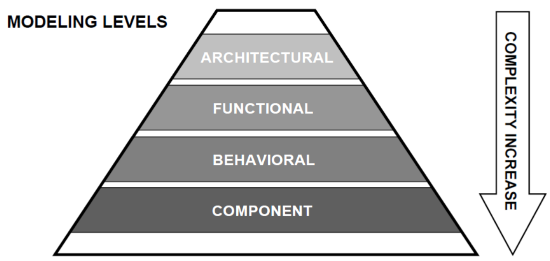
**On Aircraft Electrical Power Systems Modeling**

The electrical power systems in future more-electric or all-electric aircrafts will undergo significant changes. Many functions that used to be operated by hydraulic, pneumatic and mechanical power are being replaced by electric power due to recent advances in power electronics, electric drives, control electronics and microprocessors, improving the performance and the reliability of the aircraft electrical power systems, reducing fuel consumption per passenger per mile and increasing the availability of the aircraft.

The development and finalization of future electrical power system architectures will require *extensive simulation study*, under both normal operations and faulty conditions in order to assess overall quality and performance, transient behavior, protection and availability issues.

For design, evaluation and certification process of electrical power system networks, often several models exist which represent different modeling accuracies of the same system. Depending on the desired evaluation of an electrical network (e.g., power consumption, network stability, network quality, EMC behavior), system simulations with models of different levels of accuracy may be used.

Generally speaking, four types of models can be characterized, as illustrated on the following four-layer modeling schematic:




The four-level modeling concept

_Architectural models_ are representative of *steady-state power consumptions* (no dynamic response) [typical use: weight, cost, cabling studies and, most significantly, power budget].

_Functional models_ are representative of steady-state power consumptions and low-frequency *transient behavior* (e.g., inrush current, consumption dynamics with regards to input voltage transients, …). Such models *do not include switching*. [typical use: network logic studies, network stability studies].

_Behavioral models_ are detailed functional models. They are representative of actual dynamic waveforms: same representativeness as the functional models ones + full *representativeness of the waveforms* (switching, HF rejections…) [typical use: network power quality studies].

Finally, models at _component level_ include a *representative model of each single component* of the system or sub-system. Component modeling may be multidisciplinary and high bandwidth, covering for example electromagnetic field and EMC behavior, thermal and mechanical stressing [typical use:

verification of local operation, deep analysis of each component behavior].

The architectural layer model shows large simulation steps neglecting the detailed effects which can be seen at the behavioral layer model simulation. *The functional layer model covers the waveform of the detailed model without switching effects*. The functional level is targeted at *power system dynamics, stability, response to loading and start-up*; it aims to model the power system either in its entirety or in sections sufficiently large to obtain a holistic generator-to-load dynamic overview.

Since the number of power electronic converters and constant power loads in future aircraft electrical power systems is likely to be very high, simulations based on detailed component models will result in large and perhaps impractical computing times, memory demands and may even lead to numerical non-convergence due to the model complexity.

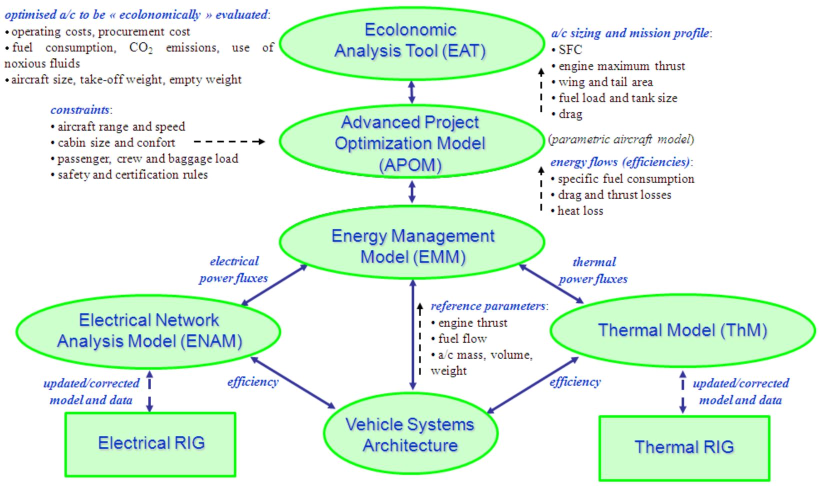
As an example, time domain simulations using the detailed non-linear, time varying, electrical power systems models which consider the switching behavior and fast transients can be useful for power quality studies (including power harmonic and EMC studies). However, as mentioned, it would be an impractical solution for system engineers to use such detailed models for system level studies, since the switching behavior, including high frequency switching transients and harmonics, does not significantly influence the dynamic performance of the overall system. Such models have an excessive accuracy for system-level issues such as power control and management, load dispatching and shedding, regeneration and protection mechanisms.

**EDS ITD Modeling Activities Framework**

Within Eco-Design for Systems (EDS) ITD framework, the demonstration of the “ecolonomic” benefits for the all-electric small aircraft concept will include, as a first step, the validation of aircraft optimization methodology, based on a set of *numerical models and data* constituting the *virtual* definition of the aircraft vehicle systems.

The validation of these models and data will be obtained through model correlations with ground tests results on the basis of a *Generic Architecture* common to all small aircraft types (i.e., business jet, regional aircraft and helicopter). The simulation results and test results will be used as validation of models assumptions and results. This will produce a set of updated/corrected sizeable models and data.

The *“virtual aircraft”* will be represented at different levels by means of specific models, from systems level up to aircraft level.



EDS modeling map for virtual aircraft

At the lowest level, provided a given vehicle systems architecture candidate, the Electrical Network Analysis Model (ENAM) and Thermal Model (ThM) will simulate the electrical and thermal power fluxes. The close interactions with the physical test benches will allow to update/correct these models and data.

More in details, the Electrical Network Analysis Model will be a representation of the electrical test rig. The main objective of the ENAM is to validate a vehicle systems architecture with respect to the electrical network quality through short term transient analysis. Therefore, the model will be representative of the actual electrical behaviour of the equipment (behavioral modeling level).

Then, the Energy Management Model (EMM) will collect the above data in a common individual aircraft model simulating all the energy exchanges in the aircraft as well as between the aircraft and the outside. In the EMM, all subsystems and the engines will be represented as transfer functions receiving from outside and providing to outside energy of various forms (electrical, hydraulic, mechanical, thermal) and the overall model will simulate the operation of an aircraft on a given mission profile in terms of energy exchanges (it will simulate, for each flight phase, the behavior of parameters such as fuel consumption, drag and thrust loss caused by management systems, heat losses etc.).

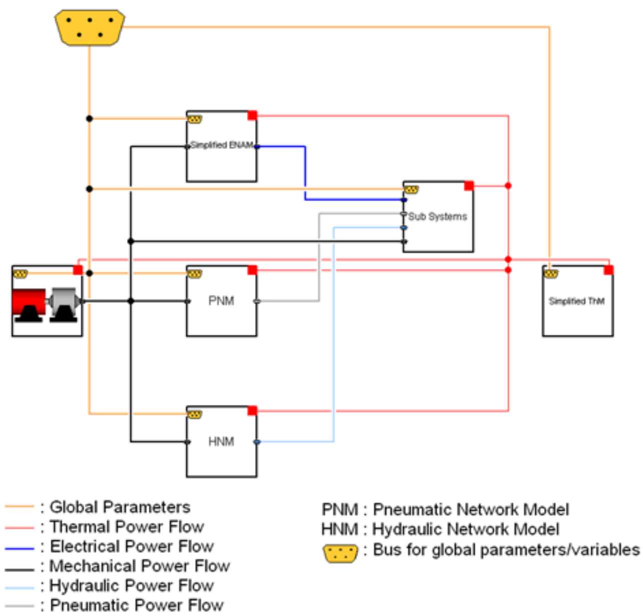
So the ENAM will be a behavioral model used for the study of short term transients whereas the EMM time scale will limit the electrical modeling level.

In particular, it will be interesting to use the EMM to study the power logics of the electrical network. These logics will control the power allocated to the distribution loads as a function of the different flight phases and/or operative conditions in order to optimize the global consumption. In addition, control logics may briefly degrade the supply of some loads to ensure the good behaviour of critical ones. This would minimize the general power demand during transient and highly consuming conditions. As a consequence, the sizing of the generators could be improved (no machine over-sizing due to overload capabilities), thus resulting in weight and volume savings.

The validation of these power control logics will be at a functional level of modeling. ENAM will not simulate these control logics. On the contrary, ENAM will ensure, for a specific power sharing among the loads, that the overall quality of the network is within acceptable limits.

The EMM will assemble models of each system around a model of the aircraft cabin, fuselage and environment. Individual models will receive as input their performance point, in terms of useful power they supply to downstream systems, or to the environment. They will calculate on their outputs the power they draw from upstream systems and the various losses.

Figure below shows a sketch of a top-level EMM developed in Modelica language which, due to the multi-physics dimension of the model, appears to be a good solution.




Top-level EMM

As represented in the figure, a simplified (functional) version of the ENAM will be used to be included inside the overall EMM.

**EDS Generic Architecture**

The EDS Generic Architecture (GA) is a complete set of aircraft systems, representative of a full aircraft. However, the GA is not an aircraft but it mainly fulfills two purposes:

a) as a basis for the test benches, it provides an opportunity to demonstrate key technologies for all-electric aircraft (*the electrical test rig will implement a part of the GA to perform a set of equipment integration, functional, performance and safety demonstrations*);

b) *as a tool for the validation of models and data*, it includes most modeling problems to be encountered and solved in the three real small a/c types.

The Electrical Generation & Conversion System of the Generic Architecture provides electrical power to supply all electrical utilization equipment during normal and abnormal operations. It includes the following subsystems: Main, Ground and Emergency Electrical Power Generation Subsystems, and Batteries and Battery Chargers Subsystem.

In particular, the GA Main Electrical Generation Subsystem links the main engines to the electrical power distribution network and it also includes the conversion stages.

The *Electrical Power Distribution System* (EPDS) of the Generic Architecture takes power supply from Electrical Power Generation & Conversion System (main, ground, emergency, back-up subsystems) and distributes it to other portions of the electrical system (subsystems) and to loads.

The GA EPDS has the following functions:

- to provide electrical power to loads. In performing this task, the transformation of conventional loads into all-electric solutions will be taken into account;
- to manage the loads electrical power consuming. A new strategy – an “Intelligent Load Power Management (I-LPM)” – will be tested thanks to peculiar EPDS features;
- to assure controllability, failure detection and overall protection in all operative modes.

The GA EPDS provides High Voltage DC (HVDC) levels to the distribution network according to the “all-electric” design concepts. In particular, the GA HVDC power is generated at 270V DC (switchable from 0/+270V to -135V/+135V) to supply main power consumers (in terms of total power consumed). The selected voltage level is tailor-made on small all-electric a/c needs and it is already a standard.

Alternative level of voltages are generated to supply, at Low Voltage DC (28V DC) and at AC (115V AC by DC-AC converters), the majority of power consumers (lighting components, avionics components, etc.). Note that 115V AC is not distributed, but only locally converted with the inverters at the equipment inputs.

Power connection between different voltage levels is ensured by adequate power converters. They convert the power from the High Voltage to the Low Voltage DC network and vice-versa, as necessary to provide the electrical energy required. The converters used for voltage levels conversion integrate protection and monitoring functions.

Electrically-powered equipment implementing the GA comply with electrical power quality characteristics defined for 270V DC power supplies in MIL-STD-704F standard under normal and abnormal system operation conditions. The standard is regarded as an entry point. Any restrictions or exceptions, which pave the way for a customized power quality document, may be issued downstream feedbacks on transformation of users into all electrical solutions.

The GA EPDS is composed of:

- HVDC circuits made of five 270V DC bars in a loop configuration,
- LVDC circuits made of three 28V DC bars in a loop configuration,
- commutation and commutation-and-protection devices (CTs, SSPCs and RCCBs),
- electronic boards for large logic, bars management and communication;
- the internal electrical connections, cables and wires, connectors, terminals;
- the parts requested for the heat dissipation and cooling arrangement.

The GA EPDS is organized around an *Electrical Power Center* (EPC) which integrates the above equipment and manage the control logics.

The GA EPC distributes the electrical power from the HVDC network to all main power consumers. It embodies various technologies of contactors (electro-mechanical breakers, intelligent, solid state, etc.), while it does not include power converters.

The GA EPC also implements the innovative Intelligent Load Power Management (I-LPM) control logics for the different operating conditions and flight phases, taking into account loads priorities and power demands (it reconfigures from any condition to any normal condition quickly, automatically and safely).

In this view, the GA EPC integrates Solid State Power Controllers (SSPC), contactors (CT) and commutation devices equipped with remote controlled protections (RCCB). They are power devices able to perform the Intelligent Load Power Management. The switching sequence is driven by a programmable logic matching several control and status signals.

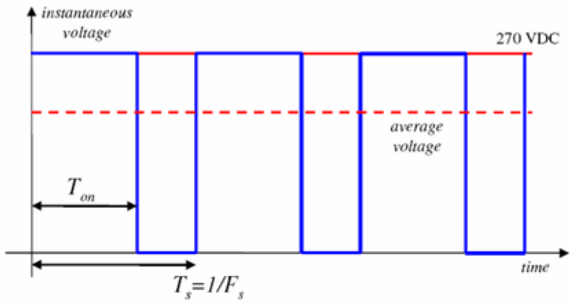
The GA EPC has a digital interface with the I-LPM controller, through which it receives the dynamic power thresholds, and transmits the loads actual power, and contactors states. It also permits the easy interchange of contactors between loads, in order to characterize those control technologies under different operating conditions.

**Intelligent Load Power Management Function**

Currently, any abnormal electrical condition (i.e., one generator missed), that results into an extra demand of electrical power, is addressed to the overload capacity of generators. Besides, shouldn't this features be enough to manage the peak power request, several loads may be totally shed as they are not flight or safe-landing essential. This policy is the so called "load management".

The trend that Clean-Sky JTI is investigating will make generators rated size higher and higher. This implies that no overload capacity can be taken into account in the design, as long as weight and volume are desired to stay within objective figures. Moreover, most essential loads change into electrical power consumers (electrical flight controls, brake, ice protections,...) therefore, they can't be easily shed. The way proposed to face this key steps towards new concept electrical network is an *"Intelligent" Load Power Management* (I-LPM).

By definition, I-LPM is an *advanced smart control* of aircraft electrical loads *optimizing weight, volume and consumption*, being able to *"smooth" extra power demands* due to power transients and/or to electrical failures (normally addressed to the generator overload capacity) by compensating them with a proper reduction of the power demand from those loads which are "non critical" for that specific flight phase or operating condition.
Its basic principle is to force global electrical power demand to decrease, even during an extra demand condition. The network voltage applied to some selected power consumers is chopped and it results in *power modulation* (not applicable to regulated constant power devices for which power management has to be managed by software signals).




I-LPM voltage chopping

But, unlike the conventional load management, the selected consumer, suffering the power decrease, is far from being shed, as the chopping is pushed just to a predefined extent. The shedding of loads suffering short circuit or unhealthy conditions (a peculiarity of conventional load management) still continues to be applied, and it may be regarded as a boundary condition of I-LPM.

Each load is connected to an Electrical Power Center (EPC) through a *Solid State Power Controller* (SSPC) device, acting as an *ON-OFF switch* (i.e., contactor-like function) and possessing *protection capability* (i.e., circuit-breaker-like function).

The SSPC is a power device which plays the main role in the electrical distribution and whose switching sequence is driven by a programmable logic matching several control signals. In particular, such a device is capable of modulating the voltage to the load, thus causing a power absorption Pi whose variation can be expressed as follows:

$$P_i^{min} \leq P_i \leq P_i^{nom}$$

So the management of overload capacity is then accomplished *at a distribution level* while the generators are going to be sized for the heaviest power demand which, thanks to the I-LPM policy, corresponds to the nominal one.

$$max\left[\sum_{i=1}^{N} P_i\right] = P^{nom}$$

The SSPC allocates for the generic i-th load a power request that is function of several parameters, such as:

- *Load-peculiar parameters*:
  - deterministic and unchangeable (electrical, thermal, ... dynamics);
  - deterministic and function of the specific flight phase or operative mode (priority, critical state);
  - random (load health status, ...).
- *Network parameters*:
  - contemporaneity and utilization factors;
  - saturation of generators capacity.

We can summarize the above with the following mathematical relationship:

$$P_i = \mathfrak{F}(par_1, par_2, par_3, \ldots)$$

wherein F is the logical function accomplished by the controller.

However, I-LPM can not apply to “fixed power” consumers (e.g., motors), as SSPC technology will not be able to modulate the power to those loads by means of a chopped voltage only. In this case, the power modulation is completely addressed to the load itself (e.g., motor controller) which receives from I-LPM core a command signal only.

As an objective, the verification of I-LPM functions and performances will consist in applying the I-LPM control logics to some selected power consumers trying to keep the overall electrical loads within the nominal rate of generator, for each combination of loads in steady or temporary state. That mainly by:

- Enforcement of priorities between power consumers;
- Controlled transfer of power without relying on generator overload capability;
- Cooperation with network active stabilization function.

The possibility of monitoring the *generator current derivative* (providing a status on how it is nearing generator capacity saturation) will give the opportunity to verify the I-LPM concept and control logics.

## WORK DESCRIPTION

### General Requirements

Given the above depicted scenario, the selected candidate shall develop an overall *functional and scalable* model of the EDS Generic Architecture Electrical Power Distribution System, simulating system level issues such as power control and management, load dispatching and shedding, regeneration and protection mechanisms of the electrical distribution network. Other specific objectives shall cover the investigation of:

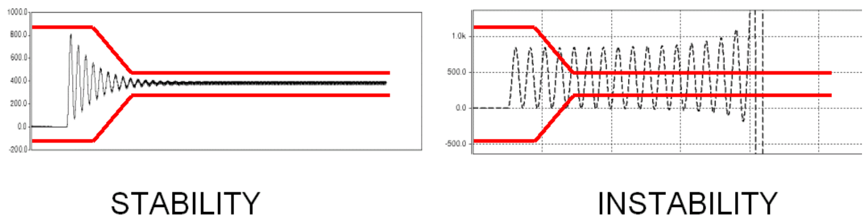
- system stability;
- dynamic system performance under all operating conditions;
- the response to faults, evolution of faults, isolation and reconfiguration, and fault clearance.

The overall model shall integrate models of equipment for generation, distribution and power users. The equipment models for distribution shall mandatory reproduce the given architecture, while models for generation and load consumers may be generic library components.

In the frame of Intelligent Load Power Management function, the model shall also implement innovative logics for an optimal sharing and allocation of the electrical energy among all distribution loads. Such logics, coming from the matching of several control laws, are supposed to be actually implemented in the control system of the Electrical Power Center, thus resulting in driving signals for the switching components (SSPCs and/or RCCBs) which address the proper power modulation to the selected distribution loads.

**Stability Analysis Requirements**

Unlike the stability definition in the control theory, the stability criterion in the industrial standard is usually formalized with the ability of a system to keep a certain system variable of interest within desired limits, which can be given in time domain or frequency domain. In particular, stability for electrical network is the ability of the voltage regulation to keep the voltage at Point of Regulation (PoR) within limits specified by the relevant standard, in either steady-state or transient operation, and either normal or abnormal condition.




Stability criterion for industrial standard

It shall be mandatory to extract from the model simulation the features as adequate indicators of the system stability. MIL-STD-704F standard shall be considered for defining the acceptable limits.

The time scales of these simulations are greater than for power quality studies. The aim of those simulations shall be to analyze the energy transfers between the generating systems and the loads in order to detect any stability problems concerning energy transfers:

- Network voltage stabilization during load power transients;
- Impacts of network voltage transients on loads power consumption;
- Detection of potential steady-state frequency modulations.

It may be highly desirable for the selected candidate to perform a stability analysis also with respect to the conventional stability theory in order to assess the overall model robustness against parametric uncertainties.

**Failure Mode Analysis Requirements**

This analysis shall consist in assessing the protection strategy in case of over-current, over-voltage, over-temperature, short circuits, open circuits, connection and disconnection of loads. It shall also look at reaction time, threshold with available measurement and monitoring capabilities. It shall examine cores logic and protection systems, network reconfiguration, algorithms for load shedding, degraded system states for dispatch, reliability of the system.

The reconfiguration capability of the electrical system shall be built into the corresponding system model by including the open/close logics of the various bus-bar switches, which link (or disconnect) the power generators and users through the electrical network. This allows to simulate the system model for various normal and abnormal operational scenarios, e.g. for system operation in degraded state subsequent to component failures.

Failure mode analysis shall be done through functional modeling. This shall include:

- Protection strategy in case of failure mode detection;
- Operational management of the electrical system, i.e. switching of bus bar contactors for normal and abnormal system operation;
- Conventional load management, i.e. algorithms for shedding of non-essential loads in cases of electrical system degradation;
- Intelligent load management, i.e. algorithms for power degradation of non-essential loads in cases of temporary extra power demand (generators overload conditions).

**Intelligent Load Power Management Requirements**

The Intelligent Load Power Management strategy shall follow a formal and innovative approach in order to facilitate the analysis phase to be successively performed. The global Electrical Power Distribution System status shall be derived and processed by the I-LPM controller which shall appropriately react to any normal or abnormal condition and consequently drive the SSPCs and/or RCCBs with an innovative control and modulation strategy, able to fulfill the management strategy objectives.

The proposed I-LPM approach shall guarantee the robust system stability, defined as the possibility to reach a safe status against all incipient recognized (possibly critical) conditions; for this reason, the approach formalism shall require to describe any possible system status. Besides, the proposed strategy shall be customizable and expandable for different system models, e.g., obtained by adding new loads with different priorities or defining alternative control logics.

Finally, the SSPCs and/or RCCBs innovative control technique shall guarantee fast and robust response to any power level variation requests, and enhanced controller performances, such as disturbance rejection and insensitivity to electrical system parameter uncertainties.

**Requirements for Model Integration into Global Energy Management Model**

The model shall be easily integrated in a global Energy Management Model (EMM) at aircraft level and shall not induce any specific parameters request which could be not compatible with other partner models.

In this view, due to the multi-physics approach of the global EMM, the model shall include appropriate interfaces (connectors, pins) for electrical, mechanical and thermal exchanges with other EMM subsystems.

**Electrical Systems Library Requirements**

The model shall comprise a dedicated electrical systems library containing a comprehensive set of object-oriented, physical models of electrical power system components designed to model the dynamic behaviour of electric systems.

The library shall be hierarchically structured to accommodate various models of different complexity, such as interfaces (plugs, data-buses etc.), basic electrical components (wiring, switches, bus-bars etc.), more integrated electrical components (generators, rectifiers, converters etc.), power users (motor drives, heatings etc.).

**Signal Analysis Tool Requirements**

An adequate signal analysis and measurement tool of aircraft electrical power system shall be required. As a matter of fact, besides modeling and simulation, the measurement of simulation results is also interesting and important for engineering tasks, e.g. the stability issues for the a/c electrical network.

The tool shall be designed and developed to provide the following features:

- User-friendly graphical interface;
- Powerful signal processing;
- Advanced functionality of plot and post-processing analysis.

**Software Requirements**

Model shall be in Modelica language format to be used with a Modelica 3.1 compatible design tool.

The Modelica files shall not be encrypted, i.e., source code models with access to internal model variables and parameters shall be required. Black box models are not acceptable.

**Other Model Requirements**

Each component model shall be provided also with a mode button and indicator lamps for an interactive control of its operative/failed status. By means of the mode buttons each equipment can be activated or de-activated before the simulation, whereas indicator lamps (or flags) shall be used to verify the status of the equipment (operative/faulty) during the simulation. This will be useful, e.g. when developing the network switching logics, since the resulting behaviour at system level can be checked quickly and readily.

**Model Inputs**

The following inputs will be provided to the selected candidate:

Generic Architecture;

Generic Electrical Power Distribution System architecture;

Any available equipment functional model by SGO supplier through EDS ITD, e.g., models of SSPCs (TBC);

Control logics (in the form of logical equations).

**WORK-FLOW**

The candidate activity shall be broken down into three tasks:

Task 1: **Analysis**

A first study/evaluation analysis shall be performed by the candidate in order to derive the functional models of equipment from the actual component characterization in terms of basic elements, functionalities, interfaces and associated characteristic equations. At the same time, the control strategies shall be investigated and the process to convert the logical equations into system control rules shall be derived.

Task 2: **Development**

The second step shall cover the creation/implementation of the Generic Architecture Electrical Power Distribution System model in Modelica language. It shall include both the functional modeling of the hardware equipment included within the Electrical Power Center as well as the software implementation of the logical equations which will drive the optimal sharing of the electrical power among the distribution loads as a function of the different operating conditions (normal, abnormal and emergency ones).

Task 3: **Validation and Optimization**

Following the model implementation, the candidate shall perform a validation analysis by correlating simulation results with given reference simulation results. In particular, the validation analysis shall be performed by using comparison with analogous detailed behavioral modeling (a single component test bench may be adopted). The coherency criterion between functional and behavioral level shall be proposed by the applicant.

For the control functions (e.g., I-LPM), the model shall be only validated with respect to the overall system stability requirements.

The selected candidate shall provide a report with the results of validation phase and a folder on electronic support with all the origin files for simulation activity in Modelica code.

The candidate shall include in the proposal a validation matrix and plan for the model. In particular, the candidate shall propose a set of significant test cases in order to validate the model with respect to system behaviour during real operations.

The model shall be released in the final version upon the optimization coming from validation results.

## 2. Special skills, certification or equipment expected from the applicant

The candidate organization shall have:

- expertise in electrical system design (power generation, power conversion, power distribution network, power consumer),
- a well recognized experience in system simulation methods and modeling,
- a well recognized experience in advanced control system techniques (Theoretical Research Centre or University to be preferred),
- knowledge of Industrial/Aeronautical field constraints and procedures,
- experience on Modelica programming language,
- availability of basic simulation tools: at least a full code licence of Modelica based tool (e.g., Dymola or AMESim),
- good practice in English language.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Functional modelling report | Report on study/evaluation analysis for functional modelling. | T0 + 3M |
| D2 | Control strategies report | Report on control strategies and system control rules. | T0 + 6M |
| D3 | Model – first release | First (beta) release of model | T0 + 12M |
| D4 | Test plan | Test plan for model validation | T0 + 13M |
| D5 | Model – second release validated and test report | Validated model release and test report | T0 + 15M |
| D6 | Model – finale release optimized | Optimized model final release | T0 + 16M |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**300,000 €**

[three hundred thousand euro]

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*If applicable*

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-ECO-02-009 | Alternator with active power rectification and health monitoring | End date | *31/03/2013* |
| | | Start date | *To* |

## 1. Topic Description

Green aircraft technology gains in efficiency over conventional technology using electrical power as a replacement for hydraulic and pneumatic power. When it is implemented with usual aircraft electrical components, the large weight of green aircraft systems offsets any saving offered by their higher efficiency on business jets and other types of small aircraft.

The part of green aircraft system in which the largest weight increase is observed is the electrical generation system. *Weight savings in this area could be a key to the economic viability of more ecologic aircraft systems.*

This topic aims to deliver an alternator making the best use of active power electronics in order to minimize the weight of the total system. This system shall include the starter/generator and the associated active rectifier operating also as a start box. Any required monitoring or control equipment associated with the two main components shall also be included.

The delivered system will be designed to generate between 40 kW and 80 kW of electrical power over a realistic range of driving speeds, and will be able to produce a constant starting torque over the low 25% of its speed range, yielding a mechanical power output which increases linearly with rotation speed from 0 to a minimum of 40 kW.

**1. State of the Art**

Current state of the art aircraft alternator rely on a separate excitation circuit which controls the rotor current and regulates the voltage of the network. Electrical power is produced on the stator of the main electrical machine. The excitation power is extracted from the rotor of a second electrical machine integrated within the alternator. A third machine integrated on the same shaft, usually a permanent magnet alternator, provides a permanent power source to the electronic generator controller unit (GCU) which regulates the weak stator field at the excitation stator winding.

Such alternators can be connected directly to three-phase AC networks, or through an integrated rectifier bridge to a DC network. They are typically designed to deliver 150% of nominal power for 5 seconds, and 125% of nominal power for 5 minutes.

For use as a starter, a different mode of operation of the excitation is required since a torque must be produced at zero speed. At zero speed, the power to the rotor and to the stator is entirely provided electrically. This function therefore requires an excitation stator winding capable of higher currents than the power generation function. A power electronic unit producing the entire power of the main stator is of course also required. The power electronic unit can be shared between multiple engines, but the limited reliability of power electronics currently imposes to have two onboard in order to achieve the target dispatch rates.

Aircraft alternators must remain safe in case of failure: the alternator case must contain the rotor should it break apart, the GCU and the structure of the machine can safely handle a short circuit in the windings (the CGU monitors the system and shuts down the excitation in case of failure). The GCU will also command the line contactor to isolate the alternator from the network if it detects that the network is in short circuit, or if it detects that the alternator has a dysfunction which prevents it from regulating the network voltage properly. With typical aircraft alternators designs, all alternator failure conditions which could lead to a fire starting at the alternator are extremely improbable.

With proper maintenance, state of the art aircraft alternators achieve failure rates on the order of $10^{-5}$ failures per flight hour. Each technology has its own maintenance requirements. For instance, greased bearings used on low to moderate speed alternators are preventively replaced every 1500 flight hours (typically).

It is well known that an electrical machine which rotates faster can produce more power for a given weight, since mass is approximately proportional to current, while power is approximately proportional to the product of rotation speed and current. It is also well known that colder machines are capable of better efficiency, since conductivity of metals is increased, and therefore Joule effect losses decreased for a given power.

**3. Limits of Current Technology**

The following limitations are clearly understood:

Wound rotor technology with rotating diodes (for the rectification of the excitation power) limits the rotation speed. Since main alternators have to operate with a variable speed driving shaft on airplanes (two different speeds for ground idle and flight on helicopters), the nominal generation power is achieved at a speed comprised between 12,000 and 15,000 rpm, and up to 22,000 to 24,000 rpm.

The safety mechanism which requires to shut down the rotor magnetic field excludes permanent magnet alternators. They are used on aircraft when the driving system can be shut down in an emergency, but are not used for high power alternators driven by the main engines unless a declutching mechanism exists (a solution mostly found on airliners).

Greased ball bearings are very light since there is no lubrication circuit, but using common technology the bearings need frequent replacement and the rotating speed has to be kept below 15,000 rpm. Oil lubricated bearings need less maintenance and allow faster rotation speeds, but the weight of the lubrication system has to be included in the system weight. For small aircraft, bearings are not monitored and a flight time based replacement schedule is the norm.

Some loads could use direct AC power from the alternator, improving efficiency and reducing weight, but passive rectification degrades both efficiency and AC waveform, making it difficult or even impossible to power both AC and DC circuits from the same alternator without using a TRU. At the same time, passive rectification of a three-phase alternator does not yield the voltage ripple which is required by applicable standards on the network, and additional capacitors are required to further filter the ripple. Six-phase alternators provide an acceptable solution, but the starter mode become much more complex to implement.

Typical overload characteristics are used to provide power to transient loads, or in failure cases to allow some time to reconfigure the power sources. With innovative power management technologies developed in Clean Sky, such overload characteristics are no longer necessary. The longer overload requirements were sometimes as constraining as permanent loads on conventional alternators. The consequence was a significant oversizing of these alternators.

Power electronic units capable of handling more than 40 kW have been introduced on current aircraft to provide starting power to large turbine engines, using the engine mounted alternator as a starter. Using common designs, the reliability of such units is not yet sufficient to use their active components for the generation of electrical power in flight (the antiparallel diodes sometimes replace a dedicated rectifier bridge).

**4. Requirements**

**4.1 Activities**

Having proposed at least one innovative preliminary design and the associated development plan in its application, the selected applicant shall perform the following activities:

- Trade-off studies proposed either in the application or during the technical negotiation phase. The mechanical interface has to be compatible with the drive stand, and the interface drawing will be supplied to the applicant.

- Preliminary system safety assessment, using well-substantiated reliability data and/or accepted standards such as MIL-HDBK-217.

- Provide an acceptance test plan (ATP) detailing the demonstrations of performance achievable using the applicant's test means, and those only demonstrable on the EDS electrical test rig.

- Provide a qualification test plan (QTP) showing which standardized tests will be performed, what are the severities, and where and when the tests will be performed. Full DO-160 qualification is not necessary. Instead, a minimum set of electrical, thermal, conducted EMI and vibration tests will be proposed.

- A preliminary design review organised in presence of the EDS electrical test rig operator, and the topic manager representatives. At this milestone, the interfaces between all the components and the performance requirements of each component will be frozen.

- Study of ancillaries in connexion with supporting test rig ancillaries, such as water for cooling, air, lubrication group, etc.

- Detailed design of the proposed system, including detailed design of the alternator, detailed design of the active rectifier, detailed design of the ancillaries, and detailed design of the wiring and tubing connecting them to each other, in the context of an evaluation at TRL 5-6 on the Eco Design for Systems electrical test rig.

- Design of the test stands which will be used by the applicant for the acceptance tests.

- Creation of models of the system intended for use by aircraft integrators, as described below.

- Tests on technology samples required to complete the detailed design, if any, including the manufacturing of samples and test setups. The topic manager will not provide any technical data to the applicant other than the documents listed in paragraph 6, below.

- A critical design review organised in presence of the topic manager representatives. At this milestone, the detailed design of all components will be frozen, and a decision made to manufacture the components.

- Manufacturing of a minimum of 3 systems, one being for the rig, the second as a spare, and the third kept for support by the applicant. In addition, spare parts shall be manufactured in sufficient quantity to support the tests performed in the Clean Sky EDS project until 2015.

- Environmental qualification testing will be performed according to the Generic Architecture Guidance document, which also describes the design operating environment (aligned on DO-160 rev. F).

- Limited acceptance will be pronounced after performance tests performed on the applicant premises in presence of the EDS electrical test rig operator and of the representatives of the topic manager, during the First Article Inspection (FAI). Acceptance will be pronounced when the system fulfills all the requirements of the acceptance test plan. A limited number of tests may be performed on the EDS electrical test rig in presence of the applicant. All the critical validation steps must be performed before delivery to the EDS electrical test rig, including the demonstration of all the critical performance points.

- A qualification review during which the equipment will be disassembled and examined for evidence of damage, then reassembled and tested for acceptance a second time.

- Delivery and installation of equipment on the EDS electrical test rig (Paris area, France).

Modeling activities beyond those supporting the optimized design of equipement, shall include the development and validation of a scalable (or several scalable) architecture models of the whole system, the development and validation of a scalable functional model of each component, and the development and validation of a behavioral model of each component. The architecture and functional models are required to be balanced in terms of energy: the difference between the power entering and leaving the system must correspond to stored energy, and stored energy must be eventually released. The functional and behavioral models shall be representative of probable failure conditions (probability of occurrence greater than $10^{-5}$/fh) and shall be matched to each other. A behavioral model shall include switching behaviour detail, but may use ideal switches instead of real transistor models. It shall include an accurate model of the power electronics control laws. The functional model is an averaged model which will include all the power management functions required by this topic, including a model of high level dialogue with avionics, but which will correctly demonstrate transients which occur in normal, overload and failure cases, and will correctly model the errors of the current-voltage regulation, both transient and steady state. The shape of transients will be matched to the behavioural model for validation. The architectural model shall also include all the power management functions, the variable voltage behaviour but will typicall use and idealized current-voltage characteristic. It shall register the maximum power seen in a simulation test case and shall be scalable between 25 kW and 80 kW in terms of power. Architectural and functional models will have parameters which can vary over a realistic range to replicate the variability of externally observable characteristics (voltage, thresholds, timings, …) in a batch of production equipment (this capability is needed to model parallel operation of real, slightly different systems). The acceptance test plan can be a base to select the correct characteristics and their allowable variability. Failures will be triggered by inputs in all models. If the optimized design differs from the demonstrated design, the models shall cover both design points.

Because testing at system level on the EDS electrical test rig involves a large number of components and suppliers, the applicant will be required to agree to support its own equipment for the duration of the tests and repair it with diligence in case of failure *at no additional cost*, whatever the cause of failure is, even if the failure is caused by mishandling or failure of another equipement. The equipment of the applicant will only be handled by qualified professionnals of the Eco Design consortium. Daily maintenance (normal care which would be performed by the crew or the lineman on an aircraft, and would not require an aircraft mechanic certificate) will normally by performed by the EDS test rig operator. The expected number of hours of operation of the rig should not require further normal maintenance.

### 4.2 System Components

The drive stand being supplied by the rig, the applicant shall deliver :

- the alternator with a mechanical interface compatible with the drive stand,

- the power electronic unit controlling the alternator,

- the wiring between the alternator and the power electronic unit.

- the local control monitoring system, which could for instance measure temperatures at important points of the alternator and power electronic unit, and interfaces the system to the rig control and monitoring subsystem.

- the wiring between the alternator and the local control and monitoring subsystem,

- the wiring between the alternator and the power electronic unit,

- the wiring between the power electronic unit and the local control and monitoring subsystem,

- the tubing for liquid cooling of power electronic, until the connection to rig ancillary circuits,

- the tubing for liquid cooling of the alternator, until the connection to the rig ancillaries or rig lubrication group,

- any heat exchanger or other piece of ancillary equipment required to interface the system to the rig.

- scalable architectural, scalable functional and behavioral models of the system.

- all the special tools needed to perform daily maintenance, assembly/disassembly of the alternator on the drive stand, if any

### 4.3 Performance

The EDS test rig will provide a drive stand capable of 150 N.m at null speed, 150 kW and up to 24000 rpm.

The electrical power of the alternator in generation mode is subject to an agreement at the negotiation phase, but shall be between 40 kW and 80 kW DC power. 70 kW is the recommended value.

The torque produced by the alternator in starter mode shall remain constant over the low 25% of its speed range, producing a mechanical power output which increases linearly with rotation speed from 0 to a minimum of 35 kW. Between 25% and 50% of its speed range, the alternator in starter mode shall be able to maintain peak power. The alternator shall be capable of performing a sequence composed of one start attempt lasting for 1 minute, 5 minutes of ventilation (half the nominal torque at low speed), and a second start attempt lasting for 1 minute. A longer resting time will be allowed at this point to let the alternator cool down.

The mass of one alternator and one power electronic unit as configured for an aircraft application shall not exceed 50 kg for a 70 kW system, and shall be minimised.

The alternator shall be designed for a maximum nominal speed of 24000 rpm or less. The design shall allow a 5% overspeed margin. The system will be designed for a speed ratio of 1.66 between the lowest rotation speed at which nominal power is achievable in all environment conditions specified in the GAG, and the maximum nominal speed.

The alternator shall be designed with limited overload capabilities:

- Short-circuits of 0,5s in duration in the worst environmental conditions (hot day)

- In cold conditions (less than 0°C ambient air), the alternator shall deliver continuously a minimum of 15% of additional power (cold rating).

- In starter mode, at -30°C the starter shall deliver a minimum of 30% of additional torque (cold rating).

- In starter mode at 0°C the starter shall deliver a minimum of 15% of additional torque (cold rating).

Power management:

The HVDC busses operate as +/-135VDC networks. The differential voltage is not regulated at 270V DC, but varies slightly around this value with the load of each source according to the current-voltage characteristic shown below. The voltage difference between $HV_{min}$ and $HV_{max}$ is around 20V. $P_{max}$ is the point of maximum power delivered to the network, and corresponds to the maximum nominal current at $HV_{min}$. $P_{required}$ is the maximum power the generating channel is set to deliver in normal conditions. This value is given to the system by a digital link with the avionics. In cold conditions, it is expected that the system will announce a higher $P_{max}$ to the avionics over a digital link. $P_{required}$ is always less than $P_{max}$.


This characteristic is only meaningful at frequencies below 1kHz. Several pieces of equipment having similar source characteristics are always connected together on the various busses. The capability to set the value of $P_{required}$ is used by the avionics to select how the various sources carry the total load, and to fine tune the network voltage.

In case of overvoltage, the blue line should be extended straight into negative current, and the system shall demonstrate handling of regenerated power by returning it to the engine inertia, while controlling power quality on the network.

Active filtering of HVDC network:

In addition to the steady state and low frequency behaviour described above, the generating channel shall filter the HVDC signal in the 1kHz to 25kHz band, and shall attempt to bring power to the network in phase with the ripple in demand in this range of frequencies.

Electrical protections:

- After a minimum delay of 0,5s the system shall de-energize itself in case of short-circuit (internal or external) so that further damage to the system is avoided.

- The alternator system shall detect the failure conditions leading to an over-voltage and shall disconnect from the HVDC network.

- Protection against over-current: the power electronic unit shall limit the current delivered at the maximum current shown in the graph above (which corresponds the maximum power). This protection will vary with temperature if needed in order to allow a cold rating without damaging the alternator.

- Differential protection of the alternator.

Health monitoring:

The integrated health monitoring function must demonstrate significant benefits at the following stages:

- At system integration time (when the system is assembled on an aircraft), the function shall contribute to a reduction of assembly line tests.
- In service, the function shall contribute to an improvement of dispatch rates and an reduction of maintenance costs.

Safety:

Safety calculations are performed for typical flights on a standard day (atmosphere with a standard temperature profile as defined by ISO2533). The presence of systems in the airframe elevates the temperature above standard inside the mechanical bays. The following formula must be used to calculate the ambient temperatures to use for each component of the system.

$$t = \Delta t + \left(t_{\max} - t_{\min}\right)\frac{T_0 - T_{\min}}{T_{\max} - T_{\min}}$$

In this formula,

- $T_0$ is the external temperature at the considered altitude
- $t_{max}$ and $t_{min}$ are the extreme temperatures in the area of the airframe considered, as described in the Generic Architecture Guidance (and DO160)
- $T_{max}$ and $T_{min}$ are the extreme seasonal temperatures as described in ERA (and STANAG 2895).
- $\Delta t$ is the local temperature elevation (inside an enclosure for instance).

The formula shall be used to recreate temperature profiles seen by each component along a typical flight described in ERA. These profiles must be used in safety assessments.

DO 254 and DO 178B are respectively applicable to hardware components (simple and complex), and to software components. The development assurance level (DAL) scale ranges from E (lowest) to A (highest). The DAL chosen for each hardware and software component is a minimum of D, and shall be chosen consistently with the consequences of hardware or software failures.

When assessing their consequences, component faults must be considered in combination with other faults in the system unless the combined failure is shown to be extremely improbable.

Single failures shall not lead to hazardous or catastrophic events.

For redundant configurations in which multiple component faults are needed before a given failure condition occurs, the DAL of each participating component can be chosen among two choices: the level associated with the failure condition, or the level immediately below it . In addition, all the combinations of component failures leading to the given failure condition which are not extremely improbable must include at least one component developed at the higher level associated with the failure condition.

The probability of occurrence of an event during a period of time τ, when that event has the same probability of occurring at any time within that period is expressed by the formula $P_f = 1 - e^{-\lambda\tau}$ . Any other probabilisitic model such as random events which may happen only when the crew moves a control (i.e. contactor does not close when commanded) must be translated to an equivalent uniform probability per flight hour, by taking into account the number of times the crew performs that action during the typical flight, and the duration of the typical flight.

Under these assumptions, the system shall satisfy the following constraints:

- Uncontrolled malfunction of one generating channel regulation evolving in over-voltage $P < 10^{-7}$/fh
- Loss of generationfunction for one generating channel $P < 10^{-5}$/fh
- Monitoring function failure $P < 10^{-5}$/fh
- Loss of communications with system $P < 10^{-4}$/fh

**5. Innovation**

Innovative solutions will aim to overcome the limitations of current technology in order to decrease weight, cooling, cost and maintenance requirements. A fully compliant solution would present a significant step beyond the state of the art, since characteristics such as no-overload design, cold rating, variable voltage regulation, integrated active filtering of DC bus and active rectification are still at the experimental stage.

This topic does not constrain the type of electrical machine which can be proposed by applicants. In order to overcome the speed limitations of current design, the applicant may attempt to eliminate wiring and/or rotating diodes from the rotor using variable reluctance, squirrel cage or permanent magnet approaches. Using power electronics, it may be possible to use remanent magnetization of the rotor in order to self power and start without a dedicated integrated permanent magnet alternator.

The active rectification approach has to potential for a drastic reduction in electrical machine losses, and a significant reduction of the size of filters on the DC side.

The health monitoring function shall be tailored to the proposed solution, in order to maximise the benefits, but is completely open for the applicant to propose. Academic research shows that monitoring of mechanical parts condition may be possible using only electrical parameters in the active rectifier.

There is also a significant potential for innovation in the integration of power electronics, with a choice between silicium and high temperature semi-conductors leading to very different thermal architectures. If liquid cooling is chosen, it will be water-glycol for the electronic control unit, and oil for the electrical machine.

If the maximum speed of the drive stand limits the ability to demonstrate the full potential of the proposed solution, the demonstration will be adapted to the drive stand (max 24000 rpm) while models will be supplied for both the demonstration setup and the optimized setup.

**6. Input**

The following documents will be available for the selected partner at T0.

- EDS electrical test rig technical description
- GAG Eco Design document **Generic Architecture Guidance**
- ERA Eco Design document **EDS Reliability Estimations**.
- An Interface Control Document describing the mechanical interface of the drive stand
- Any Modelica interface library made by the EDS project, if compliance with that library is required.
- Equipment configuration management and marking rules.

## 2. Special skills, certification or equipment expected from the applicant

The applicant shall have knowledge of the following standards:

- MIL-STD-704F Aircraft electrical power characteristics (as a guide line)
- MIL-HDBK-217F Reliability prediction for electronic component
- DO160F Environmental conditions and test procedures for airborne equipment
- DO178B Software considerations in airborne systems and equipment certification

| | |
|---|---|
| ● DO254 | Design assurance guidance for airborne electronic hardware |

In addition the applicant shall have appropriate design tools required to optimize an electrical machine design (magnetic flux FEM simulation, thermal simulation, capability to make multi-physics models in the Modelica language in order to evaluate and compare solutions globally) and a power electronic design (electronic simulation using SABER, thermal simulation, capability to develop averaged models in Modelica).

The applicant shall have good connections with industry capable to develop, industrialize and deliver similar follow-up systems to aircraft manufacturers using accepted aerospace processes such as ARP4754. In addition, the proposed project shall promote European competitiveness through a credible transition plan to industrial manufacturing in Europe.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Kick-Off Meeting and report | The development plan, preliminary design of the proposal, the trade-offs studies and an updated schedule. | T0+1 month |
| D2 | Management plan | According to organization practices, but as a minimum must cover project organisation in terms of tasks, planning and resources, document management (including the review and release process), risk management. | T0+1 month |
| D3 | Trade-off conclusions and report | Final preliminary definition. | T0+6 months |
| D4 | Preliminary system safety assessment | Shall be performed according to ARP4753 recommended practices (Failure modes and effects analysis) | T0+6 months |
| D5 | Acceptance test plan | Basic functional tests and measurement of all the parameters which could drift during the life of equipment | T0+8 months |
| D6 | Qualification test plan | Shall cover a minimum set of electrical, thermal, conducted EMI and vibration tests, for safety on the rig. | T0+8 months |
| D7 | Preliminary design review and report | Shall cover optimized aircraft equipment, demonstration equipment if different, supplier validation test means and rig test cell. | T0+8 months |
| D8 | Test cell interface control document | Detail must be sufficient to assess the compatibility of the test cell with the rig. Shall cover mechanical and electrical interfaces as well as all the ancillaries. | T0+8 months |
| D9 | Critical design review and report | Inspection of the definition file for completeness and accuracy. System safety assessment (fault tree analysis). End of design studies. Launch of manufacturing. | T0+12 months |
| D10 | First Article Inspection and report | Complete disassembly and reassembly and comparison with blueprints. Record of equipment configuration for the qualification tests. Acceptance test. | T0+18 months |
| D11 | Qualification test report | Summary of tests and all qualification test results. | T0+20 months |
| D12 | Qualification review and synthesis report | Review of qualification test results, inspection of equipment, reassembly and acceptance test. | T0+20 months |
| D13 | A set of equipment for the rig | As described in paragraph 4.2 “System components” | T0+21 months |
| D14 | Scalable architecture model(s) | Modifiable models as open Modelica 3.0 source code relying only on the Modelica standard library and EDS project-supplied libraries, model user guide, modelling guide, validation tests and test results. Models will scale for generation power ranging between 25 kW and 80 kW and | T0+8 months |

| | | | |
|---|---|---|---|
| | | for start power ranging between 30 kW and 50 kW. | |
| D15 | Scalable functional model(s) | Modifiable models as open Modelica 3.0 source code relying only on the Modelica standard library and EDS project-supplied libraries, model user guide, modelling guide, validation tests and test results. Models will scale for generation power ranging between 25 kW and 80 kW and for start power ranging between 30 kW and 50 kW. | T0+20 months |
| D16 | Behavioural electrical model | Models of each delivered component developed in the SABER simulation work bench, validated on the latest release of SABER. Model user guide, validation tests and test results. | T0+20 months |

The partner will remain involved to provide level 2 maintenance and technical support until the end of EDS electrical testing activities, which are scheduled until the end of 2015, but may slip slightly.

Related costs to be quoted and explained.

## 4. Topic value (€)

The total value of this work package shall not exceed:

**1,700,000 €**

[one million seven hundred thousand euro]

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*Total compliance with the technical specifications is not a strict requirement, but the specifications are a priority over any other function the applicant may propose.*

# Topic Description

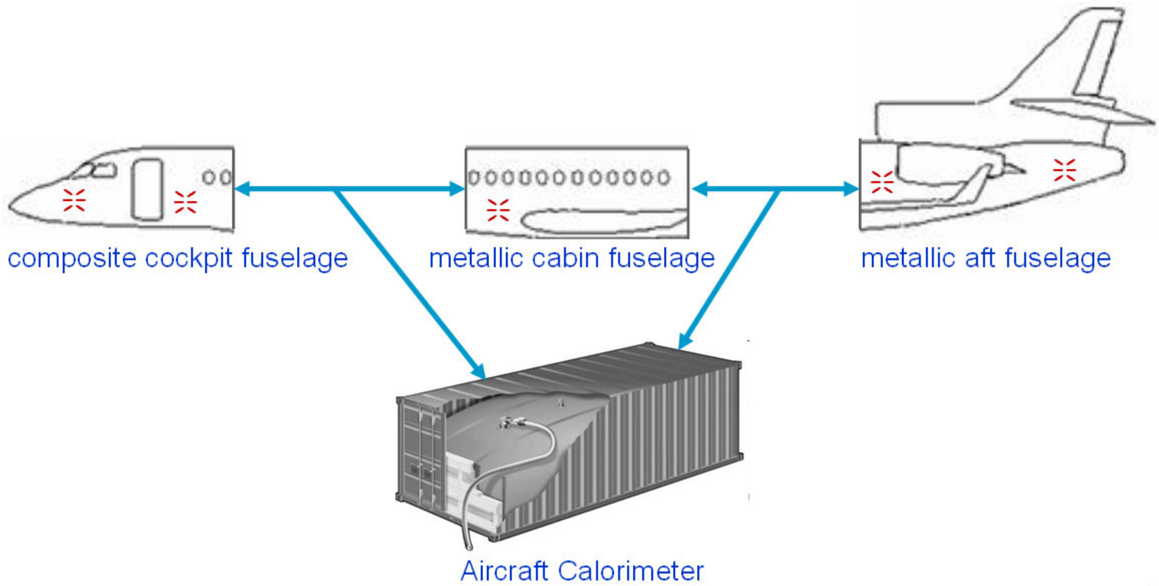
| CfP topic number | Title | | |
|---|---|---|---|
| *JTI-CS-2011-1-ECO-02-010* | Development, Construction and Integration of Systems for Ground Thermal Test Bench | End date | *T0+30M* |
| | | Start date | *T0* |

## 1. Topic Description

**Introduction**

The general objective of this part of the Eco-Design ITD is to make a significant step towards the concept of the all-electric vehicle systems aircraft. Thus the feasibility of such an aircraft has to be investigated through the study of innovative energy management architectures while reducing ground and flight tests with innovative concepts and technologies.

To develop, validate and finally demonstrate these energy management architectures a ground thermal test bench will be installed based on the use of an aircraft representative fuselage including various typical areas to cover the problems encountered for the thermal modelling. To achieve this the ground thermal test bench is planned to consist of three fuselage mock-ups containing equipment, representing the thermal dissipation of the aircraft systems, and an ancillary thermal bench element with modular measurement and calibration capability in form of generic environmental chamber(s) (hereafter Aircraft Calorimeter – ACC) able to cycle further small aircraft components:




**Objective**

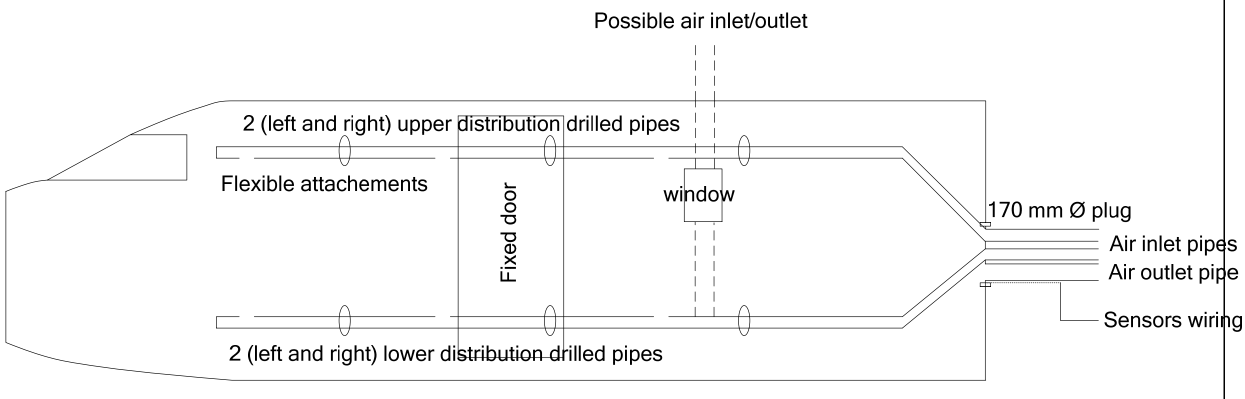
Using already existing infrastructure to condition aircraft environmental systems this call for proposal addresses the development, construction and integration of suitable systems to realise an appropriate environmental control to test a broad range of aircraft structures and systems with respect to their thermodynamic behaviour.

**Background**

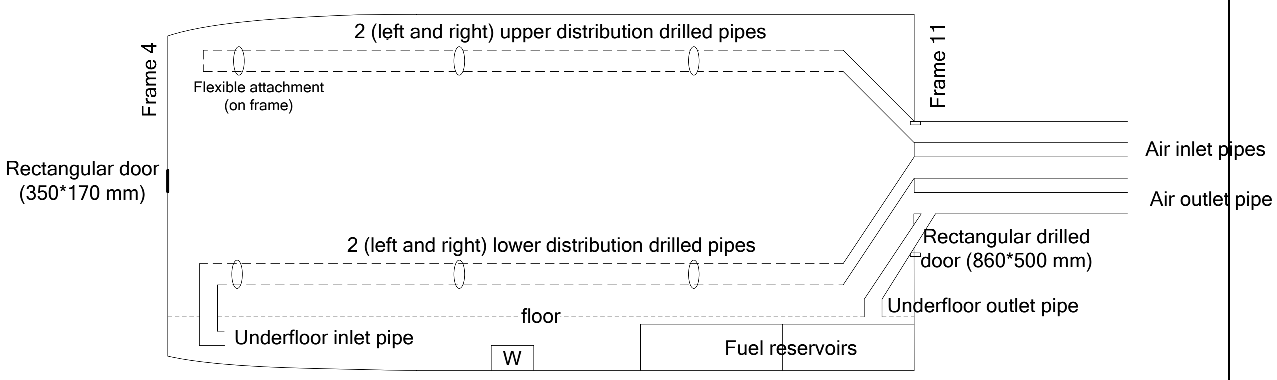
The core of the existing Test Facility is a 30 m long tubular low-pressure chamber with a diameter of 9.6 m. The first approximately 12 m of this pressure vessel, which is accessible through a 2.7 m x 3.0 m gate, are available for installations of the ground thermal test bench. To lift heavy equipment four 10 t cranes are installed inside the pressure vessel, they can move in longitudinal direction only. The floor of the laboratory outside the vessel is designed to carry loads of a forklift. The pressurisation currently is achieved inside the complete pressure vessel through three large vacuum pumps (Pneumofore UV50) of 90 kW and delivering 3240 m³/h each up to a certified differential pressure of max. 840 hPa (with outside absolute pressures of approx. 936 hPa at the laboratory, this yields ca. 100 hPa –the current system has been run at 150 hPa only, any operation below needs to be assessed by the applicant). The vessel itself has an air conditioning unit with a capacity of 9000 m³/h, 122 kW heating and 18 kW cooling power at a delivery pressure of 600 Pa under normal operation. It is possible to use this unit to remove heat and humidity generated inside the vessel, while considering heat gains through the outside environment (solar gains through transparent membrane roof construction per projected floor area of approximately 1350 kWh/m² - the vessel itself has a projected floor area of approximately 300 m²). Test items placed inside the vessel currently are supplied from outside the vessel via special grommets of which the following are available for the ground thermal test bench: 7x R2'', 1x DN100, 1x DN180, 7x DN200. Six Refrigeration compressors (Frascold / Z30-102.51Y) deliver R404a coolant which has cooling capacity down to approx. -46°C and may be used inside the vessel. For the current installation a control system based on Siemens Design Insight is available. Possibly based on this existing equipment a suitable solution for the thermodynamic conditioning of the ground thermal test bench system must be proposed.

For the ground thermal test bench the existent fuselage mock-ups must be used, which will have interfaces for conditioned air, electricity and measurement equipment and will be installed inside the low pressure vessel of the test facility near Holzkirchen, Germany. They will be equipped for testing in a representative and realistic environment. Modifications of their structure by the applicant will not be possible. Any interfacing with these parts needs approval of the CleanSky EDS members. The parts will have the following approximate grand data:

composite cockpit fuselage part (ca. 4 t with an internal volume of approx. 13 m³). This part has a 170 mm diameter plug at the rear frame through which air inlet and outlet pipes and wiring (power and sensors) can be installed. If needed, additional access can be provided through false windows (easily removable or drillable). The distribution pipes can be installed with flexible attachments to the frames.

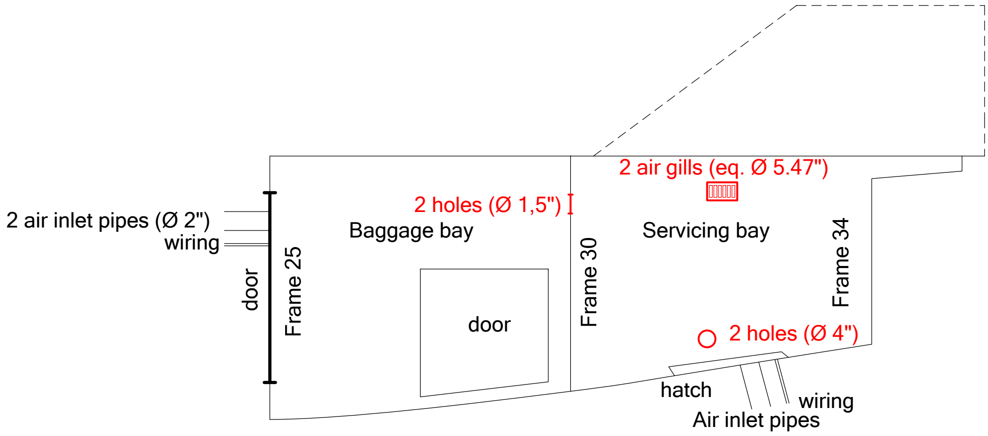



Metallic cabin fuselage part (ca. 3 t with an internal volume of approx. 16 m³). This part has two hatches: one small (350*170 mm) at the front frame and one big (860*500 mm) at the rear frame. A false door can be manufactured and drilled for the rear hatch, in order to provide access to air inlet and outlet pipes, and wiring (power and sensors). The front hatch can also be used if needed. The distribution pipes can be installed with flexible attachments to the metallic frames.




Metallic aft fuselage part (ca. 4 t with an internal volume of approx. 14 m³). This part is made up of two technical bays: the baggage bay at the front (access through two false doors: cabin interior door, and side exterior door, which can be drilled to provide access to air inlet and outlet pipes, and wiring), and the servicing bay at the rear (access through either a centre-line hatch or bulkhead which can be drilled).

UPDATED EMPENAGE PICTURE




This description of the background of the thermal test bench is preliminary and must be discussed with the EDS members during the design phase.

**Content**

Aircraft and their systems are operating under a wide range of environmental conditions, several tests are defined e.g. in the guidelines DO-160 and MIL-810 and others, yielding the following maximum boundary conditions for equivalent flight conditions for the different parts which may be operated separately and conjointly:

| | | Fuselage parts | Aircraft calorimeter |
|---|---|---|---|
| Temperature | **Maximum** | 85 °C (if possible, e.g. reduction to 80 °C may be necessary for some electric wiring) | 150 °C |
| | **Minimum** | -55 °C | -65 °C |
| | **Tolerance** | ± 2 K | |

| | | | |
|---|---|---|---|
| | **Change rate** | ± 10 K/min (controlled in a range as wide as possible) | ± 10 K/min (controlled in a range as wide as possible)<br>thermal shock with > 100 K/min (often realised through a two chamber system) – desired |
| **Pressure** | **Range** | 111 hPa to ambient (approximately 934 hPa) | |
| | **Tolerance** | ± 5 % | |
| | **Differential** | None (same as vessel) | Up to 641 hPa – desired |
| | **Change rate** | max. ± 10 m/s (controlled climb / decent) | max. ± 10 m/s (controlled climb / descent)<br>641 hPa in less than 15 s (rapid decompression) – desired |
| **Humidity** | **Range** | Nearly 0 g/kg (at low temperatures) to 200 g/kg (g water per kg moist air) | |
| | **Tolerance** | ± 5 % RH | |
| | **Change rate** | ± 1 g/kg/min | |
| | **Water quality** | Resistivity of water for humidification: 0.15 – 5 MΩ at 25 °C | |

| | | |
|---|---|---|
| **Ventilation** | **Airflow velocity*** | 0 to 6 m/s (controlled) |
| | **Airflow velocity* tolerance** | ± 10 % |
| | **Mass flow** | Up to 70 kg/min for all chambers/compartments of the bench separated in at least three differently conditioned flow sources (10 kg/min @ -55 °C to 70 °C; 30 kg/min @ 30 °C to 70 °C; 30 kg/min @ 3 °C to 20 °C). A detailed configuration of this amount, the pressure drop and the number of inlet and outlet pipes (ranging from 2 to 6 per fuselage part / ACC) shall be discussed and defined in a later stage with the EDS members. |

* air velocity at specimen inside a chamber.

Each of these environmental conditions must be achieved in each of the thermal test bench components so that single items can be tested as well as full aircraft systems using above mentioned provided fuselage items of a business jet for several operational profiles of an aircraft. These may be typical profiles as well as failure cases which are under investigation towards an innovative energy management.

Air-conditioning units must be installed to provide moist air in proper thermodynamic conditions, i.e. with defined temperature, humidity and pressure. Test chambers as well as test objects must be provided with different flows. At least four to five different articles may be delivered with this air: the Aircraft Calorimeter, the aft fuselage part (three areas), the cabin fuselage and the cockpit fuselage. Additionally an external cooling/heating of the fuselage parts – e.g. by a cocoon, or inserted into a larger climate chamber with proper HVAC-interfaces supplied by the applicant – will be necessary to achieve realistic equivalent flight conditions. Optionally innovative thermal energy harvesting systems could be integrated.

The air-conditioning units do not need to supply fresh air, so an independent operation (except depressurisation) inside the pressure vessel is possible with no fresh air duct coming from normal pressure level. The units shall operate independently from already installed air-conditioning units in the "FTF-facility", a use of the installed refrigerating plant may still be possible.

For proper energy balance the leak tightness of ducts, flaps and valves shall be as high as possible (e.g. class D according to EN 13799). Mass flows shall be measured independently from or compensated with respect to pressure and temperature. All parts shall be interconnected so that thermodynamic flows between them are possible and controllable. Energy losses through these interconnections shall be compensated appropriately.

The aircraft calorimeter is to be supplied by the applicant. It shall be equipped with additional internal ventilators to ensure a proper convective heat transfer at the test article according to the test requirements. The test cell of the ACC shall be adiabatic, thus a wall heating / cooling system will be necessary to ensure proper thermal gradients and to avoid condensation in case of very humid conditions. To achieve test requirements regarding thermal shock tests a two chamber system may be necessary – this may be integrated in or additional to the ACC.

To gain the potential for decompression tests at least parts of the ACC could be executed for differential pressure operation of up to 641 hPa overpressure wrt. the low-pressure environment inside the vessel. Depending on feasible openings and their control decompression experiments from cabin to low pressure in less than 15 s may be possible. The ACC and its core supply system shall be transportable on common container trucks. The ACC test cell shall thus have an outer dimension of approximately 2.3 x 2.3 x 4.6 m³ and an appropriate opening to enter specimens before and/or during test. At least for this system an air and/or water-cooling of the system components should be preferred.

The system must be mounted and integrated on site including sufficient interfaces, documentation and training to independently run and maintain the system in its full range. A suitable control system for bench automation and related data handling shall be implemented into the laboratories Design Insight software with appropriate GUIs. The ground thermal test bench shall be able to be operated 24 hours a day with and without operating personnel (depending on test procedure). The applicant shall ensure a proper training of operating personnel until the system is fully operational. Up to this moment the operational sub-systems shall be run under the applicant's responsibility.

All equipment needed (incl. e.g. piping/ducts, valves, fans, ventilators, humidifiers and dehumidifiers, heating devices, pumps, electric motors, frequency changers, filters, mufflers, chillers, compressors, sensors and hard-/ software, air conditioning units, coolants, etc.) must be supplied and installed by the applicant. An exception is made for the fuselage parts themselves for which suitable air-conditioning interfaces must be provided. These are to be defined during the project lifetime. Power consumption of all relevant subsystems must be logged via an data acquisition system, e.g. via the test bench control system. For electrical installation and integration local resources at the laboratory will be available. The system must comply with VDE-guidelines and be included in the emergency shutdown system of the laboratory. In general the system at the laboratory site located in a mixed used area has to be compliant with German legislation. Installed materials and components used, including sensors, must be capable of the environmental range of the ground thermal test bench and moving parts must withstand an adequate number of cycles and must not contaminate the test equipment with abrasion compounds.

The work is conducted under the auspices of EDS work package 4.3 and the technical management therein. It entails handling innovatively low temperatures versus variable to high volumes, control algorithms and differential pressures. **Therefore close liaison for technical and safety grounds is important**.

## 2. Special skills, certification or equipment expected from the applicant

Experience in planning, constructing and accomplishing projects in the area of heating, ventilation, air conditioning and refrigeration as well as vacuum technology.

Experience in developing unique test facilities for applying defined environmental conditions onto components and subsystems.

Experience in implementing and integration of suitable control strategies and interfaces.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Development plan for Systems of Ground thermal test bench | | T0+1M |
| D2 | Preliminary Definition files for Systems of Ground thermal test bench for preliminary design review | Such as HVAC-Plans, wiring diagrams, etc. | T0+4M |
| D3a | Definition files for Systems of Ground thermal test bench for critical design review for go ahead decision | Such as HVAC-Plans, wiring diagrams, etc. | T0+7M |
| D3b | Definition files for Systems of Ground thermal test bench dispatch report | Containing bill of materials, agreed recovery actions in case of failure, an interface compliance matrix checked(with member), simplified block diagram calculation check for operation/ malfunction of most critical parts; failure of cooling scenario checked with member. | T0+14M |
| D4 | Integrated Systems of the Aircraft Calorimeter of Ground thermal test bench | Integrated Systems are hardware, which is installed and running according to their specification | T0+24M |
| D5 | Detailed documentation of the Aircraft Calorimeter of Ground thermal test bench | Manuals, Plans and Maintenance guidance | T0+25M |
| D6 | Integrated Systems of the fuselage mock-ups of Ground thermal test bench | Integrated Systems are hardware, which is installed and running according to their specification | T0+26M |
| D7 | Detailed documentation of Systems for the fuselage mock-ups of Ground thermal test bench | Manuals, Plans and Maintenance guidance | T0+28M |
| D8 | Training of operating staff of Ground thermal test bench | | T0+30M |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 2,000,000.—**

**[two millions euro]**

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*The applicant is required to discuss the way to comply with the timing requirements; in case the proposal presents different timing, the differences must be explained and justified.*

# Topic Description

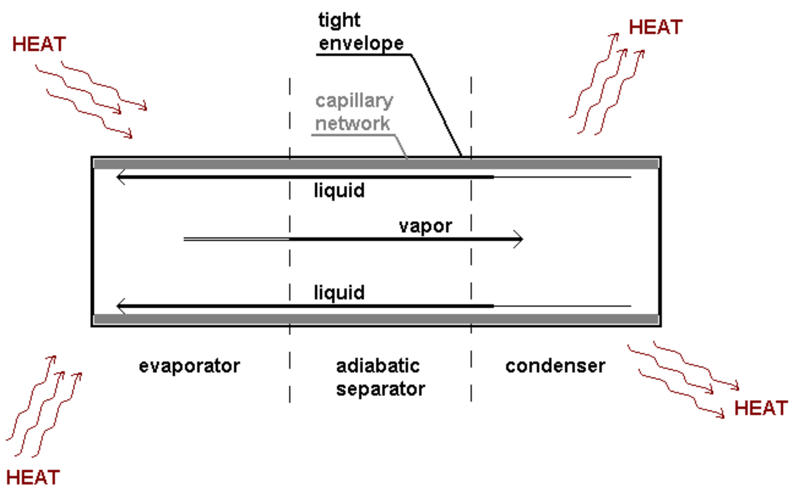
| CfP topic number | Title | | |
|---|---|---|---|
| **JTI-CS-2011-1-ECO-02-011** | Development, construction, integration, and progress toward to heat pipes monitoring and qualification on aircrafts | **End date** | *To + 21 Months* |
| | | **Start date** | *To* |

## 1. Topic Description

### 1.1 Introduction

The main objective of this part of the Eco-Design ITD is to make a significant step towards overall aircraft weight reduction in order to minimize its fuel consumption, optimize its range, and lower its impact on the environment. This can be significantly addressed with the qualification of heat pipes and thermocapillary loops on aircrafts as they are one of the lightest and most efficient ways of conductively removing the heat generated in critical areas such as confined bays for power electronics. Indeed, these reliable innovative heat transfer systems are already fully operative on several aerospace technologies such as satellites and spaceships, where the reliability, weight and efficiency constraints are even more critical than on aircrafts.

Thus, the qualification of such innovative passive heat transfer devices for future aircrafts is worth studying the different technologies and concepts that could finally lead to a significant weight reduction of the aircraft.




### 1.2 Objective

On the basis of the existing heat pipe technology and considering special constraints relative to civilian aircrafts, this call for proposal addresses the development, manufacturing, integration and a progress toward qualification on business jets of suitable heat pipes and thermocapillary loops for critical heat loads dissipation. This includes the actual device as well as the associated equipment and sensors for monitoring the functioning and the conditions of the system. An effort should be made by the applicant to use fluids that have a low impact on the environment.

### 1.3 State of the art

Heat pipes have been used on spacecrafts for several years as they are adapted to the environmental conditions met in space. Indeed, As there is no gravity in space, the capillary pressure is enough to insure the flow of the liquid. The vapor is also concerned by the gravity or the load factors, but to a much smaller extent than the liquid, and therefore this effect can be neglected in aeronautical cases.

Depending on the kind of fluid used inside the heat pipe, the temperature range of operation can be drastically changed. Indeed, using hydrogen allows an operational point around -270°C, while using silver allows an operational temperature range between 1800°C and 2300°C. The choice of the fluid depends on several factors such as the cost and the temperature range forseen for the application. For aeronautics, the minial temperature is on the skin of the aircraft, and can reach as low as -60°C in certain cold situations. The maximal temperatures in the equipment bays of the aircrafts can reach up to 120°C in certain cases, and 80°C in most cases. The most commonly used fluid for this range of temperatures is Ammonia, but some others can be used as well.

Concerning thermocapillary loops, they can be used with more reliability regarding the load factors, but they are more complex from an architectural point of view. However, they present a great advantage as the power evacuated can be several hundreds of times the one evacuated with a conventional heat pipe (600kW/cm² against 1.5kW/cm² for a heat pipe).

### 1.4 Limits of the current technology

One of the problems raised hitherto has been the influence of gravity or load factors (especially negative G), because it could prevent the condensed liquid from capillary creeping from the condenser to the evaporator. However, previous tests conducted on military aircrafts tend to prove that below +5G, the load factor does not strongly impact the functioning of the heat pipe. The limit for civilian aircrafts being under +5G, this should not be a major issue. Concerning negative G, it may lead to certain problems, and the case has not been made clear yet; and although business jets tend to encounter negative G pretty rarely, it is an issue to be addressed. The same concerns remain for the themocapillary loops.

Another difficulty is met concerning the monitoring the system. When it comes to civilian aircrafts, certification of the system is what stands between the stand alone system and the integration on aicrafts. And heat pipes qualification is hindered by the monitoring of the functioning system, because fluid leaks can be almost undetectable and prevent the whole system from working properly, or even work at all.

There are also some limitations which are specific to the heat pipes or the thermocapillary loops.

These are relying on a great amount of physical parameters of the system.

Viscous limit:

This limit can be reached on heat pipes functioning at a temperature corresponding to a very low internal vapor saturation pressure. It basically happens when the vapor is too viscous to overcome the headloss of the pipe while flowing from the evaporator to the condenser. This will not be reached in aeronautical cases.

Sonic limit:

The vapour shall not flow from the evaporator to the condenser too fast because a shock can happen and thus limit the heat flow able to be evacuated. The very low pressures (about a couple of mbars) inside the heat pipes make the flow become supersonic easier than in normal atmospheric conditions, so this constraint has to be taken into account.

Drive limit (for heat pipes only):

As the liquid and the vapor can flow at counter-current with an interface, the flowing vapor can be able to rip some droplets of liquid out of the capillary stream and drive them back to the condenser, blocking the functioning of the heat pipe. This only happens when the vapor flows at high speeds but is likely to happen on aeronautical applications.

Capillary limit:

In order to have a correct functioning of the heat pipe, the vapor mass flow and the liquid mass flow must be equal. For the same reasons as the ones described in the viscous limit for the vapor, the performance of the capillary network must allow a sufficient liquid mass flow between the condenser and the evaporator. This limit only matters if the liquid motion is induced primarily by capillary forces.

Boiling limit:

If the radial heat flow is too great around the evaporator, the liquid may be boiling before it reaches the evaporator and therefore create some hot spots in the heat pipe, that can potentially lead to a local overheat. The bubbles of vapor formed in the capillary network can indeed hinder the liquid flow and the heat evacuation. This is all the more concerning in thermocapillary loops where the bubbles of vapor cannot flow back to the condenser.

### 1.5 Context

This call for proposal comes in the context where the systems supplied by the applicant are to be tested in an environmental simulation room where Falcon fuselage parts will be installed and equipped for thermal tests. The facility is located in Holzkirchen, Germany, and run by Fraunhofer Gesellschaft. This facility includes a calorimeter, which allows re-creating extreme environmental conditions, from very cold (-65°C) to very hot (+150°C) conditions. This calorimeter is to be supplied through another call for proposal, among with the cooling and ventilating systems and pipes. Several thermal tests will have to be conducted in this calorimeter using real aircraft fuselage parts. The thermal tests conducted on these fuselage parts and on this calorimeter in the scope of the CleanSky EDS Work Package 4 include a situation where the conductivity of the material standing between a heating equipment simulator and the fuselage skin is studied. Among the supports for this equipment simulator is needed a heat pipe in order to evaluate the equivalent thermal conductivity of the device and the performance it provides. The objective is to judge whether the performance is interesting enough considering the feasibility of such a thermal system, for its certification on future aircrafts. An strong interest is also drawn to thermocapillary loops.

For now, the missing part is the monitoring of the functioning that would allow to use heat pipes in accordance with the certification authorities. Therefore, on the basis of these tests and other tests conducted in the facility chosen by the applicant, a progress toward the qualification of heat pipes and the associated equipment and sensors is expected.

### 1.6 Requirements

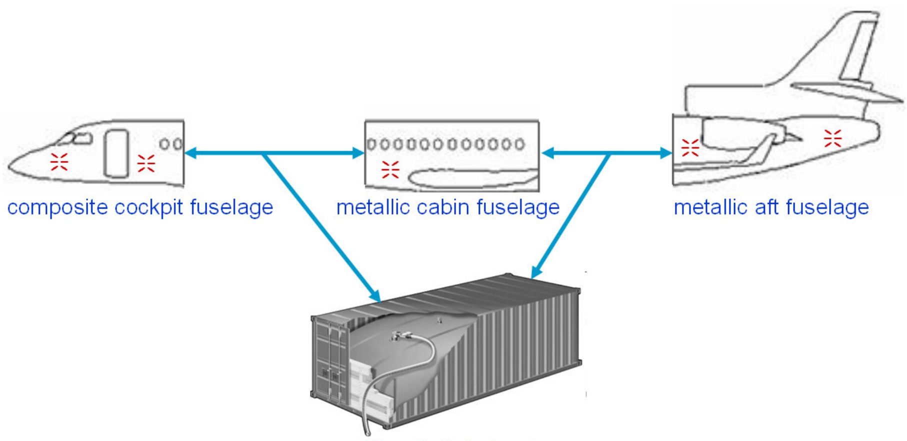
#### 1.6.1 Activities

Having proposed at least one innovative preliminary design in its application, the selected applicant shall perform the following activities:

- Perform trade-off studies proposed during the technical negotiation phase.

- Preliminary system safety assessment, using well-substantiated reliability data and/or accepted standards.

- An acceptance test plan showing the level of performance achievable and the demonstration of a TRL-5 using the applicant's test means, and those only demonstrable on the EDS calorimeter associated to the thermal test bench.




**Thermal test installations: aircraft fuselage mock-ups and calorimeter**

- A preliminary design review organised in presence of the EDS thermal test bench operator (Fraunhofer), and the topic manager representatives. At this milestone, the interfaces between all the components and the performance requirements of each component will be frozen.

- Detailed design of the proposed system, including detailed design of the pipes and of the thermocapillary loops, detailed design of the evaporator and condenser, and detailed design of the structural, thermal, and electrical interfaces with the aircraft mock-up and the equipment. A detailed design of the monitoring devices and the wiring must be provided in accordance with the readiness level achieved on the monitoring fonction. All of this in the context of a use at TRL 5 on the Eco Design for Systems calorimeter.

- Design of the test facilities which will be used by the applicant for the acceptance tests.

- Creation of models of the system intended for use by aircraft integrators, as described below.

- Tests on technology samples required to complete the detailed design, if any, including the manufacturing of samples and test setups. The topic manager will not provide any technical data to the applicant other than the documents listed in paragraph 1.8, below.

- A critical design review organised in presence of the topic manager representatives. At this milestone, the detailed design of all components will be frozen, and a decision made to manufacture the components.

- Manufacturing of a minimum of 3 systems, one being for the test facility, the second as a spare, and the third kept for support by the applicant. In addition, spare parts shall be manufactured in sufficient quantity to support the tests performed in the Clean Sky EDS project until 2015.

- Environmental qualification testing will be performed according to the Generic Architecture Guidance document, which also describes the design operating environment (aligned on DO-160 rev. F).

- Limited acceptance will be pronounced after performance tests performed on the applicant premises in presence of the representatives of the topic manager. Acceptance will be pronounced when the system fulfills all the requirements of the acceptance test plan. A limited number of tests may be performed on the EDS calorimeter in presence of the applicant.

- Delivery and installation of equipment on the EDS calorimeter (Holzkirchen, near Munich, Germany).

### 1.6.2 Components

The testing facility (calorimeter) being supplied through another call for proposal and another applicant, the applicant shall deliver :

- the heat pipes designed for critical heat loads, and designed to fit on both their ends for their integration (exchange surfaces to match with fuselage skin on one side, and with a heating equipment on the other)

- the fluid contained in the heat pipes,

- the local control monitoring system, which could for instance measure temperatures at important points of the heat exchangers and power electronic unit (if any), and interfaces the system to the calorimeter control and monitoring subsystem.

- any other piece of ancillary equipment required to interface the system to the calorimeter and its testing devices (heating equipment simulators, …)

- the thermocapilary loops designed to fit in the representative aircraft mock-up (interfaces with fuelage skin and equipment skin), and also designed for critical heat loads,

- the fluid contained in the thermocapillary loops,

- the local control monitoring system,

- any other piece of ancillary equipment required to interface the system to the calorimeter, the representative aircraft mock-up and its testing devices (heating equipment simulators, …)

- any mean of maintenance that may be required in order to allow a proper operation of the devices until the end of the CleanSky project (2015)

- a 1D thermal model of the heat pipes and thermocapillary loops implemented in Modelica 3.0 or any further version.

### 1.6.3 Performance

The system to be provided by the applicant shall be capable of transfering the maximum heat power dissipated by the heating equipment simulator (900W) from the skin of the equipment to the skin of the aircraft. Note that the skin of the aircraft can be either metallic or made of composite structures. The temperature of the equipment shall never exceed the value corresponding to the type of equipment that is simulated.

Therefore, the sizing case would be for sensitive electronics, that must stay below 70°C in order to function properly. The heat pipe shall be able to prevent an equipment dissipating 900W of heat and functioning under a maximum temperature of 70°C from overheating. If a single heat pipe is not adapted for a maximal temperature of equipment between [70°C; 120°C], at least one heat pipe shall be designed for each of the maximal temperatures of equipment: 70°C, 90°C and 120°C. This has to be achieved with various external conditions, going from -55°C to +60°C, and with an air water content going up to 27g/kg of dry air.

An extract of the thermal test requirements including the sizing tests will be provided to the applicant.

The choice of the fluid inside the heat pipe shall be the result of a trade-off between performance, reliability, ability to be monitored, and impact on the environment. For example, liquids shall have a low GWP (global warming potential) according to the european legislation, shall have a level of reliability corresponding to the criticity of the heating equipment, and shall be monitored to a level that allows a further qualification of the device on civilian aircrafts.

The overall weight of the heat pipe and the associated equipment, including the monitoring, shall be as light as possible without reducing its reliability as overall aircraft weight reduction is the main goal.

### 1.7 Innovation

There is no restriction on this equipment, which can be an already existing technology adapted to civilian aircrafts, a mixture of already existing technologies, or even a brand new concept as long as its qualification on small civilian aircrafts such as business jets or regional aircrafts is at least partially provided, with a road map towards its full qualification before 2015.

Irreversibility of the heat transfer can also be a way to be explored. With one heat pipe on each side of an aircraft, there would always be one on the solar-radiation-protected side allowing the heat generated by equiments to flow to this colder end of the heat pipe.

### 1.8 Input

The following documents will be available for the selected partner at T0.

- Extract of the EDS thermal test requirements
- GAG Eco Design document **Generic Architecture Guidance**
- ERA EDS Reliability Estimations.

## 2. Special skills, certification or equipment expected from the applicant

The applicant shall have experience in the design of innovative heat transfer devices.

It shall have knowledge of the following document:

- DO160F Environmental conditions and test procedures for airborne equipment

In addition the applicant shall have appropriate design tools required to optimize a heat pipe, as well as models which can be shared at least partially with the aircraft manufacturer.

The applicant shall have good connections with the industry capable of developing, industrializing and delivering similar follow-up systems to aircraft manufacturers, using accepted aerospace processes such as ARP4754. In addition, the proposed project shall promote European competitiveness.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | Technical design document | | To + 3 Months |
| D2 | Trade-off conclusions report | | To + 6 Months |
| D3 | Acceptance/certification program | | To + 8 Months |
| D4 | Performance report | | To + 12 Months |
| D5 | Qualification report | | To + 14 Months |
| D6 | Qualification review | | To + 15 Months |
| D7 | Delivery | | To + 14 Months |
| D8 | Acceptance Test Report | | To + 20 Months |
| D9 | Acceptance/certification report | | To + 21 Months |

## 4. Topic value (€)

The total value of this work package shall not exceed:

**€ 360,000.—**

[three hundred sixty thousand euro]

Please note that VAT is not applicable in the frame of the CleanSky program.

## 5. Remarks

*If applicable*

# Clean Sky - Green Regional Aircraft

| Identification | ITD - AREA - TOPIC | topics | VALUE | MAX FUND |
|---|---|---|---|---|
| **JTI-CS-GRA** | **Clean Sky - Green Regional Aircraft** | **6** | **1.330.000** | **997.500** |
| *JTI-CS-GRA-01* | *Area-01 - Low weight configurations* | | **770.000** | |
| JTI-CS-2011-1-GRA-01-035 | Smart maintenance technologies | | 220.000 | |
| JTI-CS-2011-1-GRA-01-036 | Development of methodology for selection and integration of sensors in fuselage stiffened panels. Testing | | 100.000 | |
| JTI-CS-2011-1-GRA-01-037 | Advanced fuselage and wing structure based on innovative alumiunium lithium alloy - numerical trade off study | | 450.000 | |
| *JTI-CS-GRA-02* | *Area-02 - Low noise configurations* | | **460.000** | |
| JTI-CS-2011-1-GRA-02-015 | Advanced concepts for trailing edge morphing wings - Design and Manufacturing of test rig and test samples - | | 210.000 | |
| JTI-CS-2011-1-GRA-02-016 | Novel nose wheel evolution for noise reduction | | 250.000 | |
| *JTI-CS-GRA-03* | *Area-03 - All electric aircraft* | | | |
| *JTI-CS-GRA-04* | *Area-04 - Mission and trajectory Management* | | | |
| *JTI-CS-GRA-05* | *Area-05 - New configurations* | | **100.000** | |
| JTI-CS-2011-1-GRA-05-006 | Updated Regional traffic scenario to upgrade Requirements for "Future Regional Aircraft". | | 100.000 | |

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-01-GRA-01-035 | Smart Maintenance Technologies | End date | T0 + 12 |
| | | Start date | T0 |

## 1. Topic Description

**Acronyms**

CFRP - Carbon Fibres Reinforced Plastics
MsS - Magneto-Strictive Sensors

### 1.1 – Scope of work

Developing smart maintenance technologies to enable self-sensing of strain field in components manufactured by CFRP, using magnetostrictive sensors, as well as to initially correlate strain measurements to internal damage.
The smart maintenance methodology will then be evaluted by testing on sub-component scale demonstrator.

### 1.2 – Reference documents

Documents related to test panel manufacturing, geometry, loads will be provided to the CfP winner(s).

### 1.3 – Introduction

Self sensing of CFRP components is a major step towards improving reliability and performance of aircraft structural elements. The ability to reliably monitor developed strains during or after structural loading will greatly assist in reduction of aircraft weight, through lowering of safety factors, and minimization of aircraft downtime, by increasing inspection speed and enabling prompt isolation and quantification of damaged areas.
Within this CfP the required methodology to achieve these objectives is expected to be developed, by using magnetostrictive wires and magnetic flux sensors. Moreover, an initial correlation of strain measurements to internal damage is required. Finally, a demonstrator (sub-component scale), including artificial damage and repaired with smart composite bonded patch, should be manufactured for the evaluation of the developed smart maintenance methodology.

#### 1.3.1 - Background

Inspection of composite structures is regularly required to ensure their structural integrity. However, existing technology is generally time consuming, complicated and expensive. By integrating self-sensing capabilities to CFRP structures, a direct reduction of maintenance requirements and costs is expected, while increasing structural reliability, thus assisting in increasing of EU manufactured aircraft competitiveness, greening of aircraft operations and maintenance activities, and reduction of aircraft operations and maintenance costs.

#### 1.3.2 – Interfaces to ITD

A Kick-off meeting will be held at the beginning of this project. The preliminary geometry of test panel and typical damage to be repaired with smart pacth will be provided.

### 1.4 - Activity Description

Strain sensing should be achieved using magnetostrictive wires appropriately embedded into composite materials. Potential changes to the magnetic flux response induced to the magnetic sensors should be traced, and received data should be converted to strain measurements to trace internal damage. For this reason, extensive numerical modelling should be performed to correlate surface strain measurements with internal damage (delaminations, debondings etc.). Finally, the appropriate software to convert and compare current magnetic flux / strain mapping against previous readings, as well as correlation algorithms between strain readings and damage propagation should be developed, enabling quick and easy exploitation of results.

The specific objectives of this Topic would include:

**1.4.1**_To identify appropriate strain sensitive magnetic wire to be applied to composite structures, in combination with or totally replacing the existing lightning protection mesh.

**1.4.2**_To develop non-contact magnetic flux sensor arrays for quick scanning and strain mapping of the composite structures.

**1.4.3**_To numerically define the correlation between surface strain mapping and internal damage, i.e. such as debondings and delaminations.

**1.4.4**_To develop the appropriate algorithms and software supporting the magnetic flux scanning, the conversion of magnetic flux to strain measurements, the comparison to previous strain readings and the correlation surface strain readings to internal damage.

**1.4.5**_To test the smart repair bonded patch on manufactured sub-component scale demonstrator for evaluation of the developed smart maintenance methodology. The smart bonded repair patch, embodied after the introduction of artificial damage, must be able to:
(1) Sustain the applied loads (static / fatigue) and restore the initial structural strength; and,
(2) Correctly perfom its intended function of structural health monitoring.

Note that the artificial damage will consist of a typical three-dimensional structural damage, i.e. one stringer broken and the skin cracked on LH and RH sides of the stringer for a certain length.

## 2. Special skills, certification or equipment expected from the applicant

The applicant(s) should have experience in the following areas:
- Development of sensors using magnetostrictive wires.
- Measurements using high accuracy magnetic flux sensors.
- Development of tools for composite inspection and repair for aeronautical structures.

Moreover, the applicant(s) should be able to:
- Develop the required simulation and software tools.
- Manufacture component scale demonstrator (repair patch) for the evaluation of the smart maintenance methodology.

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| **D1** | Magnetic wires sensors report | Identification of appropriate strain sensitive magnetic wire to be applied to composite structures. | T0 + 3 |
| **D2** | Magnetic flux sensing elements report | Development of non-contact magnetic flux sensor arrays, for quick scanning of structures. | T0 + 8 |
| **D3** | Numerical modelling report | Numerical modelling for correlation of surface strain measurements to internal damage information. | T0 + 8 |
| **D4** | Sensing software and algorithms report | Development of sensing supporting algorithms and software. | T0 + 10 |

| | | | |
|---|---|---|---|
| **D5** | Development of sub-component methodology demonstrator report | **D5.1**_Demonstration tests of developed smart maintenance methodology.<br>• Stiffened panel, sub-component scale (*), Artificial damage type and location (*), Loads specifications and Tests execution will be available within the WP 1.3.7 testing phase.<br>• Artificial damage (three-dimensional), Composite repair bonded patch with embedded sensor monitoring, Repair embodiment, and All necessary software / hardware instrumentation and utilization/personnel related to smart technology will be provided by CfP winner(s).<br>(*) The panel is a typical panel stiffened with stringers and frames. The artificial damage will be similar to the typical 2bay-crack damage (one stringer broken and the skin cracked on both sides of stringer). In this specific case, the skin will be cracked for about half-bay of skin on each side and the central stringer damaged). The panel will sustain static and/or fatigue loads. | T0 + 11 |
| | | **D5.2**_Evaluation of developed smart maintenance methodology further to the tests results. | T0 + 12 |

## 4. Topic value (€)

Budget: The Maximum Allowed Topic Budget is

**220.000,00 €**

[Two hundred twenty thousand Euro]

The maximum funding value is between 50% and 75% of the Maximum Allowed Topic Budget indicated above according to the CfP rules.

Please note that VAT is not applicable in the frame of the CleanSky programme

## 5. Remarks

(1) The expected starting date for this project is before mid-2011.
(2) The activity related to D5 Deliverable is linked to WP 1.3.7 activities execution.
(3) The activity will be monitored by 2-monthly Progress Reports delivered by the CfP winner(s) and Meetings, as necessary, at Prime or CfP winner(s) site.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-GRA-01-036 | "Development of methodology for selection and integration of sensors in fuselage stiffened panels. Testing scheme, testing of sensorised fuselage stiffened panels and data processing" | End date | $T_0 + 5$ |
| | | Start date | $T_0$ |

## 1. Topic Description

### 1.1 – Scope of work

The work is focused on the development of all methodology procedures and instruction sheets related to the selection and integration of sensors in specific fuselage stiffened panels, as well as the destructive and non destructive testing of the panels. The contractor will be responsible for the implementation of a series of compression static and fatigue tests on "sensorised" stiffened composite panels. Fiber Optic Bragg Grating (FOBG) sensors and / or standard strain gauges (SGs) for strain monitoring purposes will be integrated (embedded or bonded) in the panels. The aim of the work is to perform the defined destructive and non destructive tests and record the output from the testing equipment and integrated sensors (FOBGs and / or SGs).

Summary of Objectives

- Definition of methodology for FOBGs sensor integration
- Definition of test plan
- Impact damage application
- Destructive and non destructive testing of panels
- Analysis and reporting of test results

### 1.2 – Reference documents

Related ISO / EN standards

### 1.3 – Introduction

The size of the panels is expected to be approximate 1 x 2 m.

The FOBG and / or SG sensors will be placed (embedded or bonded) at various locations around the structure.

Two different panel configurations (in terms of damage introduction) are foreseen:

- Undamaged panels (Reference Panels)
- Panels damaged by impact (low velocity impact)

Non destructive inspection (Ultrasonic B & C-Scan) of the panels is planed after the application of the impact damage.

The corresponding destructive tests are planned as follows:

- Compression tests to failure of undamaged panel for stiffness and strength evaluation of panels
- Compression tests to failure on damaged panels (by impact) for evaluation of residual stiffness and strength of panels
- Fatigue loading of an impacted panel (damaged) and Compression test to failure (so as to obtain residual stiffness and strength data for the "damaged" & "fatigued" panel)

Non destructive inspection (Ultrasonic B & C-Scan) of the panels is planned after each test

**1.3.1 – Interfaces to ITD**

The activities of the present Call for Proposal are part of the WP 1.3.7 of the GRA ITD. More specifically, the activities are closely related to the panels testing activity realised for Fuselage WP 1.3.7-02.

A kick-off meeting will be held at the beginning of the project object of this call in order to (i) supply the documentation about the activities performed at that time, (ii) supply the needed input data, (iii) decide how to manage the data exchange during the project.

**1.4 - Activity Description**

All panels will be manufactured by HAI. The contractor will cooperate with HAI in the technical aspect of sensors integration (FOBGs) in the structure and the definition of all appropriate interfaces (connectors)

It is the contractor's responsibility to undertake the following tasks:

- Definition of methodology for integration (embedding) of the selected sensors (FOBGs) in the structure related to the manufacturing process selected (autoclave process). Special attention must be given on ingress / egress points as well as the definition of appropriate interfaces (connectors) to the testing equipment
- Definition / selection of appropriate testing plan (static & fatigue loading scheme), representative of typical fuselage panels loading
- Design and fabrication of associated test rigs / jigs / tools / necessary for the correct application of loading in the panels.
- Testing of panels (destructive and non destructive)

All the panels will be manufactured by HAI. Non destructive inspection (Ultrasonic C-Scan) of the panels will be applied after manufacturing, in all panels by HAI, so as to access the manufacturing process / quality of the panels.

The contractor is responsible for the application of impact damage on selected critical locations of the panel. The damage definition / location and means of application will be decided by HAI, in cooperation with the contractor.

The contractor is responsible for non destructive inspection (Ultrasonic B & C-Scan) of the panels after the application of impact damage, so as to access the damage induced (size / location).

The contractor is responsible for the preparation of the set up arrangements (test machine and associated data acquisition equipment, mounting and adjustment of the panels test setup, definition and necessary preparation of sensor connections / setup to the data acquisition devices). The loading scheme (static & fatigue) will be decided by HAI in cooperation with the contractor.

The number, type and locations of sensors to be integrated in the structure will be decided by HAI, in cooperation with the contractor.

The contractor is responsible for non destructive inspection (Ultrasonic B & C-Scan) of the panels after each test (at selected intervals which will be defined in the loading scheme), so as to access the integrity of the panels (damage accumulation / propagation) throughout the entire loading scheme.

The contractor is responsible for the test execution / data acquisition, analysis and reporting.

- Sensor output must be recorded at appropriate rates during the whole duration of the testing scheme and from all sensors placed on the panels simultaneously.
- Analysis of the acquired data and results representation in a format useful for the assessment of the mechanical performance of the panels (i.e. load vs strain, load vs displacement data)

## 2. Special skills, certification or equipment expected from the applicant

The contractor's laboratory that will undertake all testing activities should be organised according to ISO 9001 and be equipped with the appropriate certified Mechanical Testing Equipment.

Appropriate equipment must be available in terms of physical size / loading capacity / monitoring / acquisition capabilities of data, for the execution of the test plan (static & fatigue compression tests as described above). This should take into account:

- size of the panel
- anticipated strength of the panel
- data acquisition devices and associated software for simultaneous recording of data from a min. number (TBD by HAI in cooperation with the contractor) of sensors (FOBGs / SGs)

Experience in testing of structures with embedded FOBGs and SGs and the preparation of appropriate connections of sensors (FOBGs & SGs) to the data acquisition and data logging equipment

Experience in destructive testing (static & fatigue) on large scale components

Experience in non destructive testing (Ultrasonic B & C-Scan)

Expert knowledge in CFRP components

Certified / calibrated equipment for assuring accuracy of measurments

## 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| CfP 1.3.7-01 | Sensors integration in structure | Definition of methodology for the integration of sensors in the structure | T0+1 |
| CfP 1.3.7-02 | Test plan definition | Definition of test plan according to the requirements set | T0+2 |
| CfP 1.3.7-03 | Test rig design and fabrication | Design and fabrication of appropriate test rigs / jigs / tools / necessary for the correct application of loading in the panels | T0+2 |
| CfP 1.3.7-04 | Impact damage application on panels and associated NDT | Definition of impact damage and application of damage on panels. Non destructive inspection of "impacted" panels | T0+3 |
| CfP 1.3.7-05 | Test plan execution | Test plan execution (destructive and non destructive tests) and associated test data acquisition from sensors / testing equipment | T0+4 |
| CfP 1.3.7-06 | Analysis and reporting of test results | Analysis and reporting of results from testing in a format suitable for assessing the mechanical performance of the panels. | T0+5 |

## 4. Topic value (€)

Budget: The Maximum Allowed Topic Budget is

**100.000,00 €**

[One hundred thousand Euro]

The maximum funding value is between 50% and 75% of the Maximum Allowed Topic Budget indicated above according to the CfP rules.

Please note that VAT is not applicable in the frame of the CleanSky programme

## 5. Remarks

During the period allocated for the CfP, it is possible that additional information / requirements are given to the contractor. The contractor shall therefore adjust accordingly and embody the given information / requirements, prior to delivery of final product.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-GRA-01-037 | Advanced fuselage and wing structure based on innovative Al-Li alloy – Numerical trade off study and experimental stiffened panel validation. | End date | $T_0 + 10$ |
| | | Start date | $T_0$ |

## 1. Topic Description

**1.1 – Scope of work**

The work is focused on the identification of innovative metallic material Al-Li alloy and the development of Laser Beam Welding process most suitable for fuselage and wing applications.

Three fuselage and three wing innovative Al-Li alloy flat large stiffened panels shall be designed, manufactured and tested in order to validate the applied process.

**1.2 – Reference documents**

Related ISO / EN standards

**1.3 – Introduction**

Aluminum-lithium alloys are increasingly important materials for light weight high stiffness applications such as aerospace components. In the last years, these kind of alloys have shown possibilities of density reduction and mechanical properties improvement.

**1.3.1 – Background**

Al-Li alloy represents a fairly new class of aluminium alloy which provides not only density weight saving but also many property benefits such as excellent corrosion resistence, good spectrum fatigue crack growth performance, a good strength and toughness combination, increased elastic modulus and compatibility with standard manufacturing technique. This results in well balanced, light weight aluminium alloy.

**1.3.2 – Interfaces to ITD**

A kick-off meeting will be held at the beginning of the project object of this call in order to (i) supply the documentation about the activities performed at that time, (ii) supply the needed input data, (iii) decide how to manage the data exchange during the project.

**1.4 - Activity Description**

The specific objectives of this Topic would include the following WP's:

**WP 1: Identification of innovative metallic materials Al lithium alloy most suitable for fuselage and wing applications**

In order to achieve the objective of weight reduction respect to the reference configuration, a preliminary ranking of different innovative metallic materials for both fuselage (crown and bottom stiffened panels) and wing (upper and lower stiffened panels) applications shall be performed based on requirements provided.

Evaluation will be carried out with reference to the conventional all-riveted today metallic structure. The activity shall be addressed to different items as well as skin, stringer, frame or rib of the flat large stiffened panel.

**WP 2: Development of innovative Laser Beam Welding process most suitable for fuselage and wing applications**

Innovative Laser Beam Welding process most suitable for fuselage and wing applications shall be developed. An evaluation of innovative different processes shall be performed for metallic stringer-frame-skin assembly.

In particular shall be studied:

• Development and welding of load-adapted stringer and frame configurations for a fully laser welded integral structure

• Design proposals for laser weldable integral knots (stringer-frame-skin-joint)

• Developing the manufacturing and laser welding parameters in order to optimise the joint characteristics and to produce point allowable for a preliminary configuration study / analysis.

Post welding heat treatment will be optimised in order to reduce the distortions and increase mechanical properties of the welded joint.

**WP 3: Ranking of most interesting materials and relative process solutions**

A ranking of most interesting materials and relative processes solutions for fuselage and wing by means of preliminary numerical activities and small components manufacturing (mono-stringer) shall be performed.

This WP shall include a choice of appropriate materials and assembling processes for the given load case provided.

**WP 4: LBW Flat large stiffened panels (fuselage and wing) preliminary design**

A preliminary design of flat large stiffened panels representative of fuselage and wing shall be provided in order to identify the preliminary panel geometry (thicknesses, stringer pitch, frame pitch, ..). The flat large panel will be conceived at different level in order to have the different weight and configuration of the stringer ( no rivet, no sealant, “L” geometry)

**WP 5: LBW Flat large stiffened panels (fuselage and wing) design**

FE models of sized flat stiffened panels representative of both fuselage (bottom and crown) and wing (upper and lower) to be manufactured and tested shall be provided.

The drawings of panels shall be also provided.

**WP 6: Flat large stiffened panels manufacturing**

**- Task 6.1: Fuselage flat large stiffened panels manufacturing**

Skin, stringers, frames of the three flat large stiffened panels (about 900 x 1650 $mm^2$; at least 5 stringers and 3 frames) shall be manufactured and assembled for tests to be performed in WP 7. The panels will be made considering the above analysis and using the best parameters found. The result should also consider the tooling and of the type of laser used.

**- Task 6.2: Wing flat large stiffened panels manufacturing**

Skin, stringers, ribs of the three flat large stiffened panels (about 900 x 600 $mm^2$; at least 3 stringers and 2 ribs) shall be manufactured and assembled for tests to be performed in WP 7. The panels will be made considering the above analysis and using the best parameters found. The results should also consider the tooling and the type of laser used.

**WP 7: Experimental validation**

The following test shall be carried out by the contractor on each panel manufactured:

- Test on fuselage LBW flat large stiffened panels:
  - Compression static test (bottom);
  - Impact + Residual strength (bottom);
  - Crack growth propagation (crown).
- Test on wing LBW flat large stiffened panels:
  - Compression static test (upper);
  - Impact + Residual strength (upper);
  - Crack growth propagation (lower).

A results analysis and an experimental – numerical correlation of results shall be performed.

## 2. Special skills, certification or equipment expected from the applicant

The applicant shall have a proven ability in the production of aerospace innovative Al Lithium alloy having high performance and all the relevant production and lab equipment needed for the complete characterization of the materials.

## 3. Major deliverables and schedule

| Deliverable | Title | Description<br>(if applicable) | Due date |
|---|---|---|---|
| Del.1 | Innovative metallic materials for fuselage and wing applications | Within this technical report, the identification of the Al-Li alloys suitable for fuselage and wing panels. shall be provided. | T0+1 |
| Del.2 | Laser Beam Welding process for fuselage and wing applications | Within this technical report,<br>full details on the Laser Beam Welding process shall be provided. | T0+3 |
| Del.3 | Ranking of most interesting materials and relative process solutions | Within this technical report, the ranking of most interesting materials and relative process solutions shall be provided (type of process, process parameters, critical aspects, quality concerns, etc.). | T0+4 |
| Del.4 | LBW flat large stiffened panels (fuselage and wing) preliminary design | Within this technical report, the preliminary design on the design of the fuselage and wing LBW stiffened panels shall be provided. | T0+5 |
| Del.5 | LBW Flat large stiffened Panels (fuselage and wing) design | The deliverable consists of:<br>• technical report (full details on the design of the fuselage and wing LBW stiffened panels);<br>• related FEM<br>• related drawings. | T0+6 |
| Del.6 | Flat large stiffened Panels (fuselage and wing) manufactured | The deliverable consists of:<br>• technical report (full details on the production of the fuselage and wing LBW stiffened panels): type of process, process parameters, critical aspects, quality concerns, etc.<br>• six LBW panels: three for fuselage and three for wing. | T0+9 |
| Del.7 | Experimental validation and correlation report | Within this technical report, the results of the experimental validation performed on six panels shall be reported and critically discussed. | T0+10 |

## 4. Topic value (€)

Budget: The Maximum Allowed Topic Budget is

**450.000,00 €**

[Four hundred fifty thousand Euro]

The maximum funding value is between 50% and 75% of the Maximum Allowed Topic Budget indicated above according to the CfP rules.

Please note that VAT is not applicable in the frame of the CleanSky programme

## 5. Remarks

During the period allocated for the CfP, additional information / requirements as well as the reference configuration of flat large stiffened panels representative of both fuselage (crown & bottom) and wing (upper & lower) shall be provided by identifying materials, architecture, loads and design criteria in a joint preliminary phase with the GRA ITD member that has launched the CfP.

The contractor shall therefore adjust accordingly and embody the given information / requirements, prior to delivery of final product.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-GRA-02-015 | Advanced concepts for trailing edge morphing wings - Design and manufacturing of test rig and test samples - Test execution | **Start date** | $T_0$ |
| | | **End date** | $T_0$+5** |

## 1. Topic Description

**Acronyms**

*DESA: Deeply Embedded Smart Actuators*

*HW: Hardware*

*RP: Report*

*SACM: Smart Actuated Compliant Mechanism*

*SMA: Shape Memory Alloy*

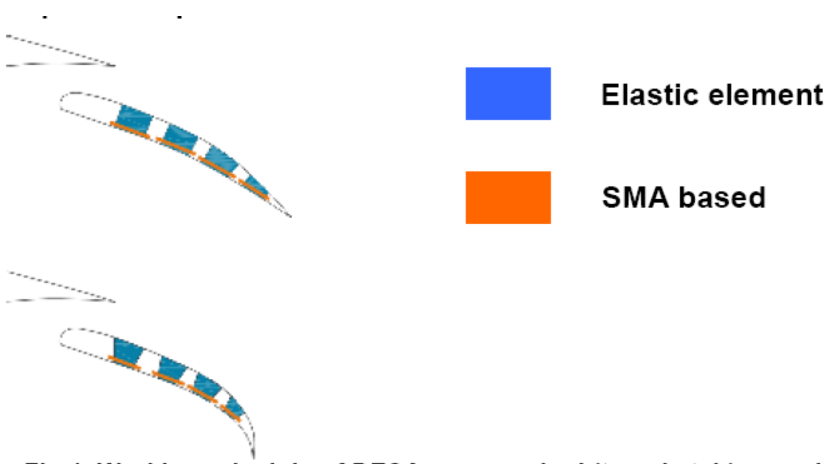



**Fig.1. Working principle of DESA: no morphed (top sketch), morphed (bottom sketch) extended flap.**

**Short description**

The Deeply Embedded Smart Actuators (DESA) is an actuation architecture aimed at producing camber variations of a movable flap, thus increasing airfoil performance wit respect to specific requirements.

The architecture (shown in Fig.1) is constituted by elastic elements connected in serial way along the flap chord. The edges of these elements are linked by SMA based actuators. Contraction of SMA (by Joule effect) causes chamber variations. When SMA is cooled, the structure elastically reverses to its original shape. SMAs and elastic components are also “load-bearing” elements. SMAs have to be pre-loaded to accomplish their working ability.

SACM (Smart Actuated Compliant Mechanism) is another architecture aimed at the same target, but implementing a different concept. SACM uses SMA based actuators. SACM architecture will be designed and manufactured by Airgreen

This “smartflap” was conceived to be integrated within a regional aircraft.

<u>The Applicant will be required to</u>:

1. Manufacture DESA prototype
2. Manufacture a test rig for DESA and SACM characterisation
3. Characterise both statically and dynamically SACM and DESA prototypes

## 1.1 Introduction

### 1.1.1 Background

This activity is foreseen within GRA LNC WP2.2.1.3, "HLD low-noise advanced concepts".

**A preliminary design of DESA architecture will be provided**.

In addition, **the preliminary design of SACM and related prototype will be provided** in order to allow a proper design of test rig and to perform the characterisation of both DESA and SACM.

The following INPUT will be provided for DESA architecture:

- Global *information* on the prototype:
- Requirements on internal elastic elements:
- Specifications on SMA elements:
- Specifications on the skin:

The following INPUT will be provided for SACM architecture (The manufacturing of SACM prototype is not part of this contract):

- Detailed sketch of the architecture
- The prototype itself.

The following INPUT will be provided for the interfaces:

- Requirements for DESA-test rig interfaces
- Requirements for SACM-test rig interfaces
- Requirements for DESA components interfaces
- Requirements for test rig interfaces

The following INPUT will be provided for the test rig:

- Global requirements for the test rig
- Test plan requirements

The document containing this information will represent the input of this CfP.

The proposed work is aiming to the realisation of DESA lab demonstrator and the execution of related experimental tests on both DESA and SACM, contributing either to validate numerical predictions and to highlighting eventual deviations.

## 1.2 Reference documents

Not Applicable

## 1.3 Scope of work

The objectives of the CfP are:

- Manufacture DESA prototype
- Manufacture a test rig for DESA and SACM characterisation
- Characterise both statically and dynamically SACM and DESA prototypes;

Remark: Topic Manager will guarantee its support (i.e. provision of power supplier for SMA activation) and supervision during critical phases (i.e. SMA integration)

The following activities will be performed:

1) a FE model of DESA prototype shall be realised and on the base of achieved results executive drawing shall be realised.
2) a DESA prototype will be realised on the base of the executive drawings specifications and of a tailored manufacturing procedure; the applicant is requested to provide an evaluation of the full scale system (object of the present call) in terms of: overall weight, needed actuation power, safety levels on-board (also pointing out at the most relevant parameters affecting safety levels).

3) a suitable test rig shall be designed and assembled to assure the characterisation of SACM and DESA demonstrators and the validation of numerical schemes used during design phase.

4) a detailed test plan will be filled in

5) a test campaign will be performed on DESA and SACM; obtained data will be used as reference for validating numerical predictions and for estimating prototype real performance for several load conditions.

**1.4 Type of work**

**Task1:** Advanced (executive design) design of DESA architecture (see Fig.1), providing all manufacturing aspects (material choice, interface problem among the several components, and so on); this task will be performed through the realisation of a suitable FE model of the DESA prototype and the output will be the executive drawings, considered as reference for subsequent manufacturing task.

**Task2:** A dedicated test rig and related interface component will be designed and assembled; this test rig, shown in Fig.2, will allow the testing under several operative conditions (loads for several mission phases like take-off / landing, cruise), defined in the test plan.

**Task3:** On the base of the DESA executive drawings, the manufacturing of DESA prototype will be performed. A functionality test will be carried out.; during this phase, also the pre-compression status of the springs will be set.

**Task4:** DESA and SACM architectures will be integrated on the test rig and the experimental characterisation under static loads and dynamic excitation will be performed. The SACM architecture will be delivered by the TM with the same DESA interface, thus allowing for its integration within the test rig.

Remark: Topic Manager will support SMA activation system set-up (i.e. provision of power supply) and will supervise critical phases (i.e. SMA integration, sensor installation, …).

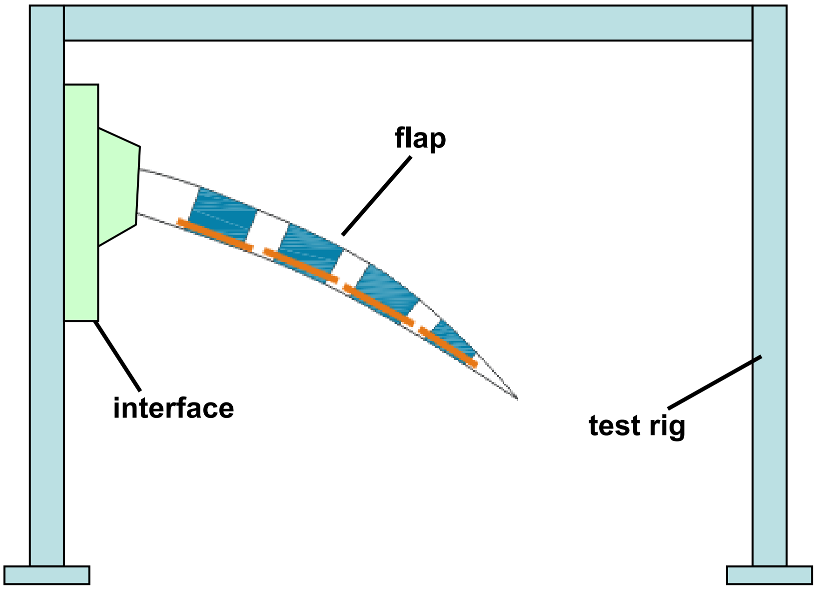



**Fig.2. Test rig and interface.**

**1.5 Requirements**

The following requirements will be provided as input when starting the project

- Requirements on internal elastic elements:
  1. number of springs: along the chord (up to 4 unities) and the span (up to 4 unities), (provisional info)
  2. dimensions and weight of each spring
  3. bending and/or torsion stiffness
  4. location within the architecture
  5. estimate of loads acting on each spring

- Specifications on SMA elements:
  1. number
  2. dimensions
  3. material characteristics
     - 3.1. alloy
     - 3.2. Austenite/Martensite Young moduli
     - 3.3. transformation temperatures
     - 3.4. recovery strain
     - 3.5. pre-load
- Specifications on the skin:
  1. type of material
  2. thickness
- General requirements for the system:
- Requirements for DESA-test rig interfaces:
  1. dimensions of the interface for static tests
  2. dimensions of the interface for dynamic tests
- Requirements for SACM-test rig interfaces:
  1. dimensions of the interface for static tests
  2. dimensions of the interface for dynamic tests
- Requirements for DESA components interfaces:
  1. characteristics of the connection between spring elements and surrounding DESA structure
  2. locations and connection features of SMA with springs
  3. connection features between skin and internal structure
  4. Topic Manager will give support for SMA integration tasks
  5. Topic Manager will provide SMA activation electronics (power supply)
- Requirements for test rig interfaces:
  1. ground connections

- Global requirements for the test rig:
  1. external loads
  2. SACM and DESA prototype weights
  3. SACM and DESA interfaces weights
  4. maximum dimensions
  5. accessibility necessity (truss type structure)
- Test plan requirements:
  1. static tests:
     - 1.1. prototypes morphing without external loads
     - 1.2. prototypes morphing with external loads
  2. dynamic tests:
     - 2.1. prototypes modal analysis with and without external loads
     - 2.2. prototypes forced response with and without external loads

The document containing this information will represent the input of this CfP.

**1.6 Other**
Not Applicable

## 1.7 Milestones:

| Milestone | Description (if applicable) | Due date** |
|---|---|---|
| M1 | DESA architecture advanced design ready for manufacture | T0+2 |
| M2 | DESA prototype manufactured | T0+4 |
| M3 | Test rig design ready for manufacture | T0+2 |
| M4 | Test rig manufactured | T0+4 |
| M5 | SACM and DESA eexperimental results available | T0+5 |

## 2. Special skills, certification or equipment expected from the applicant

Background in:

- Mechanical design, FE modelling
- SMA expertise
- CAD
- Static and dynamic experimental characterisation of lab structural prototypes;
- Measurements of displacement, strain, loads, Eigen-frequencies and Eigen-modes

## 3. Deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date** |
|---|---|---|---|
| D1 | RP: executive drawings of DESA lab demonstrator | A document describing and containing the executive drawings of DESA demonstrator, produced in task T1 | T0+2 |
| D2 | HW: DESA prototype | This prototype is the output of task T3 | T0+4 |
| D3 | RP: Test rig executive drawings | A document describing and containing the executive drawings of test rig, produced in task T2 | T0+2 |
| D4 | HW: Test rig available for test | This test rig is the output of task T2 | T0+4 |
| D5 | RP: SACM and DESA experimental results | A document describing and containing the experimental results produced in task T4 | T0+5 |
| D6 | HW: DESA prototype and test rig | Mentioned prototype and test rig will be delivered to the proposer | Close of the Project |

## 4. Topic value (€)

Budget: The Maximum Allowed Topic Budget is

**210.000,00 €**

[Two hundred and ten thousand Euro]

The maximum funding value is between 50% and 75% of the Maximum Allowed Topic Budget indicated above according to the CfP rules.

Please note that VAT is not applicable in the frame of the CleanSky programme

## 5. Remarks

Not Applicable

## Topic sheet

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-GRA-02-016 | **Novel dressings for Nose Landing Gear noise impact reduction** | Start date | *T0**(Indicative : July/2011)* |
| | | End date | *T0 +14* |

## 1. Topic Description

***1.1 Short description of scope of work***

Retracted nose landing gears are one of the major contributors to A/C noise in takeoff and approach.

The topic of the present call for proposal is the development of noise influencing nose landing gear NLG parts. The approach would be semi-empirical by application of add-on elements to the NLG assembly (for those mechanical parts from the main attachments downwards). These elements can be proposed as non-damaging removable dressings to the assy w/o qualified fixture, bondage since in the pratical experiment mechanical qualification is not a main consideration. Their effect would be acoustically characterised in a special WTT setup done by the GRA member in co-operation with the partner.

The best add-on element should be further designed and theoretically investigated for a later integration vision.

This including ideas on manufacturing and analysis of maintenance, study towards non-conflict of installation to kinematics and general operations taken into account.

One would also analyse issues impacting safety, especially to avoid loss of parts, say by forced displacements or assumed special loads.

***1.2 Abbreviations and Definitions***

*A/C* *Aircraft*
*CfP* *Call for proposal*
*GA* *Grant agreement*
*NLG* *Nose landing gear*
*WTT* *Wind tunnel test*
*Assy* *Assembly*

**1.3 Type of work**

The organization of work consists of the following required tasks:

T1: The successful applicant has to make available a NLG including wheels representative in size and type for regional A/C or least similar assembly principal.

T2: Cooperative selection of promising and feasible NLG elements for noise reduction; providing the additional mounting structures accordingly for the WTT environment.

T3: Design of additional NLG elements and mounting structures, feasible for usage in defined WTT (the member facility) and promising for later enhancement for usage in-flight tests; The design should nevertheless allow a fast and easy attachment and detachment of the additional parts

T4: Manufacturing and cooperative installation of the parts designed in T3 for WTT

T5: Support to down-selection of the add-on element, provide general strength and weakness assessment complementarily to the acoustic analysis performed by GRA member

T6: The most promising add-on element shall be further designed and theoretically investigated for a later integration vision.

**1.4 Requirements**

Some sensitive information may be released only at a later date to the successful applicants. Other Requirements as noted in section two. In case of special tooling needed for attachment and detachment of the additional parts, support for the following WTT is requested. Information for actuation and handling of provided NLG in WTT environment are not mandatory but would be appreciated

**1.5 Other**

Not applicable

**1.6 Schedule, milestones and deliverables**

T0 Kick-off meeting, delivery definition of NLG

T0+4 Progress meeting 1 and report A1: preliminary mechanical design of noise reducing additional NLG elements

Report A2: interface document for mounting and handling of NLG including matters under section 1.5

T0+5 Delivery of NLG assembly to be used, co-operative installation of the NLG into the WTT environment.

T0+7 Progress meeting 2 and report B: improved design and mounting structures for attachment of the additional parts to the NLG

T0+8 Delivery and support to mounting of noise reduction elements and mounting structures

T0+10 Analysis and co-down selection of most promising solutions to then be further theoretically analysed

T0+14: Final meeting and integration vision report

## 2. Special skills, certification or equipment expected from the applicant

Should evidence certificates of quality and exemplary performed research and or practical development/ integration.

## 3. Major deliverables/Milestones and schedule

| Deliverable | Title | Description (if applicable) | Due date** |
|---|---|---|---|
| D1 | Report | Main technical characteristics of the NLG under examination | T0 + 1 |
| D2 | Report A | Short intermediate report in two part ref. description under T0+4 schedule | T0 + 4 |
| D3 | Hardware delivery | Delivery of NLG assembly to be used. | T0 + 5 |
| D4 | Report B | Short intermediate report on improved design and manufacturing technology of the mounting structures | T0 + 7 |
| D5 | Hardware delivery | Delivery of noise reduction elements and mounting structures | T0 + 8 |
| D6, M1 | Final Report 1 | Report on the analysed and co-down-selected most promising solutions | T0 + 10 |
| D7, M2 | Final Report 2 | Final integration vision report. | T0 +14 |

## 4. Topic value (€)

| |
|---|
| The total value of this work package shall not exceed:<br>**250,000.--€**<br>[two hundred and fifty thousand Euro]<br><br>Please note that VAT is not applicable in the frame of the CleanSky programme. |

## 5. Remarks

| |
|---|
| *If applicable*<br>*** T0 and duration may be negotiated on the basis of the final JU time slots* |

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-1-GRA-05-006 | Updated Regional traffic scenario to upgrade Requirements for "Future Regional Aircraft". | Start Date | *T0* |
| | | End Date | *T0 + 9months* |

## 1. Topic Description

*Introductory statement.*

In the timeframe of Clean Sky (CS) Joint Technology Initiative (JTI), a market survey project was awarded as result of the first Call for Proposals (CfP) of the Green Regional Aircraft (GRA) Programme.

Such project, lasted 7 months, was to collect and analyse the requirements of future regional aircraft, in view of the near, stricter and 'green' oriented global regulatory framework within which the European Regional Airlines will be required to operate.

The project constituted the first opportunity - in the frame of the GRA Integrated Technology Demonstrator (ITD) - for airlines to be involved in 'shaping' the future green regional aircraft. The results of the project will 'feed' the research efforts of the NC ('New Configurations) domain (within the scope of the GRA ITD) as far as the selection of the most appropriate/viable future regional aircraft configurations, out of those examined.

*The Call for Proposals.*

A further wider market survey is requested to allow upgrading of Top Level Aircraft Requirements, since were not involved in the aforementioned project the regional airlines from geographical areas pregnant with green regional A/C requirements, i.e.:

- ✓ North America, whereas tighten environmental constraints are increasingly dictated by the advanced economical market demand,
- ✓ Africa and the like, whereas soft environmental contraints are driven by the weak market demand,

two areas with opposite perception of the relevant requirements.

Hence and getting by potential conflict of green regional A/C requirements, a Call thick of innovation with respect to the first one has been demanding, whereas Call's innovation worths are:

- ✓ methods of analises,
- ✓ objectives and goals of analises, focusing on environmental and A/C requirements impacts.

The purpose the Call aims to understand the consciouness of operators in the matter of breakthrough technologies in order to reduce environmental impact and translate that in aircraft requirements.

The target of such market research is to foresee the airline/operator requirements related to future operational scenarios (new ATM systems, rules, ICAO emission management rules, maintenance, ground operations, end of life issues, etc.), of paramount importance to regional aircraft and their operators peculiar features.

For this purpose it's requested to perform a survey with the main Regional Airlines, both coming from mature market (North America) and emerging Economies (Africa and the like), making use of innovative and ad hoc tools (e.g. multicriteria technics approach) able to translate the collected information into real technology options to support decision-making during the GRA ITD technology developments.

Furtherly use of survey results will allow a preliminary estimation, from airlines point of view, of future fleet composed of current technology and green-technology aircraft.

The work to be performed by three phases:

WP1

The objective of WP1 is focused on the preparation work for the survey.

The survey is intended to collect key information on airline requirements by interviewing qualified sample of high level executives from Regionall Airlines.

The information to collect is related to issues as the environmental aspects, on-board comfort, airport capability, operative costs structure and basic performance of future "green" regional aircraft. The information will be utilised for multidisciplinary evaluation of the technologies being developed by GRA ITD.

The survey design, its philosophy and the questionnaire preparation, has to be approved by Alenia Aeronautica and it will be based on most recent market researches output to be provided by Alenia.

Starting from GRA ITD green reference aircraft data and assuming a set of possible variations, it should be possible to identify the relevance of several parameters as:

- *Cabin passenger comfort*
- *Performance (Range, Cruise Speed, Rate of Climb,Time to Climb…)*
- *Field Performance (Take Off Field Length, Landing Field Length, Turn Around Time…)*
- *Engine Type (TurboProp, TurboFan, etc…)*
- *Avionics functions*
- *Airport operations*
- *Operating Costs*
- *Maintenance operations and their trends*
- *End of life*
- *Noise level around airport*
- *Pollution.*

WP2

The survey has to be based on the voluntary cooperation of selected Regional airlines.

At least 15 airlines have to be considered (the sample should be well splitted between mature market, at least 8 airlines, and emerging market).

Senior airline managers will be interviewed de visu (at least 5 interviews) or through telecon. The aim of the interviews is to understand their opinions and ideas on the requirements that have an impact on the technology choices for the future Regional Aircraft.

The individual responses from participating airlines will be classified "confidential".

Alenia delegates could attend the survey/interviews.

WP3

The objective of WP3 is the interpretation of the survey findings significance and the presentation of the results by a complete report including all raw data.

The specific evaluation/trade-off models developed in the research must be available to GRA ITD.

## 2. Special skills, certification or equipment expected from the applicant

The applicant must have proved extensive experience in the air travel market research sector and well introduced into airline industry.

The applicant must have conducted similar survey in recent years; it's required an adequate dedicate staff and management capability to assure the objective and schedule of the project.

Past involvment inside European Research Programmes will be appreciated.

Previous published research studies on specialized aeronautic journals are appreciated.

| |
|---|
| The documentation and the reports are to be in English and also available in electronic format (Windows operative system and applicative software). |

### 3. Major deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| WP1 | Survey preparation – Methodology – Collection of airlines profile & contacts | Preparation work for the survey and questionnaire | *T0 + 2 months* |
| WP2 | Survey & Airline reports | Interviews | *T0 + 7 months* |
| WP3 | Assessment work and final report | Interpretation of the significance of the findings of the survey | *T0 + 9 months* |

### 4. Topic value (€)

The Maximum Allowed Topic Budget is

**100.000,00 €**

[One hundred thousand Euro]

The maximum funding value is between 50% and 75% of the Maximum Allowed Topic Budget indicated above according to the CfP rules.

Please note that VAT is not applicable in the frame of the CleanSky programme

### 5. Remarks

None

## Clean Sky - Green Rotorcraft

[redacted]

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-2011-1-GRC-03-006 | *EMA for utility consumer systems:* **EMA for Landing Gear** | **End date** | To +36 months |
| | | **Start date** | To |

## 1. Topic Description

**1. Background:**

The Green Rotorcraft research consortium of Clean Sky invites proposals for the generic study and development of innovative solutions for electrical systems and technologies overall rotorcraft efficiency and reducing (and other undesirable) emissions in the frame of GRC3 program.

The overall aim of this call is to provide the ability to utilise on ground, the electromechanical actuator located inside the landing gear.

The work package GRC3.5.3.1 “EMA for landing gear” aim is to provide an alternative method of manoeuvring helicopter on ground without rotor spinning in aim to reduce to burn large quantities of fuel.

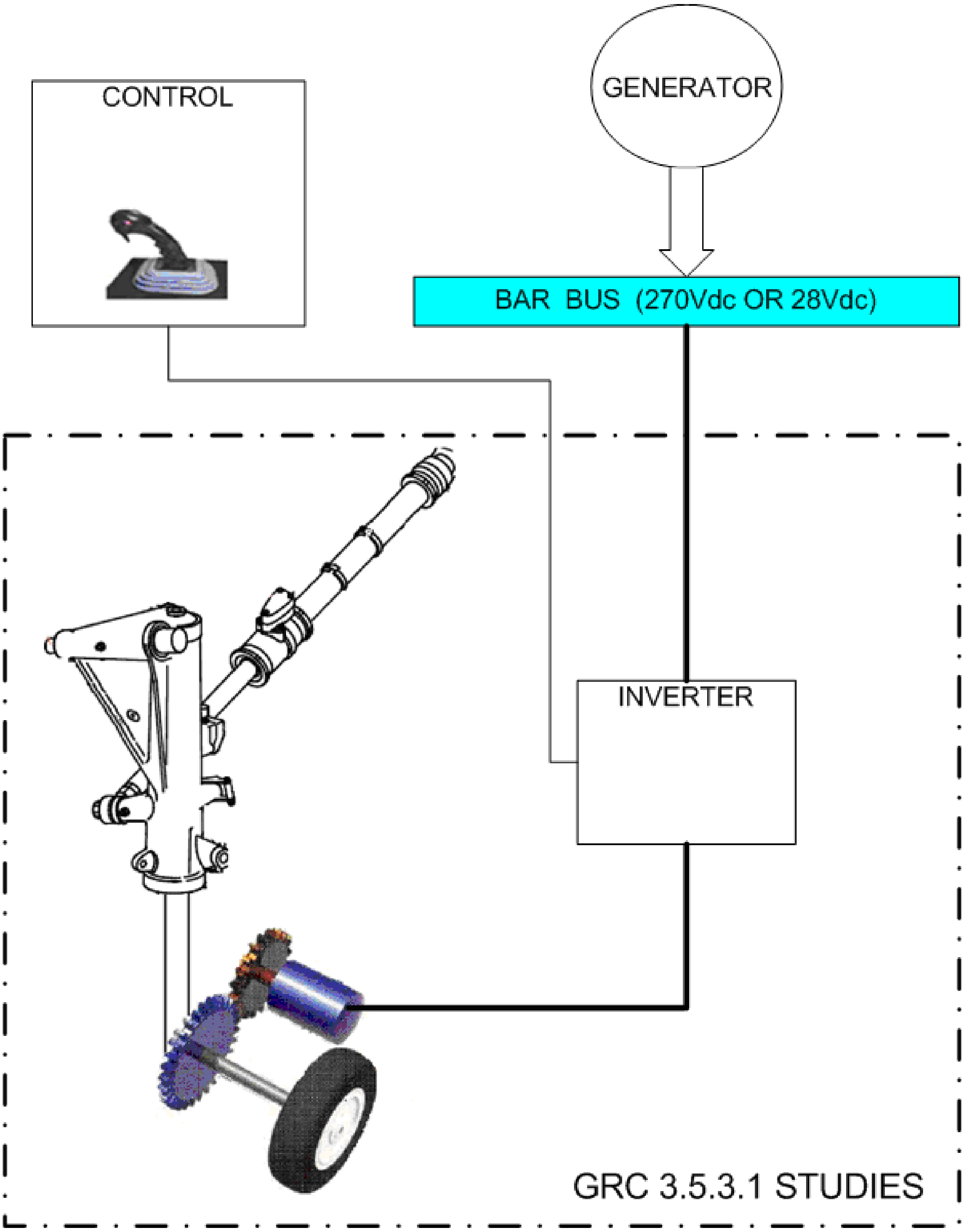
The work package GRC3.5.3.1 “EMA for Landing Gear” (EMALG) focus on:

EMALG Systems that will support the implementation of electrical actuators localised near the landing gear in order to actuate the rim wheel.

Key advantages sought are:

- Find the optimised voltage level for supply the EMALG (28Vdc or 270Vdc) in aim to minimise overall weight system.
- Use of EMALG system allows:
  - Reducing fuel consumption thus CO2 emission,
  - Reducing noise,
  - Reducing wear of mechanical parts,
  - Removing machine for towing aircraft,
  - Increasing mission duration,
  - Improving ground personal safety (rotor not spinning).

General overview of this project :




The boundary of the study represented by dotted line.

Objective:

- Definition of requirements for EMALG system in embedded system,
- Provide study about EMALG with 28Vdc and 270Vdc, in order to determine the feasibility and the "*ecolonomic*" results in accordance with clean sky objectives
- Design and develop EMALG for the system
- Perform tests on EMALG (supplier and airframe manufacturer facilities).

Critical performance and design criteria include system efficiency, power management efficiency, mass and volume.

Technologies will need to be intrinsically safe and minimise the use of hazardous materials or emission of 'greenhouse' gasses such as CO2.

Protections for human security ( 270 Vdc) shall be part of the analysis – design and included in the demonstrator delivery.

The leading specific objectives to be demonstrated will include:
1) EMALG system feasibility,
2) Highlight: energy consumption (mass/cost… in aim to compare with the actual system).

During the negotiation phase, technical's specifications and statement of work will be performed to be part of the contract.

## 2. Scope of work:

**The study will comprise:**

**- FIRST PHASE:**

**Medium aircraft (6 tons),**

**the aim:**

**the partner shall perform a preliminary study where different hypothesis shall be considered for the following parameters:**

**Maximum speed: 20km/h**
**Average speed: 10km/h**
**Acceleration: 0 to 18km/h in 35 s (TBC),**
**Slope: 4%,**
**Maximum time on wheel: 10mn**
**Average distance on wheel: 1.6km**
**Power 270Vdc or/and 28Vdc (one study with only 28Vdc and another one with 270Vdc and 28Vdc)**
**Identification of the technology and topology potential matched to airborne system application**

**The partner will study the performances in parallel to the power needed. The power range is: 5kW to 10kW. During study, airframe manufacturer can modify the range of power available.**

Performance characteristics including environment/installation, and issues in relation to airborne application (Power available function of thermal environment) and to power management efficiency.

These will be identified in accordance to the specification (technologies trade-off study):

Inverter
Characteristic and Technology electrical engine
Engine control

**- SECOND PHASE - Identification of potential solution options – selection of the optimal solution**

These will be developed sufficiently to identify potential physical implementations and to simulate electrical and mechanical behaviour (using SABER software)

For each solution, modelling EMALG system on aircraft and parametric assessment will be developed to include:

* system functional and behavioural SABER models ( electrical, mechanical, thermal….)
* a parametric mass / volume / cost effectiveness model
* system behavioural model including safety flight.
* 3D model (CATIA V5 or compatible))

**Milestone:** Selection by the Topic Manager team of the optimal solution, based on performed preliminary studies and electrical system constraints, to perform a detailed analysis and to manufacture the demonstrator.

**- THIRD PHASE - Optimal solution manufacturing and test**

Development of the solution selected (called Demonstrator) in second part, analysis and comparison with the predicted results.

Tests on Demonstrator:

- Test plan document will be provided to the partner and discussed during the negotiation phase.

The partner shall provide to airframe manufacturer:

- Demonstrator composed of:
    - Electrical motor and gear box associated,
    - Inverter,
    - Laboratory control system,
    - Wheel (wheel delivery will be discussed during the negotiation phase).
- Test tool,
- Load test rig.

**- FOURTH PHASE – Study with extrapolation**

At the end of the project the partner shall perform a study where different results of the first second and third phases shall be considered and an extrapolation related to **Heavy aircraft (10 tons) with the same parameters shall be made.**

## 2. Special skills, certification or equipment expected from the applicant

The applicant shall have experience in electrical actuators, mechanical system, and possibly in aeronautics applications (please provide details)

The applicant should be able to cover the complete process chain from the study of various solutions to the manufacturing of the selected one.

The applicant should have the industrial capacity to exploit the demonstration results – i.e. to further develop, optimise, support the evalutation tests and customers on a sustainable basis, and extrapolations , …

The applicant should be able to demonstrate capability and experience in electromechanical actuator system.

The applicant must be able to use and support specific performance modelling associated with power management, electromechanical actuator systems and efficiency (*via SABER ).*

The applicant shall be able to cover the complete process chain for the manufacturing, this includes the specification analysis, technology choice for the different components, design, manufacturing, and validation of prototype bench in relevant configuration.

The applicant should have the industrial capacity to develop, optimise and produce EMA system under commercial conditions and support the customers on a sustainable basis.

### 3. Major deliverables and schedule

**The table below highlights the major deliverables from Supplier to airframe manufacturer:**

| Deliverable | Title | Short Description (if applicable) | Due date (month) |
|---|---|---|---|
| 1 | Requirement analysis<br>(in order to freeze detailed specification) | Review of requirements defined in System Specification and SOW: EMA for Landing gear specification<br>( KOM development Minute of Meeting) | *Begin of July 2011* |
| 2 | Preliminary study for : | preliminary study to determine the EMA technology design concept and architecture for the EMA system presenting the best performance according to the requirement specification | *Begin of December 2011* |
| 3 | List of possible solutions | Report on the possible solutions including:<br>- electrical motors<br>- gears-box<br>- power electronics<br>- control | *Begin of December 2011* |
| 4 | SABER Models | Functional models* → high level | *March 2012* |
| 5 | Detailed analysis or technology implementation and performance. | Delivery of the detailed analysis including the behavioural simulation of the intended solution | *Begin of June 2012* |
| 6 | SABER Models | Behavioural models** → low level | *July 2012* |
| 7 | Demonstrator and individual test results | Delivery of physical and functional demonstrator and of the individual tests results with the update of the simulation models | *End of May 2013* |
| 8 | Results synthesis delivered | Synthesis of test results | *Begin of October 2013* |
| 9 | Study synthesis delivered whit high weight A/C extrapolation | Study and test results extrapolation | *Begin of October 2013* |

Note: this list is the minimum deliverables to be provided;

**The complete deliverable list will be defined during the negotiation phase**

* Functional models are representative of steady-state power consumptions and transient behaviour (inrush current, consumption dynamics with regards to input voltage transients...). Such models do not include switching. Functional models are energetic models, less complex than behavioural models and typically based on the transfer function representation. Each model shall be representative of the associated actual AC or DC system in terms of:

- Steady-state energy transfer in operational and maximum power consumption;
- Dynamic energy transfer (including power-up phases);
- Protective functions.

** Behavioural models are detailed functional models. They are representative of actual dynamic waveforms: same representativeness as the functional models ones + full representativeness of the waveforms (switching, HF rejections…). Models of all electrical network elementary bricks shall be representative of the actual systems in terms of:

- Steady-state current/voltage waveforms in operational and maximum power consumption;

## 4. Topic value (€)

| |
|---|
| The total anticipated eligible cost of the proposal including manpower, travel costs, consumables, equipment, other direct costs, indirect costs, and subcontracting shall not exceed:<br>**€ 1 000 000**<br>[one million euro]<br>(VAT not applicable) |

## 5. Remarks

- It is expected that the Applicant describes the current technical solution capability and availability that he is aware of and provides some key factors (for a correct technical evaluation).

- All core RTD activities have to be performed by the Applicant. If some subcontracting is included in the proposal, it can only concern external support services for assistance with minor tasks.

The proposal must :

- indicate the tasks to be subcontracted ;
- duly justify the recourse to each subcontract ;
- provide an estimation of the costs for each subcontract.

*(concerning subcontracting, see provisions of the Grant Agreement Annex II.7)*

- if necessary , a consortium can be organize to answer the perimeter of the CFP . In this case, a description of the responsabilities of the participants shall be detailled

*The proposal length should be about 50 pages and include details of the Applicant skills, potential solutions, Work description ( work packages & deliveries) , planning ( main milestones), risks , management of the project , human resources and budget .*

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-01-GRC-03-007 | **Innovative Dynamic Rotor Brake** | Start Date | To |
| | | End Date | To+ 27M |

## 1. Topic Description

### Background:

A primary objective under Clean Sky's Green Rotor Craft ITD is the removal of hydraulics from all Rotorcraft systems. Most current Rotor Braking systems employ hydraulic devices and therefore a new, all electric common solution is sought.

A second objective is to reduce through life emissions and fuel consumption. Typically current Rotor Brake systems use a hydraulic powered disk brake and calliper assembly to dissipate the kinetic energy associated with the main and tail rotor assembly. The current technique dissipates that energy as waste heat which implies a significant loss of energy during the braking process.

This program therefore aims to exploit electrical technologies for an all electric solution that can also recover and use a significant part of that lost energy.

This CfP programme comprises work supporting the analysis, modelling, design, manufacture, test and demonstration of the new system.

The program will be carried out in close collaboration throughout with a leading airframe manufacturer.

Recognising the wide range of activity in regenerative electrical braking system developments, proposals which exploit solutions in other vehicle applications are welcome. However the activity in this study must be developed and applied to helicopter airborne systems and provide demonstrable solutions that include airborne safety considerations.

### Scope of work:

The proposal will support the following work program:-

- Preliminary study to determine potential design options (including modelling and simulation)
- Design and size a machine and system to slow down, stop and hold the Main and Tail Rotor
- Develop a power management process and associated devices and interfaces
- Design and provide a passive load dissipation mechanism as in WP2
- Develop and supply all required system interfaces
- Perform system integrity and failure mode analysis
- Design and manufacture a demonstration prototype test rig for demonstration & performance validation
- Manufacture and deliver a working prototype
- Support and maintain the the prototype through the validation and Clean Sky common test bench program to T+27

More details on all tasks can be found in the following sections.

The total work of this Call for Proposal can be split into six primary topic packages:-

1. Rotor Deceleration system,
2. Electrical Power Conditioning,
3. Rotor Stop and Hold,
4. Aircraft installation configuration,

5. Safety and Certification factors.
6. Prototyping & Test

The work will include an **initial study to determine potential design options,** and **modelling** capable of predicting the efficiency, behavioural and thermal characteristics of the proposed braking system options to allow for the selection of the preferable arrangement, sizing, operating modes and other conditions. The options will then be reviewed, assessed and refined in terms of energy recovery efficiency and braking performance at a Preliminary Design Review stage which will determine the options for the demonstration solution to be implemented.

The system must be optimised to achieve the highest efficiency with the minimum penalty on mass and volume. The main energy flow design aim is to **convert the Kinetic Energy of the Main and tail Rotor into electrical form** for recovery via the main aircraft power distribution network. The electrical Power Distribution Networks are to operate at **High Voltage Direct Current** of **270 VDC** or **540 VDC** (540v may be considered as derived from +/-270Vdc if necessary). If not compatible with both operating voltages the system must at least be scalable to match either voltage regime.

The preferred solution will be developed into a technology demonstration architecture design targeted for demonstration at **Technology Readiness level (TRL) 6**.

**WP.1 – Rotor Deceleration system**

The Rotor Deceleration mechanism work package will be selecting, **designing/modifying and sizing a machine to stop the high inertia corresponding to the Main and Tail Rotors rotating freely from an initial speed.** This operation must be performed without exceeding a specific deceleration rate or applying a Braking Torque (values provided in **Error! Reference source not found.**) that could cause damage to this or other drive train system and airframe components.

It is expected that the proposed system will utilise similar rotating power conversion device designs as in current electrical machines installed on the aircrafts (Generators, Starter-generators, etc). An intermediate kinetic, compressed air or other storage stage may be acceptable; however to be viable this solution must provide significant advantages on areas such as system mass, volume, integrity, or energy transfer efficiency when compared to a "fully-electric" solution. Therefore detailed quantitative justification and reasoning must be provided for the inclusion of an intermediate stage to be considered.

The selection of all machines and associated devices (electrical or mechanical) must be supported by appropriate trade-off studies, including system mass and volume analysis, CAE optimization process, as well as a preliminary system safety analysis. The proposed overall system solution shall include status and diagnostic data, and ideally be maintenance free.

| System Characteristics | Data |
|---|---|
| Gear Ratio between brake and Main Rotor Shaft | 20:1 |
| Nominal rated speed at RB shaft (100% RPM) | 5000 rpm |
| Kinetic energy to be dissipated during emergency braking | 2000 KJ |
| Natural Deceleration Stopping time (friction and aerodynamic drag only) | 120 seconds |
| Minimum stopping time | 20 seconds |
| Maximum Main rotor shaft deceleration during braking | <28 rad/s$^2$ |
| Maximum braking dynamic torque | 1500 Nm |
| Maximum static Torque at parking | 400 Nm |
| Maximum Torque at quick starting condition | 1150 Nm |

**Table 1 - System Data**

Note: A minimum stop time is provided as a target indication of the potential performance limit boundary under emergency conditions to enable initial understanding of the system performance for proposal response. The actual time to stop period will be determined following analysis and review of design options and performance trade-off advantages. This includes exploiting the natural decay interval allowed before brake application which relates to the amount of recovered energy and total braking time.

**WP.2- Electrical Power Conditioning,**

The Electrical Power Conditioning task includes management of the energy recovered by the machine developed under WP.1. Here, the design intent is to **develop an interface and power management process which will provide the means to efficiently harvest and distribute the energy** between three main possible destinations, the electrical power distribution network, a storage device and a static dissipative load resistance. Static dissipative resistor mode is included for high integrity failure management and must be configured for minimum use including fail safe load shedding purposes or energy spike smoothing as the main intent is to maximise the recovered energy amount.

The study should identify and resolve how peak power flow and retardation to stop time is to be managed. This must include a capability to limit the power or current transfer level into any aircraft bus system.

Provision for excess load management in operation and high integrity failure reversion to support safety factors must be provided. Under this work package and **in addition to the previous machine a reversionary passive load dissipation mechanism is therefore required.**

The energy storage process itself is not in the scope of this call however, the output voltage and current ratings must be controlled to enable its integration within aircraft common regenerative power distribution architecture and to maximise the life-time of all interfacing components. The responder is expected to **propose and describe a basic system interface** which will be further developed together with an Airframe manufacturer and a Storage Systems supplier to achieve maximum efficiency during charging/discharging process of batteries and compatibility with the distribution network.

A **system integrity and failure mode analysis must be performed** in order to identify systems failures and provide system reconfiguration solutions according to those failures.

A particular case which requires critical assessment is in stopping the Rotor within the minimum time (nominally 20 seconds) In addition to managing the power levels to maximise energy recovery this must also cover the case where there is no alternative other than diverting all power flow to a passive dissipation device. This operation must be reliably performed assuming complete aircraft power distribution system failure, potentially using only power derived from the braking process and without causing damage to adjacent systems or interfaces. Hence thermal and behavioural analysis of this application must be modelled and developed. After this event no maintenance procedure shall be required, apart from a system inspection.

The proposed system will interface to the standard aircraft High Voltage Direct Current distribution network and must comply with the requirements for the 270VDC within MIL-STD 704F and an equivalent scaled set of requirements for the 540VDC distribution network.

**WP.3 – Rotor Stop and Hold,**

Once the energy recovery potential has faded (the rotor has reached a low rotation speed) **the main rotor must be stopped and held static for a period of at least 48 hours** while subjected to toque values (caused by wind or other source) up to that specified on **Error! Reference source not found.**. The solution must be achieved with the minimum extra specific components or changes to the devices of WP1 and WP2 and ideally without requiring any further maintenance. This system shall also be free of hydraulic circuits or fluids.

**WP.4 - Aircraft installation configuration,**

The system shall include installation mounting solutions for the primary torque conversion device and associated components that have minimal impact of the airframe structure and existing components, both dynamic and static.

Current rotor braking systems generally use a mechanical friction brake attached to an existing main gearbox rotating coupling such as for the tail rotor drive shaft. To allow its installation in existing design configuration helicopters at low cost and installation impact the new system shall share the same type of coupling and installation demands. However innovative alternative installations and braking mechanisms that offer clear advantages may be proposed in addition to this core requirement.

The mounting of thermal dissipation devices must also consider how temperature is controlled and thermal hazards are contained. Ideally the device will be low loss and hence thermally efficient and no forced air or liquid cooling shall be necessary.

**WP.5 - Safety and Certification**

The development of the system must consider the **prospective aviation certification process** hence, safety requirements must be satisfied by proposed solution options. Considerations on how to prevent engagement of the system during flight must be provided and the solution included in the proposed system architecture. The control and safety logic shall be compliant with a current vehicle application. More details on the interface with the control module will be provided to the successful responder.

The system interfaces are outlined in Figure 1 together with overall component representation and associated work packages.

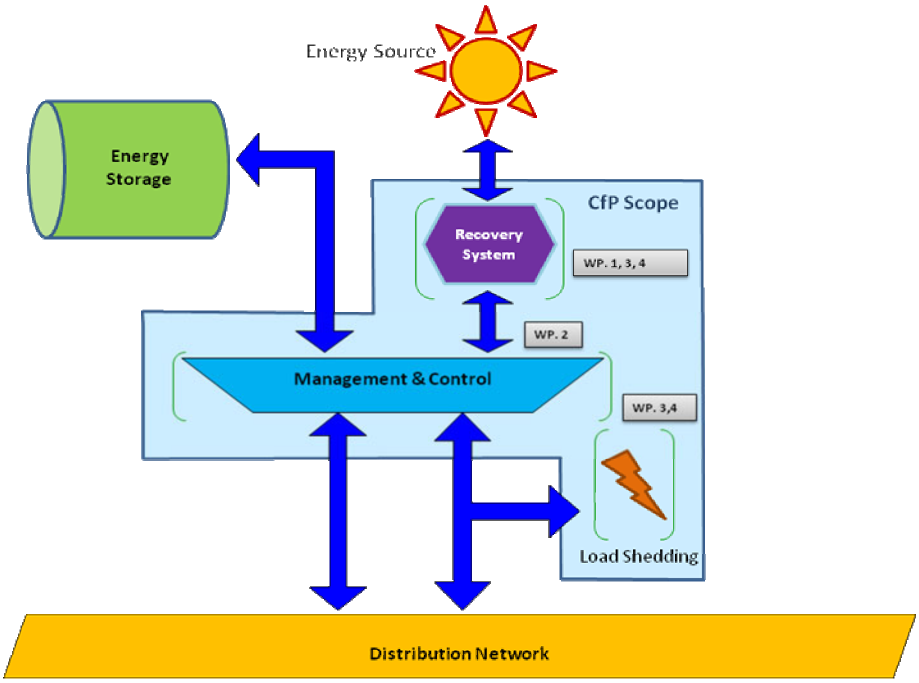



**Figure 1 – Call for Proposal scope representation and work package distribution**

**WP.6 – Prototyping & Test**

The work will culminate with the delivery of a prototype of the system followed by a set of tests to demonstrate and validate the completed system. The responder shall provide support during testing and address any issues or failures to the equipment so to allow for a successful conclusion of the testing schedule. The testing schedule will be addressed initially at the preliminary design review stage and all details agreed by the critical design review meeting. Furthermore it is expected that the responder shall provide for any spare parts that would be required for the successful completion of the test program.

The responder is expected to provide prototype with at least the following components with the capabilities as described above:

1- Rotor Deceleration Machine (Including Stop & Hold device)
2- Electrical power distribution management device
3- Static dissipative load resistance
4- Interfaces between 1,2, 3 and the main distribution network (TBD)
5- System test bench

Monitoring data output and status signals outputs will be further discussed and addressed at a preliminary design review stage.

| **Further Requirements** |
|---|
| Detail capability may be identified and included following the Preliminary Design Review and the design refocused to resolve identified issues and exploit new solution options.<br>Key performance, thermal behaviour and system integration shall be modelled and such models made available to the co-ordinating aircraft manufacturer for overall system modelling.<br>Modelling shall be developed to support flexible configuration options and provide prediction system operation and performance characteristics particularly including the dynamic transient energy flow waveforms during braking and recovery as an aid to design solution and capability assessment. Test and demonstration should be linked to include model and assumptions validation<br>Models shall be based on open standard working files for application on general purpose commercial tools and all modelling shall include a Matlab/Simulink based tool set and file version. Compatibility may be extended to other widely used commercially available tools including Modelica and SABRE where they assist the ability to derive effective solutions. All critical modelling parameters, values, algorithms and outputs relevant to this program shall be described in English language or mathematical form, or graphical representation as appropriate, for information conveyance without the tool.<br>The respondent shall be prepared work with other study programs in related regenerative systems under the Clean Sky program.<br>The overall program shall complete demonstration within 27 months of placement of contract. |

## 2. Special skills certification or expected equipments from applicant

| |
|---|
| Experience should include regenerative power systems and electronic power interface design.<br>High power/mass density, variable speed, dual mode regenerative machines design & manufacture electrical power interface and control components used in the mobility industry and have a proven background in the application and development of such systems both through modelling and prototyping.<br>Dynamic thermal and performance modelling and analysis (Preferably integrated with Matlab/Simulink standard tools)<br>Familiarity and access to Aircraft safety certification standards and analysis such as;<br>MIL-STD-704F, Aircraft electrical power characteristics<br>MIL-E-7016F, Electric Load and Power Source Capacity, Aircraft, Analysis of<br>MIL-HDBK-217F, Reliability prediction for electronic component<br>CS-29, Certification specifications for large rotorcraft |

## 3. Major deliverables and schedule

| Deliverable | Title | Short Description | Due Date |
|---|---|---|---|
| D1 | Preliminary system design options | Description of work, preliminary design proposal including trade-off studies.<br>System design, capability and performance options – document | To+1 M |
| D2 | Trade-offs Final Version | Trade-off Studies final document issue including final design intent | To+6 M |
| D3 | Preliminary System Design and component models | Modifiable models as described in CfP<br>Tool application files and supporting documentation (operation, characteristics, | To+8 M |
| D4 | Preliminary Design Review and associated documentation pack | Preliminary design review and supporting documents.<br>Safety assessment documents (failure modes effects and system reconfiguration)<br>Electrical, thermal EMC and vibrations tests definition | To+10 M |
| D5 | Final System design analysis and component models | Full Analysis of topics as outlined in above CfP. | To+18 M |

| | | | |
|---|---|---|---|
| | | Final modifiable models as in final product | |
| D6 | Critical Design review | Complete design, models, analysis, and test documentation suite | To+20 M |
| D7 | Demonstration system | Full demonstration system including spare components and system rig | To+24 M |

## 4. Topic Value

The Total value of this work package shall not exceed:

**700,000 €**
(Seven hundred thousand Euros)

Please note that VAT is not applicable in the frame of the Clean Sky program.

## 5. Remarks

This CfP is one of a co-ordinated series of technology developments under the Clean Sky Rotorcraft ITD supporting energy reducing electrical power systems and it is intended that, where practical, common or compatible approaches will be developed. In addition the demonstration implementation should allow its inclusion in a common systems rig environment.

The proposer is therefore asked to include provision in the program for the interactive development of the design, and the test program as co-ordinated by the ITD CfP lead.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-01-GRC-03-008 | **Innovative High Voltage Energy Storage System for Advanced Rotorcraft Integration** | Start Date | To |
| | | End Date | To+ 27M |

## 1. Topic Description

**Background:**
Efficient, low mass energy storage and recovery is a widespread challenge in vehicle platforms. Solutions are being sought in many different applications which aim at similar objectives in storing energy in the lightest and smallest possible way. The scope of this Call for Proposal is on exploiting energy storage to reduce overall power consumption, which carries particular challenges and potential in a Rotorcraft.
The main intent is to develop a **high voltage, rapid charge/discharge, electrical energy storage system** based power distribution architecture for aircraft that plays an active role during flight and ground operations in reducing the overall aircraft energy usage and thus increasing the useful payload and reducing fuel consumption and pollutant emissions. It is **not the intention to develop new storage technology** in this program. However current and future new storage technology developments must be considered. New storage or other technology adaptation and introduction may be included if achievable within the call schedule and budget.
The objective is to identify a **viable airborne storage system solution** that can support both long duration normal range load power flow and short duration high energy storage and recovery. Existing technology should be selected with this aim for system demonstration. It is recognised that new existing/emerging technology (such as novel electrochemical storage devices for example) may not yet be mature enough or light enough to justify aircraft integration and therefore assessment and justification of future viability and migration of component technologies towards higher power/mass density should be included.

**Program:**
The program will assess **system level approaches to energy storage** and develop host architecture configuration options and functions that exploit new storage technologies on a common helicopter primary electrical power distribution system.
This shall **initially establish indicative performance and system design outline options** to support a technology assessment design review. A preferred system technology approach will be selected from a Preliminary Design Review (PDR) in conjunction with an airframe manufacturer. The outcome will be used as the basis for the **design, test, manufacture and integration of a demonstration system.**
The preferred solution will be developed into a technology demonstration architecture design targeted for demonstration at **Technology Readiness level (TRL) 6**.
Recognising the wide range of activity in electrical energy storage development, **proposals which exploit solutions in other vehicle applications are welcome**. However the activity in this study must be applicable to helicopter airborne systems.
All systems must be developed considering a prospective **aviation certification process** and therefore critical airborne certification factors, safety arguments and conclusions should be included in the report. It is advisable that the applicant is familiarized with MIL-STD 704F, CS-29 and MIL-E 7016F having in mind that changes to industry standards may be necessary to achieve the desired system outcome. Any such changes and potential standards and good practice amendment issues must be identified.
The program will be carried out in close collaboration throughout with a leading airframe manufacturer and should be designed to support interactive co-operation with other power system CfP programs to develop a common approach to energy conversion interfaces and management.

**Scope of Work:**
The proposal will support the following work program:-

- Identify and define potential design options for a multiple energy source and storage based airborne power supply system utilising existing or emergent storage and control technologies.
- Determine the capability and performance and critical factors impacting performance,

efficiency, cost and technology risk for each option by analysis and modelling. Perform a comparative trade-off study of the system solution options.

- Support joint assessment and selection of preferred solution with airframe manufacturer
- Model, design and develop the preferred solution into demonstration system
- Test and assess the demonstration system to validate critical factor and performance modelling and analysis
- Design, manufacture and supply a demonstration test system, storage components and supporting test rig
- Support introduction of the demonstration system to the Clean Sky power system test bench
- Provide technical support and equipment maintenance through the test and demonstration programs to completion of the demonstration program at T+27m

**1. Load waveforms**

Rotorcraft has a wide range of load demands. These loads have, in most cases, a known operating power demand waveform, however their occurrence in flight is often of random nature and the system therefore has a **complex overall load profile**. A simplified load chart for a current Rotorcraft flight profile is presented below in Figure 2. It should be noted that the peak power demand is often intermittent and considerably greater than the average.

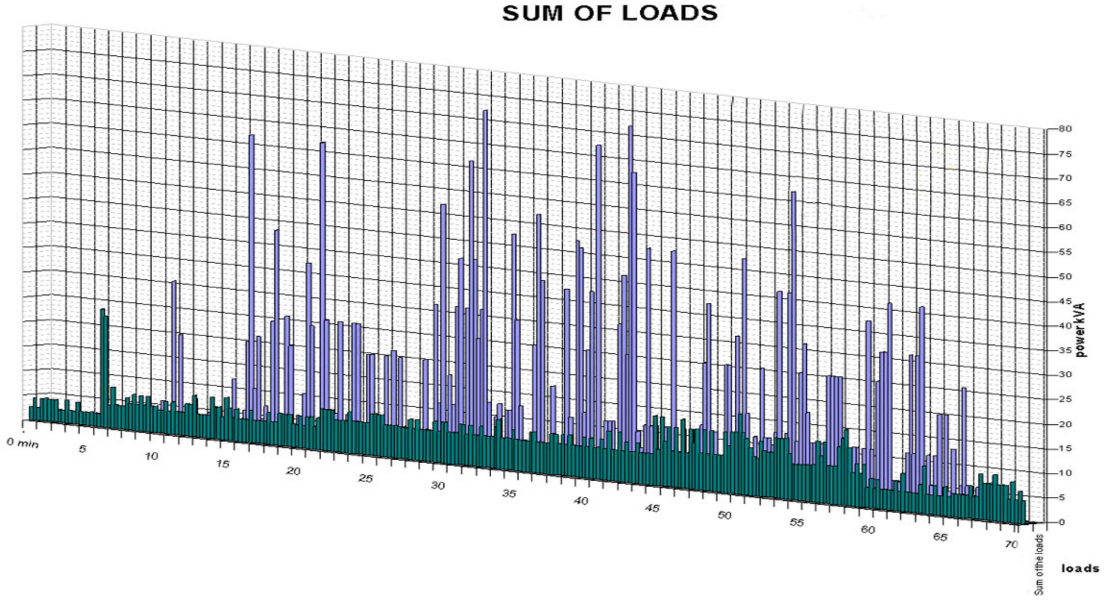



**Figure 2 - Simplified Load Chart for a Typical Flight Profile**

The innovative storage system must provide a power quality improvement through **Power Bus waveform 'smoothing'** and hence **actively work forwards mitigating voltage sags and other power disturbances,** often caused by sudden load demands and other unpredicted events. Ideally, solutions would consider peak load demand mitigation through some form of strategically located rapid charge/discharge storage to stabilize the load demand seen from the main power supplies.

**2. Source waveforms**

Apart from established power generation devices (generators, starter-generators) used on present aircraft there is an increasing interest in recovering energy otherwise wasted in thermal, kinetic or other forms. There will typically be multiple energy recovery sources with a wide dynamic output waveform range from short duration high power pulses to long term varying level continuous or intermittent low level power levels.

The system must be able to capture the energy content from these multiple sources managing the efficient conversion, storage and re-use via a common distribution bus

To enable effective design and demonstration an example primary application requirement is defined in the System capability section below and includes nominal energy levels.

**3. Network distribution waveform**

The system will be operating in an "all electric aircraft" environment with a **High Voltage DC Electrical Power Distribution Network**, in a **270 VDC** or **540 VDC** network (540v may be considered as derived from +/-270Vdc if necessary). If not compatible with both operating voltages the system must at least be scalable to match either voltage regime.

The system shall operate in concert with conventional rotating machine, self regulating generators on a nominally constant voltage regulated bus common to the overall aircraft power distribution system,

In addition to the primary distribution bus provision should be included to enable integration with a conventional low voltage main battery and legacy systems

**4. System capability**

The system must be scalable at both architecture and power level, capable of integrating multiple energy sources on a common power distribution bus and be extendable to a zoned bus distribution architecture.

A simplified example application is provided to illustrate primary storage system application requirement modes. A further set of requirements is then provided to define key modes of the storage system capability. **Single system solutions** must be provided with each one capable of supporting all the primary and additional extended storage system capability modes.

The program shall **describe in detail** how each storage system is **devised** together with a description of the **normal operating** conditions and also a **failure modes analysis** which should include a description of the **system reconfiguration** for operation under such failures.

**4.1. Primary Application Requirements**

The following requirements represent Scenario 1 and should also be considered throughout the subsequent scenarios. Quantitative values are specified to establish design scaling limits and targets. Where these values present specific demonstration difficulty the proposer may wish to present options with trade-off justification and future scalability assurance to enable effective demonstration.

**Start-up/Shutdown:** Power must be supplied to maintain Avionics during Start-up/Shutdown procedure.

**Engine Start:** The system must be able to perform 3 consecutive Starts with 10 seconds duration each and a peak power demand of 55kW. While maintaining capability for the previous requirement (provide duty-cycle details for the 3 starts). The Starting process shall not have any impact on the rest of the network power, i.e. – main distribution busses.

**Specific Energy Density:** The minimum specific energy density for a given system component/assembly shall be **> 100 Wh/Kg,** including any associated electronics. Greater values will be highly valued.

**Energy Density:** The minimum specific density for a given system component/assembly shall be **>150 Wh/L**, including any associated electronics. Greater values will be highly valued.

**4.2. System Capability Modes**

The two following requirements shall be added to the previous ones, initially separately, Scenarios 2 and 3 and afterwards considering them both at the same time, Scenario 4. Therefore, **4 different architectures** will be described in the end, although similar technologies must be used for every proposed solution;

**Scalable Storage:** In order to cope with future increase in stored energy requirement the solution should provided for at least **6kWh** of total storage at 80% nominal storage capacity and beginning of life, the applicant shall provide further details of assumed conditions and system limitations. For this case an **integrity systems analysis** must be performed so to allow it to be used as a "fly by wire" single power source.

**Power Exchange Rates:** The systems must be able to store and provide up to 0.6 kWh of energy within 20 – 50 seconds. The system should address how to optimise the current flow levels and power mass density at the distribution voltage levels. The study must include analysis of systems robustness and expected life-time against operating duty-cycles.

**5. Demonstration and modelling**

The program shall develop and supply storage system and component models supporting a modular component approach to integrated system model creation, exploratory modelling, simulation, performance and behaviour assessment. This shall include functional descriptions, characteristics and operation data requirements.

Modelling shall be developed to support flexible configuration options and provide prediction system operation and performance characteristics in long term, static and transient conditions as an aid to design solution and capability assessment. Test and demonstration should be linked to include model and assumptions validation

Models be based on open standard working files for application on general purpose commercial and all

modelling shall include a Matlab/Simulink based tool set and file version. Compatibility may be extended to other widely used commercially available tools including Modelica and SABER where they assist the ability to derive effective solutions. All critical modelling parameters, values, algorithms and outputs relevant to this program shall be described in English language or mathematical form, or graphical representation as appropriate, for information conveyance without the tool.
Following definition, scaling and selection of preferred storage system options a functional prototype of the system shall be developed containing the selected features. The prototype will then be used on a demonstration program in conjunction with other available technologies where appropriate. The applicant must include provision for support throughout the demonstration programme.

6. **Further Requirements**

Any additional devices required to control the charge and discharging process of the proposed storage systems as well as interface with distribution bus should also be included, described and modelled within the proposed solutions. Further requirements and changes may be added to such devices in order to achieve acceptable standards and address any compatibility issues with other power system devices and network. Hence co-operation with other CfPs and the airframe manufacturer should be expected at this point.
The storage system capability and performance should also be looked at in terms of its **compatibility with a regenerative network.** The intent is to see how such system would cope with a network that allows multiple Electro Mechanical Actuators to enter regenerative mode, in a random fashion, and thus feedback energy to the distribution bus. Such network would also be comprised of dedicated devices to recover energy from various sources and hence presenting different energy recovery profiles. Include comments on how could the system be used or changed to perform under such conditions and even enhance energy recovery potential.
Mechanisms for any control processing, monitoring, and data exchange necessary for management of the storage capabilities should conform to an open architecture, open format, transmission format and medium and use openly available commercial components. Algorithms and processes defining operation and capability critical to the system capability shall be defined and made available for assessment.
Note that it is essential that all systems present the **most volume and weight effective solution,** which will be the primary criteria of evaluation. In airborne applications the mass of energy recovery systems must not create a net increase in fuel consumption or through life cost.
A comparative analysis of commercial viability shall be provided including the system provision, through life support costs.
The design should minimise energy losses and subsequent temperature gain. Thermal gain should be recovered or self stabilised by passive or solid state dissipation techniques.
Active motor/pump based cooling solutions are non-preferred and their use should be justified and minimised on overall system mass and volume grounds
An analysis of the systems thermal behaviour and EMC issues for all likely demanding conditions must be included.
The use of potentially **noxious or dangerous** materials should be identified together with a detailed description of such substances including the quantity used.

## 2. Special skills certification or expected equipments from applicant

The applicant must be familiar with current electrical storage technologies, electrical power interface and control components used in the mobility industry and have a proven background in the application and development of such systems both through modelling and prototyping.

Experience should include regenerative power systems and electronic power interface design.

Access and familiarity with airborne safety certification standards and requirements such as;

MIL-STD-704F, Aircraft electrical power characteristics

MIL-E-7016F, Electric Load and Power Source Capacity, Aircraft, Analysis of

MIL-HDBK-217F, Reliability prediction for electronic component

CS-29, Certification specifications for large rotorcraft

## 3. Major deliverables and schedule

| Deliverable | Title | Short Description | Due Date |
|---|---|---|---|
| D1 | Preliminary system design options | Description of work, preliminary design proposal including trade-off studies.<br>System design, capability and performance options – document | To+1 M |
| D2 | Trade-offs Final Version | Trade-off Studies final document issue including final design intent | To+6 M |
| D3 | Preliminary System Design and component models | Modifiable models as described in CfP<br>Tool application files and supporting documentation (operation, characteristics, | To+8 M |
| D4 | Preliminary design review and associated documentation pack | Preliminary design review (host), and documents.<br>Safety assessment documents (failure modes effects and system reconfiguration)<br>Electrical, thermal EMC and vibrations tests definition | To+10 M |
| D5 | Final System design analysis and component models | Full Analysis of topics as outlined in above CfP.<br>Final modifiable models as in final product | T+18 |
| D6 | Critical Design review | Compete design, models, analysis, and test documentation suite | T0+20 |
| D7 | Demonstration system | Full demonstration system including storage components and system rig | T0+24 |

## 4. Topic Value

The Total value of this work package shall not exceed:

**450 000 €**

(four hundred and fifty thousand Euros)

Please note that VAT is no applicable in the frame of the Clean Sky program.

## 5. Remarks

This CfP is one of a co-ordinated series of technology developments under the Clean Sky Rotorcraft ITD supporting energy reducing electrical power systems and it is intended that where practical common or compatible approaches will be developed. In addition the demonstration implementation should allow its inclusion in a common systems rig environment.

The proposer is therefore asked to include provision in the program for the interactive development of the design, and the test program as co-ordinated by the ITD CfP lead.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-2011-1-GRC-05-005 | *Integrated Air Traffic Control/Tiltrotor simulation of low-noise procedures and evaluation of the impact on operators* | End date | To +39 months |
| | | Start date | To |

## 1. Topic Description

**1.1- Background:**

Cleansky-GreenRotorCraft (GRC) sub-project 5 (Environment-Friendly Flight Paths project) will develop and test new flight procedures for both helicopters and tiltrotors, aiming at significantly reduce environmental impact in terms of noise and gas emissions.

Low-noise procedures in particular will require to accurately track possibly complex and steep trajectories both in take-off and landing, using optimized paths to avoid highly populated areas.Such a strategy heavily relies on advanced navigation and piloting aids to guarantee an acceptable level of pilot workload while retaining the benefits of the optimized paths. On the other hand, these advanced piloting strategies are one of the most promising technologies to improve rotary-wing environment impact, as they can be immediately and effectively applied to currently flying vehicles.

Moreover, future expansion of rotary-wing transportation will ask to fly in low visibility conditions under Instrumental Flight Rules (IFR), similarly to fixed-wing aircraft and using again sophisticated guidance means to ensure safety and low pilot workload. The transportation system will be strongly affected by the increased air traffic level and the need to control rotary-wing vehicles in IFR flight, in particular in terms of workload of the air traffic controllers.

Finally, new unconventional players like tiltrotors will stress the use of current and future airspace: one of the few technologies allowing to sharply improve rotary-wing productivity, the tiltrotor has the potential of using cruise speeds and altitudes compatible with fixed-wing traffic while taking-off and landing similarly to a conventional helicopter. These peculiar capabilities will push air traffic control flexibility even further and requires to foresee adequate scenarios and infrastructures.

Although dedicated flight tests can be considered to finally demonstrate all these novel technologies, cost and safety considerations call for strong simulation capabilities. In particular simulation tools are routinely employed to analyze the acceptability of innovative procedures for vehicle and air traffic control operators and the community, and can be beneficial in assessing the reciprocal impact of low-noise procedures, new air traffic regulations and the operation of unconventional vehicles like tiltrotors.

**1.2- Scope of work:**

To support the development of environmentally friendly procedures specifically for tiltrotors, the GRC5 consortium looks for expertise in Air Traffic Management (ATM) and Air Traffic System (ATS) simulation.

1) new Instrumental Flight Rule (IFR) procedures for tiltrotors will be considered and a special attention will be given to tiltrotor capability to fly in either helicopter or aircraft mode using nacelle tilt degree of freedom. The general development of these procedures, in accordance with other GRC5 novel procedures, will be responsability of the GRC5 consortium: the candidate expert will ensure the harmonization of tiltrotor procedures with current and future navigation and ATM requirements, taking into consideration regulations and indications from ICAO (International Civil Aviation Organization) and from the European research project SESAR;

2) future operational scenarios will be analyzed, dealing with airport-like environments as well as generic, uncontrolled take-off and landing surfaces like private helidecks or heliports. Since the target of the simulation activity is to validate tiltrotors and their procedures, operational scenarios will be defined by tiltrotor manufacturer, possibly in accordance with vehicle and airport operators. Based on its know-how, the candidate will verify the consistency of proposed procedures and foreseen scenarios. Scenarios are expected to be characterized in the following manner:

- at least one scenario to reproduce Simultaneous Non-Interfering (SNI) tiltrotor procedures;
- at least one scenario to reproduce tiltrotor Approach with Vertical guidance (APV);

- at least one scenario to reproduce current city-center Visual Flight Rule (VFR) tiltrotor operations;

- at least one scenario to reproduce future tiltrotor IFR operations;

3) tools for pilot-in-the-loop simulation of the vehicle, provided by the consortium, interacting in real-time with a realistic ATS simulation environment, provided by the candidate, will be used to finally assess and demonstrate the novel procedures and scenarios. Specifically, objective of the simulations will be the assessment of the following aspects:

- tiltrotor pilot workload;

- impact of low-noise procedures with respect to conventional ones;

- compatibility of proposed procedures with current and future ATM constraints and workload.

To reduce costs and risks as much as possible, the final coupled simulation activity is expected to be based on an all-virtual, on-ground distributed environment made up of (at least):

- fixed-base tiltrotor simulator (provided by vehicle manufacturer) with realistic flight dynamic vehicle representation, generic but complete representation of most relevant piloting guidance means, generic cockpit, field-of-view adequate to conventional and steep take-off and landing profiles;

- ATS simulator (provided by candidate expert), with possible pseudo-pilots to mimic standard air traffic. Simulation models, operator interface and visual representation shall be sufficient to render the operational environment of the control tower of a major European city airport (e.g. Milan) with an acceptable degree of accuracy, in order to assess tiltrotor conventional and low-noise procedures in terms of Air Traffic Control workload;

- audio bi-directional communication between simulators;

- remote (quasi) real-time data communication from vehicle to ATS simulator, to represent tiltrotor operation into the simulated ATS environment.

The Air Traffic Control/Tiltrotor (ATC/TR) simulation expert will be involved in the following tasks of GRC5:

- GRC5.1.6: Requirement Analysis & Specifications Definition, specific tiltrotor aspects;

- GRC5.5.5: Low noise procedures, specific tiltrotor activity;

- GRC5.5.6: Mission profile optimization and validation.

The contribution is expected to last for about 3 years, starting from T0.

## 2. Special skills, certification or equipment expected from the applicant

To achieve successfully the expected contributions, skills and capabilities are required in the following domains:

• Air navigation and ATM regulations, including the most recent ones and those currently in preparation by International Civil Aviation Organization (ICAO) rulemaking groups;

• simulation of Air Traffic Control and airport / heliport operations;

• distributed simulation with remote pilot-in-the-loop filght simulators.

Proved capabilities in the following areas will be considered desireable:

• aircraft procedure design, in accordance with local national norms and regulators;

• analysis of the operations of  tiltrotors or other non-conventional air vehicles;

• previous participations in research projects or working groups dealing with ATM simulation and aircraft procedures.

The work shall take into consideration equipments, systems and/or standards developed in the European research programme SESAR aiming at ensuring a fully interoperable ATM system in Europe.

## 3. Major inputs, deliverables and schedule

| Deliverable | Title | Description (if applicable) | Due date |
|---|---|---|---|
| D1 | ATC/TR scenario simulation requirements | Scenario definition for airport and helipad/vertiport operation simulation, in accordance with GRC5.1 req. harmonized with SESAR concepts | $T_0$+3 M |
| D2 | Hardware, software and communication requirements | Definition of infrastructure required by simulation and compliance verification of available systems | $T_0$+12 M |
| D3 | Low noise tilrotor-specific IFR procedures | Review of procedures proposed in GRC5.5.5, finalization of procedures to simulate | $T_0$+15 M |
| D4 | ATC/TR simulation: first experiment and shakedown | Concept and system verification, first test | $T_0$+21 M |
| D5 | ATC/TR simulation: conventional vs low-noise procedures | Consolidation of results on low-noise procedure impact | $T_0$+27 M |
| D6 | ATC/TR simulation: nacelle tilt | Consolidation of results on the use of nacelle tilt | $T_0$+33 M |
| D7 | Final report | Report on support activity to ATC/TR simulation in GRC5 | $T_0$+39 M |

## 4. Topic value (€)

The total anticipated eligible cost of the proposal including manpower, travel costs, consumables, equipment, other direct costs, indirect costs, and subcontracting shall not exceed:

**800 000 €**

**[eight hundred thousand euro]**

VAT not applicable

## 5. Remarks

- All core RTD activities have to be performed by the organisation(s) submitting the proposal. If some subcontracting is included in the proposal, it can only concern external support services for assistance with minor tasks that do not represent per se *project* tasks. The proposal must :

- indicate the tasks to be subcontracted ;
- duly justify the recourse to each subcontract ;
- provide an estimation of the costs for each subcontract.

*(concerning subcontracting, see provisions of the Grant Agreement Annex II.7)*

- The expected length of the technical proposal is about 50 pages.

# Topic Description

| CfP topic number | Title | | |
|---|---|---|---|
| JTI-CS-2011-01-GRC-06-003 | Dismantling and recycling of ecodesigned helicopter demonstrators | End date | T0 + 27 months |
| | | Start date | T0 = July 2011 |

## 1. Topic Description

**Background:**

The objective of the GRC 6 workpackage is to design and manufacture rotorcraft demonstrators, such as airframe and transmission parts, by using ecolonomic (sustainable and cost-efficient) materials and processes. The goal is to achieve a cost & weight saving compared to today's solutions by integrated design and reduced number of manufacturing steps, including assembly, surface finishing, reduced re-work, fully recyclable products and by being easy to dismantle for recycling.

The demonstrators are mainly based on two technologies: airframe structures based on thermoplastic composites and metallic dynamic parts with novel (read: more environmentally friendly) surface treatments. Examples for thermoplastic composites are a helicopter door, skins, stringers and fittings, while for the dynamic parts a gear box with mast, transmission and shafts are considered. For the metallic parts titanium magnesium, aluminium and steel structures with Cadmium and Cr6+-free surface treatments are relevant. The thermoplastic composites are based on stiffened skin structures likely made of carbon fibre reinforced PEI, PPS, PEEK or PEKK.

The main goal is to make a qualitative analysis considering dismantling and recyclability of such a helicopter element based on these technologies, including assessment of the possibilities for recycling of such components, verify the environmental aspects, cost analysis of the end-of-life steps, and supply of quantitative input for the life cycle assessment tool. In other words, an assessment shall be made of the possible end-of-life routes and impact on the total demonstrator life cycle, with the aim to propose an end-of-life scenario that provides the most favourable ecolonomic impact. Inputs should be provided to the design stage where possible.

**Scope of work:**

The applicant is responsible for the following tasks:

- Collect and assess possible end-of-life scenarios, such as dismantling and recycling, for particular helicopter structures based on composite and metallic materials and technologies, leading to preferred scenarios. This task has to be carried out by considering that there are four demonstrator activities in parallel (two based on thermoplastic technologies and two on helicopter transmission parts), which are independently developed by two company groups.
- Investigate the reformability and possibilities of reuse of the dismantled and remaining structures, including part replacement
- Investigate the design influence on the end-of-life possibilities, and provide design recommendations
- Demonstrate the preferred scenarios (the best possible solutions based on today's or near-future technologies for disassembly, possible reuse, and materials recycling) for the four selected demonstrators (see below). This means to define with the cooperating companies a dismantling plan and carry out demonstration activities for meaningful dismantling process
- Collect and provide input for the Life Cycle Assessment tool

Below, an overview is given on the selected demonstrators to define the work volume and help the applicants to answer to the call for proposal. Four demonstrators based on two technology fields can be identified: thermoplastic composites (WP 6.1.5 and WP 6.2.5) and metallic parts with 'green' surface treatments (WP 6.3.5 and WP 6.4.5).

| Work package | Part | Parts number | Weight (g) | Materials/ technology |
|---|---|---|---|---|
| Thermoplastic Pilot Door (WP6.1.5) | Door frame | 1 | ~3000 | Continuous carbon fibre reinforced thermoplastics |
| | Window | 1 | ~500 | Thermoplastic |
| | | | | |
| Thermoplastic Structural Components (WP6.2.5) | Skins | 3 | | CFRP Thermoplastic laminates |
| | Stringers/Longerons | 6 | | CFRP Thermoplastic laminates |
| | Metallic attachment fitting | | | Aluminium alloy machined parts. Non-chromate protection |
| | | | | |
| Tail Rotor Transmission & Main Rotor Mast (WP6.3.5) | Casing (Mg Alloy) | 1 | | Cr6+ free |
| | Casing cover(Mg Alloy) | 1 | | Cr6+ free |
| | Packing housing | 2 | | SAA (sulfuric acid anodisation) |
| | Oil plug | 1 | | Carbon fibre reinforced TP |
| | Flange | 1 | | Ti Alloy Wear protection in WC (Tungsten Carbide) |
| | Mast RC and RP | 1 | | Cd free thermal spray Cr oxide coated locally |
| | Studs | | | Ti Al (Titanium - Alumiunium) IVD (Ion Vapour Deposition) coated |
| | nuts | 28 | | Free cadmium |
| Intermediate Gear Box (WP6.4.5) | Gear box | 1 | 3500 | Cr6+ free |
| | Gear box lid | 1 | 3000 | Cr6+ free |
| | Attaching flange | 2 | 150 | Cr6+ free |
| | Joint support | 1 | 40 | Cr6+ free |
| | IGB[1] flange | 1 | 600 | Cr6+ free |
| | Bevel gear | 1 | 2000 | Cr6+ free |
| | IGB (intermediate gear box) wheel | 1 | 2800 | Cr6+ free |
| | nuts | 28 | | Free cadmium |
| | screws | 5 | | Free cadmium |
| | washers | 23 | | Free cadmium |
| | shaft | 2 | 20000 | bonding and composite |
| | tap | 1 | 125 | thermoplastic |
| | Accelerometer support | 1 | 45 | thermoplastic |
| | plate stop | 1 | | composite |

*GRC6.1.5: Thermoplastic composite pilot door frame*

The door demonstrator will be based on structural thermoplastic composites (with PPS (polyphenylene sulphide), PEI (Polyether Imide), PEEK (polyetheretherketone) or PEKK (Polyether ether ketone Ketone) matrix). These materials have the promise of easy dismantling and recycling and possibly reforming. The aim of this WP is, therefore, to investigate the possibilities to fulfil this promise to improve the life cycle carbon footprint.

*GRC6.2.5: Demonstrators for Thermoplastic Structural Parts*

Thermoplastic reinforced with carbon fibres can be used in primary structures. The main advantage

[1] Intermediate Gear Box

shall be evaluated from the reduced number of manufacturing operations and the weight reduction as well as the saving due to simpler material handling and storage operations.

The reference part is the same structure made with CFRP thermosets

*GRC6.3.5: Transmission*

The demonstrator is a complete tail gearbox and the main mast of the main gearbox. The technologies of the two boxes are similar and the main mast can be taken as one of the most interesting components to evaluate the improved technologies. Magnesium casing shall imply an improvement of the corrosion protection as well as case hardened steel parts needing environment compatible paling

*GRC6.4.5: Gear box demonstrator*

Considering the GRC6.4 the goal is to analyse a gear box with a transmission and shaft. On this GRC6.4, 20 parts will be analyzed, from screw to a gear box. Studied materials will be surface treatment on metals (magnesium, aluminium and steel), steel assembly, thermoplastic.

## 2. Special skills, certification or equipment expected from the applicant

The applicant (single organisation or a consortium) should include research laboratories or institutes having the following facilities and knowledges:

- Strong knowledge on aerospace materials (CFRP with thermoset as well as thermoplastic matrices, magnesium, titanium, aluminium and steel stuctures including coatings)
- Extensive experience and capabilities for disassembly, dismantling and recycling of composite and metallic materials
- Extensive experience and capabilities for collecting data that serve as input for a life cycle assessment tool.

## 3. Major deliverables and schedule

| Deliverable | Title | Short Description (if applicable) | Due date (month) |
|---|---|---|---|
| D1 | Concerted plan for dismantling demonstration activity | Report with accurate definition of the dismantling activity based on consultation of the different actors | T0 + 2 (months) |
| D2 | End-of-life technologies report | Report with assessment and recommendation of suitable end-of-life technologies for GRC6 demonstrators | T0 + 6 (months) |
| D3 | Feasibility demonstration for metallic structures | Demonstration of economic preferred solution | T0 + 15 |
| D4 | Feasibility demonstration for composite structures | Demonstration of economic preferred solution | T0 + 15 |
| D5 | End-of-life technology demonstration report on metallic demonstrators | Report with results of demonstration of end-of-life technologies on metallic structures with novel surface treatments | T0 + 24 |
| D6 | End-of-life technology demonstration report on TPC demonstrators | Report with results of demonstration of end-of-life technologies on TPC composite demonstrators | T0 + 24 |
| D7 | Software file with input for life-cycle-assessment tool | | T0 + 27 |

## 4. Topic value (€)

The total anticipated eligible cost of the proposal including manpower, travel costs, consumables, equipment, other direct costs, indirect costs, and subcontracting shall not exceed:

**€ 200 000.00** (VAT not applicable)

[two hundred thousand euro

### 5. Remarks

| |
|---|
| All core RTD activities have to be performed by the organisation(s) submitting the proposal. If some subcontracting is included in the proposal, it can only concern external support services for assistance with minor tasks that do not represent per se *project* tasks. The proposal must :<br>- indicate the tasks to be subcontracted ;<br>- duly justify the recourse to each subcontract ;<br>- provide an estimation of the costs for each subcontract.<br>*(concerning subcontracting, see provisions of the Grant Agreement Annex II.7)* |
| The candidates should know that, in case that they are successful, they would have to undersign an implementation agreement with several industrial companies with a binding commitment to protect confidentiality of their own proprietary data. |
| - The length of the technical proposal is expected to be 20 pages. |

**====== End of Topic Descriptions for ECO, GRA and GRC ======**

Due to the large number of topics in this call and the inclusion of graphics in many topic descriptions, the topic descriptions for **SAGE, SFWA** and **SGO** have been moved into annexes of the Call Fiche. These annexes can be found in the additional documents section of the call web page.