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PROJECT FINAL REPORT

Grant Agreement number: 605474

Project acronym: RESEARCH

Project title: Reliability And Safety Enhanced Electrical Actuation System Architectures

Funding Scheme: Collaborative project

Period covered: **from** October 2013 **to** August 2016

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate) [4]:

  ☐ has fully achieved its objectives and technical goals for the period;

  X has achieved most of its objectives and technical goals for the period with relatively minor deviations.

  ☐ has failed to achieve critical objectives and/or is not at all on schedule.

- The public website, if applicable

  X is up to date

  ☐ is not up to date

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: .....Eva Novillo Diaz...

Date: ..../ ..../ ....

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism and in that case, no signed paper form needs to be sent

[4] If either of these boxes below is ticked, the report should reflect these and any remedial actions taken.

3.1 Publishable summary

Reduction of fuel burn has become a priority for most aircraft (A/C) operator due to environmental and cost implications. Such interest has made the aerospace industry to look at sources to minimize fuel consumption, concluding that the approach towards a more electrical aircraft, i.e. use of electricity to operate the consumers, could provide some benefits. In first place, this approach tends to remove hydraulic actuators and the hydraulic system that feed them, which require a significant amount of maintenance effort, are heavier and consume significant amounts of energy. Additionally, this kind of electrical components allow a higher integration of sensors for their monitoring, providing a better view of their performances and structural integrity (from a safety point of view) or achieving an improved degree of "intelligence" improving the integration within the controlling system or aircraft. This feature facilitates its use in UAVs, which are required to be able to take decisions based on the information received from the integrated sensors.

The use of electrical Power on Demand systems in place of hydraulic systems is increasing in all new aircrafts developments. The continuous need to reduce overall fuel burn on the aircraft leads to the use of more electrically powered systems. **With this approach RESEARCH project will investigate different system configurations, more electrically powered**, where the performance, power consumption, weight, safety and reliability factors are considered in order to obtain the optimum solution.

Along RESEARCH development, is expected to continue the establishment of harmonized integrations on a wide range of existing aircraft projects between EU and Russian Federation as main aim of this consortium, being composed by companies from both nationalities.

1	CESA	Ind	ES
2	ONERA	RTD	FR
3	UMBRA	Ind	IT
4	TECNALIA	RTD	ES
5	TsAGI	RTD	RU
6	United Aircraft Corp.	Ind	
7	Moscow Aviation Institute	Univ	

The main objective of this project is:

1. Definition of an electrical architecture for Flight Control System capable of controlling a flight control surface on an A/C with the help of electrically operated actuators, thus replacing the hydraulic actuators commonly used in current A/C designs.

This architecture will be designed with the main objective of being electrical, as this is the main purpose of this call, and as much as possible compliant with aerospace certifiable requirements, since the intention is to be able to use it in a possible future A/C. The objective of the RESEARCH project is to find a robust architecture to meet the constraints imposed by safety regulations while keeping other system performances (as weight, Reliability) as optimal as possible.

Based on the architecture selected, a specification will be generated for the system (composed of one or several electronic control units), and the electric actuators (electro mechanical actuators or electro hydrostatic actuators). These specifications will be used to generate the corresponding equipment, which will be installed in a test bench in order to validate the concepts used in the generation of the architecture and the performances of the system and the electric actuators.

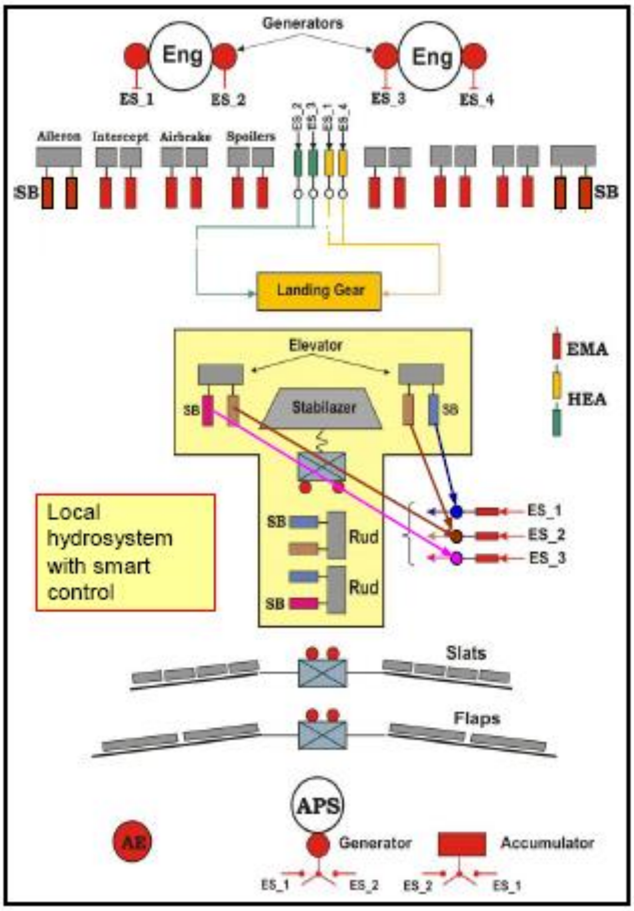


Figure 1 – One of the architectures analyzed

Aside of the design of the architecture, the project incorporates a number of additional sub-objectives, some focused on the system and others focused on the improvement of the design of EMAs and EHAs. Amongst these we can find the following:

2. Development of mathematical and computer program models of electrically powered actuators. The use of SMART hydraulic system will allow to triple decrease of peak hydraulic power consumption by FCAS according to the preliminary estimations made in TsAGI. This will lead to the decrease of necessary motor-pump power and its mass. The detailed estimation of mass reduction will be obtained during this work.

3. Study focussing on the management of thermal environmental aspects, in order to handle thermal dissipation during the architecture definition phase:
    - Thermal model of wiring
    - Lumped parameters model of thermal environment behaviour of actuator depending on environmental conditions and heat releases.
4. Study focusing on the management of the electromagnetic compatibility (EMC) aspects in order to evaluate mainly the conducted emissions of new architectures. This part is mandatory to check the good integration of these architectures in an aircraft certification. For this, our study focus on:
    - The consideration of a new wiring losses model at cable level
    - The modelling of the electrical wiring interconnection system (EWIS) taking into account its installation
    - The description of the equivalent models (Thevenin's models) of real loads (EMA / EHA/SECU)
    - Testing and modelling of real wiring architectures (EWIS + real loads)
5. Development of technologies of local hydraulic systems smart control (with pressure adaptation) for power consumption optimization. The use of SMART hydraulic system will allow to triple decrease of peak hydraulic power consumption by FCAS according to the preliminary estimations made in TsAGI. This will lead to the decrease of necessary motor-pump power and it's mass. The detailed estimation of mass reduction will be obtained during this work.
6. Development of an EMA pursuing weight optimization (10-15% reduction) and lower consumption (10-15% reduction) with respect to current EMAs under development (between 23-25 kg weight and 2.8 kW for 30 kN load continuously working) as well as monitoring for increased safety while maintaining high level of reliability with respect to systems installed on board existing aircrafts.
7. Development of the System Safety assessment and **HUMS (Health And Usage Monitoring System)** to assure the compliance of the proper operation and Airworthiness requirements and to maintain high levels of Reliability at the same time as decreasing the Maintenance costs:
    - **Usage monitoring**, establishing Mathematical algorithms from measurements the status of critical parts.
    - **Life estimators** depending on actuator status and signals from sensors.
    - **Prognosis**, to predict the useful life of the items before failure, based on usage monitoring
    - **Measurement related to efficiency** of system.
    - **Detection of faults and failures**, diagnosis including identification and isolation of failures.

This Periodic report (2nd reporting period) summarize the progress of the RESEARCH project from 1st April 2015 to the end of the proyect (31st August 2016), and includes the main achievements, delay explanation, detailed task progress and a recovery plan with the new schedule proposal, deliverable dates and milestones and meetings, that was fixed after internal consortium agreement.

This section provides a concise overview of the work done from March 2015 to September 2016.

Activities for work package 1 are completely finished:

- Aircraft system definition and requirements is completely closed, Task 1.1, meaning that the Aircraft system definition is finished, list of requirements included. The analysis of different architectures (task 1.2) is also finished, requirements and specifications closed and health monitoring and safety assessment activities shows a high level of progress.
- List of deliverables 1.3, 1.4, 1.5, 1.7 and 1.8 have been completed from Safety assessment side in order to cover the activities performed in WP1.
- HUMS description strategy have been also evaluated to check the mechanical and electrical status of EMA and ECU.

Activities of work package 2 are completely finished:

- Final actuators models accomplished at a 100% without its validation due to delays in manufacturing of actuators but with good level of models preciseness;
- Mathematical & HIL simulation of A/C motion completed at 100% without complete HIL testing campaign but with extended (in comparison to original planning) wind gusts simulations;
- Management of thermal environmental aspects and Management of EMC performed including thermal behaviour assessment through the complete flight scenario;
- The numerical modelling of A/C with SMART local hydrosystem was completely (100%) finished with the use of developed algorithm of local hydrosystem pressure control;
- AltaRica models of the EMA, ECU and SECU developed, in order to clarify the failure detection and reconfiguration logic for the elevator control system

Activities of work package 3 are completely finished:

- Scheduled activities were also performed within the framework of work package 3, specifically task 3.1 and 3.2 (conceptual design of EMA and ECU). EMA architecture is finished, its detailed design completed and manufacturing in process. A demonstrator is used in order to validate the performances of this technology. BLDC motor and ballscrew specified, manufactured and tested. Electronic Control Unit (ECU) and SECU architectures are also tested with the EMA demostrator.
- Basing on the conceptual and design of EBHA for elevator control system (task 3.5), the detailed design was accomplished and manufacturing of the actuator was started. The test rig (task 3.4) was also performed to test demonstrator of EHA. This activity was not originally planned in the frame of RESEARCH, but it was possible to prolong this development in the frame of new Russian project. The EBHA manufacturing and tuning are expected to be completed in November 2016.
- Basing on the test-rig design one test-rig was manufactured and assembled in TsAGI (task 4.5). The figure shown below contains the view of the test-rig but without installed inertial elements on the ends of the twisting shaft ((task 3.4)).

Activities of work package 4 are completely finished:

- The complete ECU system made up of three PCBs and electronic cabinet or box has been manufactured. After system assembling the ECU has been validated with the demonstrator of EMA actuator, task 4.1 and 4.2.
- The task 4.3. SECU validation is completely finished with the design of a customized hardware and the development of the control software. Control software routines and

functionalities were tested on a dedicated test environment built with National Instruments hardware.

- EHA actuator was upgraded (task 4.4) as planned by the sub-contractor of TsAGI and was delivered for testing campaign to TsAGI's facilities.
- Basing on several draft designs for the test-rigs proposed and discussed inside the consortium the selection of final test bench equipment was done(task 3.14). One test-rig was assembled in TsAGI (task 4.5), the second test-rig was planned to be delivered to CESA from Umbra.

Activities of work package 5 are completely finished. The estimated improvements in the EMA actuator performance are not completely achieved due to maximum current limitations. The root cause that limits the improvement has been focussed and future works for system will be oriented by using pre-filter, signal saturator implementation, or other solutions implemented in hardware.

- Finally, planned activities of WP5 were also performed. Validation test planning and test procedures were completed.
- The complete ECU system has been tested with the demonstrator of EMA actuator with current limitations.
- EHA actuator was upgraded as planned and delivered for testing campaign to TsAGI's facilities.

Activities of work package 6 are completely finished:

- Activities of WP6 Dissemination and Exploitation were accomplished: the final version of the awareness and dissemination plan and also exploitation plan were prepared. The project website was started.

3.2 Core of the report for the period: Project objectives, work progress and achievements, project management

3.2.1 Project objectives for the period

The main technical project objectives are

- ✓ to define mathematical and simulation models including the results WP2, as well as thermal environment and EMC aspects
- ✓ to test a design ready according to of WP3 (including manufacture, assembly of EMA, EHA, ECU, SECU)
- ✓ to manufacture and issue the conclusions in the framework of WP4.
- ✓ to issue the Validation test in the framework of WP5.

3.2.2 Work progress and achievements during the period

The progress of each task is:

Work Package 1 – System Architectures and requirements

Task 1.1 A/C system definition and requirements

The aircraft type is selected and requirements available. Deliverable 1.1 finished.

Task 1.2 Analysis of different architecture

Analysis and definition of a more electrical architecture for Flight Control System. It includes proposal of different architectures, safety considerations, weight preliminary discussion and estimations, flight control surface analysis, candidates, selection and a chapter dedicated to the electronic architecture. The work is detailed in Deliverable 1.2.

Task 1.3 Health monitoring and safety assessment

This task is divided into two main axes:

- Health Monitoring: Control and monitoring architecture definition and the analysis of HUMS system is completed and documented in Deliverable D1.6
- Safety Assessment: the work done is summarize below, but for more details refer to deliverables D1.3 and D1.4
    - Complete definition and detail explanation of Safety requirements at system level
    - Preliminary Safety Assessment process
    - Functional Hazard Assessment
    - Fault Tree Analysis and budgeting of safety requirements at equipment level

The activity shows a 100% progress in the framework of *Deliverable 1.5 System Safety Assessment report.* Deliverables D1.3, D1,4, D1.5 and D1.6 are finished and delivered.

In D1.5, the overall system safety has been assessed. It was a work parallel to the progress of the detailed EMA and corresponding ECU and SECU design and manufacturing. The proposed overall architecture evolved several times during the project for design reasons, but also due to the results of the preliminary safety assessment of D1.4. For each evolution step, the safety was reassessed following the same model based approach detailed in D1.4. The following safety requirements of Table 1 stem from the FHA and are the inputs for the PSSA.

	Safety Requirements	Design Decisions	Remarks
1	No single failure within the Aircraft Longitudinal Stability (Pitch) Control System shall lead to the loss of control of both elevators at the same time	More than one control channel. More than one elevator surfaces. Avoid common paths.	
2	No single failure within the Aircraft Longitudinal Stability (Pitch) Control System shall lead to the uncommanded or erroneous uncontrolled movement of one elevator	Actuators attached to the same surfaces controlled by different means. Redundant control. Avoid common paths.	
3	No single failure within the Aircraft Longitudinal Stability (Pitch) Control System shall lead to the jamming of one elevator.		(Conservative approach is kept)
4	The loss of control of both elevators during Take-off or Approach and Landing shall have a probability of occurrence per Flight Hour less than 1E-09	More than one control channel per system.	
5	The loss of control of both elevators during Climb, Cruise or Descent shall have a probability of occurrence per Flight Hour less than 1E-07	See previous requirement.	
6	The uncountered runaway of one elevator (erroneous or uncommanded uncontrolled operation or movement) during Take-off or Approach and Landing shall have a probability of occurrence per Flight Hour less 1E-09		
7	The uncountered runaway of one elevator (erroneous or uncommanded uncontrolled operation or movement) during Climb, Cruise or Descent shall have a probability of occurrence per Flight Hour less 1E-07		
8	The countered runaway of one elevator (erroneous or uncommanded controlled operation or movement) during Take-off or Approach and Landing shall have a probability of occurrence per Flight Hour less than 1E-07		
9	The countered runaway of one elevator (erroneous or uncommanded controlled operation or movement) during Climb, Cruise and Descent shall have a probability of occurrence per Flight Hour less than 1E-05		
10	The jamming of one Elevator surface out of neutral position during Take-off or Approach and Landing shall have a probability of occurrence per Flight Hour less than 1E-09	Actuators shall have an anti-locking mechanism.	Conservative approach is kept
11	The jamming of one Elevator surface out of neutral position during Climb, Cruise or Descent shall have a probability of occurrence per Flight Hour less than 1E-07	See previous requirement.	
12	The loss of control of one elevator shall have a probability of occurrence per Flight Hour less than 1E-05		

Table 1 : PSSA inputs

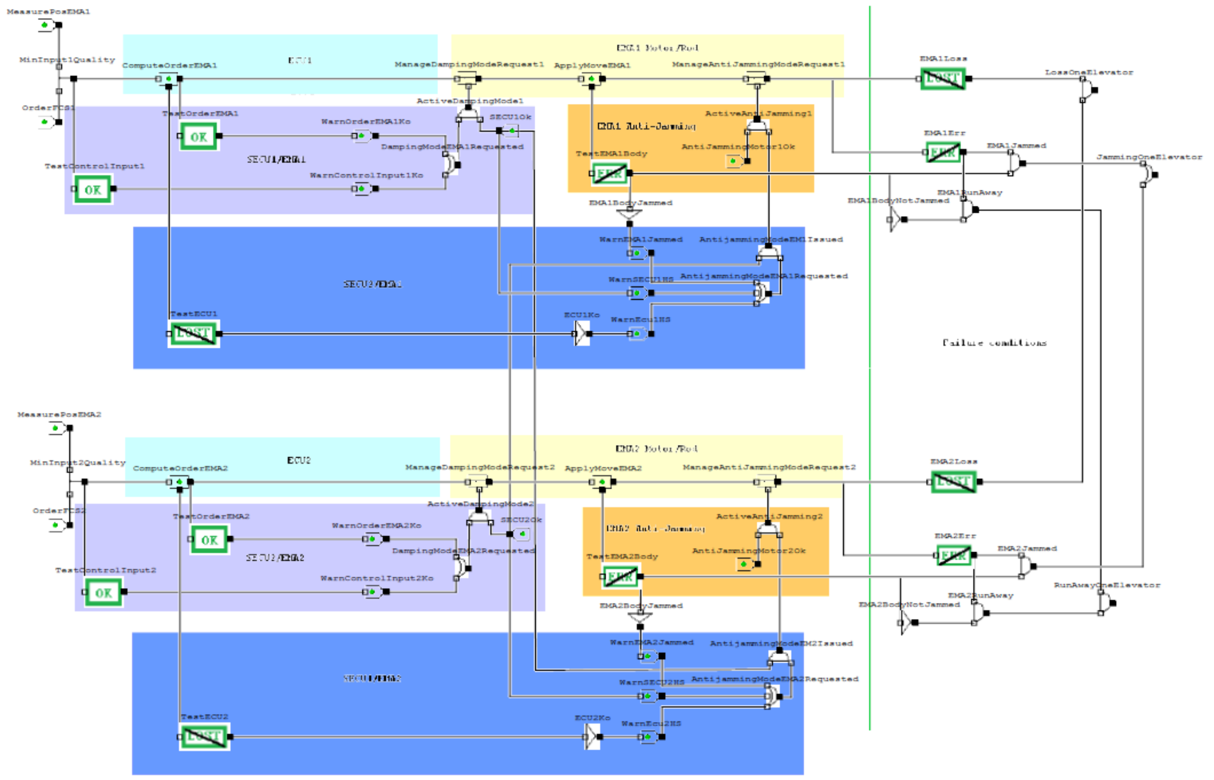


Figure 1 : AltaRica model used for the safety assessment

The model which has been used for all assessments is the AltaRica® model given in Figure 1. It describes the links between the different (sub-)functions and allows to trigger a failure in one (sub-)function. The top level requirements of Table 1 have been added to the functional description by logical operators on the right. The propagation of the failures can therefore be simulated in order to evaluate qualitatively and quantitatively the impact on the 12 safety requirements. From this model, it is possible to automatically generate the different fault trees corresponding to the safety requirements and to identify the corresponding functional failure and minimum cuts sets.

The system design is compliant with the applicable safety requirements. The mitigation of runaway and loss of control is achieved by numerous barriers which provides some safety margins that can be used to later optimize the detailed design. However, the mitigation of the elevator jamming is not over specified, further design steps shall remain compliant with the hypothesis of this safety assessment.

Task 1.4 System ECU (SECU) requirement and specification

The system ECU requirement and specification is completed and detail in deliverable D1.7. It defines the ECU/SECU architecture, SECU functions, mechanical architecture, EMA/EHA compatibilities, SECU requirements definition and the partner's responsibilities in this task, since all consortium participates in it.

Task 1.5 Actuators and System Test Rig requirements and specifications

The list of requirements and specifications for the EMA, EHA and the System Test Rig is completed. Test rig discussions also involved all the partners. Refer to deliverable 1.8 for detail information. Although this activity is already finished, it was closed with some delay regarding the recovery plan.

Work Package 2 – Mathematical modelling, simulation and assessment

Task 2.1 Actuators/ECU and SECU mathematical & numerical modelling

The task was completely finished under TsAGI leadership with CESA, Umbra, Tecnalia and MAI participation. The task covered 3 deliverables which contain the description of mathematical models of EMA and EHA of different level of details: general (based on general knowledge and typical schematics), detailed (based on the data from actuators design) and final.

The final deliverables (D2.1, D2.2 and D2.3) contains the most precise description of final actuators models and it is delivered as according to original planning the models had to be validated, but the activity was not completed due to delays in manufacturing of actuators (EMA and EHA). As the result, the models are based on the actuators design data.

The static (static characteristic, velocity characteristic), dynamic (transients, frequency response) and energy properties of actuators was obtained during the simulation.

Task 2.2 Mathematical & HIL simulation of aircraft motion

The task is completely finished under TsAGI leadership and covered 3 deliverables as previous task due to every step on its process is based on the use of the models of actuators prepared in the frame of T2.1. Every step of simulation of A/C closed control loop used the models of different levels of details.

The final deliverable D2.6 contains:

a) the description of full aerodynamic model of modern regional jet with state-of-the-art flight control system;

b) the description of tools for investigation the stability of the control loop (frequency response analyzer, step response analyzer, etc.);

c) the description of research plan and procedures;

d) The simulation results and its analysis for longitudinal A/C motion with three different actuators (EHSA, EMA, EHA). The simulation campaign covered A/C reactions to step inputs from the pilot control (in order to obtain transient responses properties), sinewave generation (to order to obtain closed loop stability margins and A/C reaction to the wind gusts of different forms (order to check the control system stability at high control signals).

The simulation showed the acceptable level of control and stability quality aligned with the requirements for the case of using electrical actuators for elevator deflection.

The task was completed with deviation from original planning excluding HIL simulation due to delays in manufacturing of EMA and EHA. As the result, all simulation activities were based only on final actuators models from T2.1.

Task 2.3 Management of thermal environmental aspects

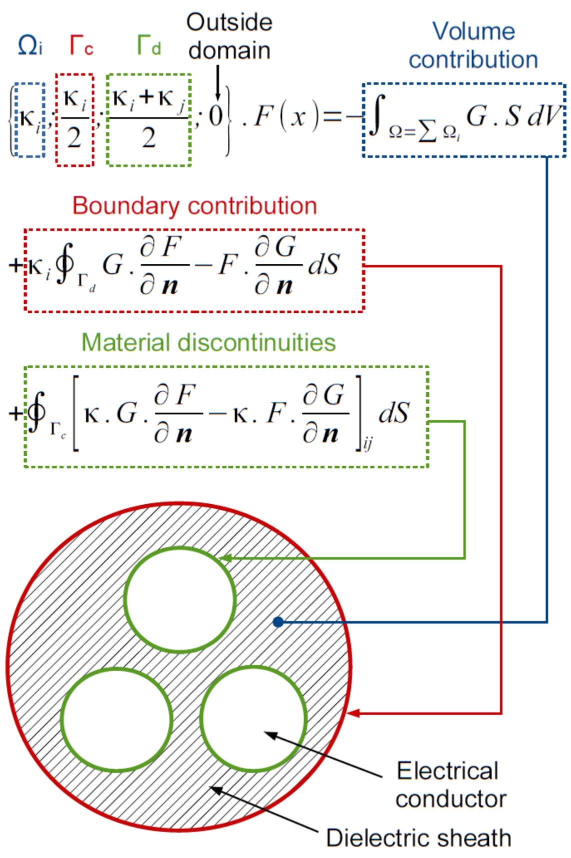
The task has been defined and completed under ONERA leadership with participation of mainly ONERA, TsAGI Siemens and MAI. All activities are on time and the status is at about 100% of the total foreseen activity. ONERA initiated the modelling of thermal effects around wires.

All activities are completed and reported. ONERA has defined and implemented a new model to take into account the losses (skin effect and dielectric insulator) in its EMC tool (CRIPTE Software). These new models have been applied on an ONERA's reference complex harness in using CRIPTE Software. The first comparison (simulation and measurement) has been performed on a crosstalk approach and has shown a good relevance.

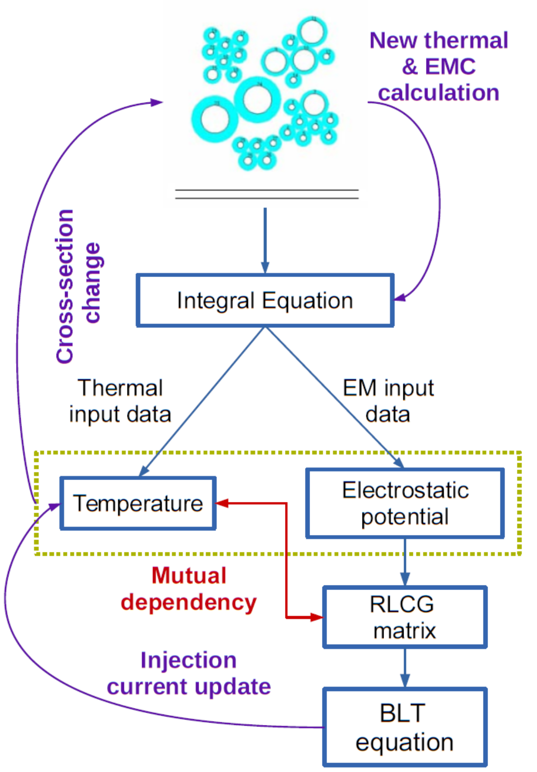
The purpose of the thermal simulation is to predict, from a topological representation of the EWIS, the total amount of heat produced by groups of cables. Although norms and abacus exist, these ones are often inaccurate in a wide range of practical applications and thus tend to overestimate the temperature of such bundles.Temperature and electrostatic field are derived from the same potential notion. Hence, when applying to a cable bundle, a single resolution of the Laplacian must give the p.u.l properties of the transmission line and its temperature distribution at the same time. Couplings between thermal and electromagnetic phenomena are therefore totally defined by the characteristics of the electrical currents (intensity, frequency), the thermal properties of materials and the estimation of the heat transfer coefficient to the surrounding environment.

In the aim of providing a unique computational tool for both thermal and EMC issues, Poisson's equation is expressed in its integral formulation.

$$\left\{\kappa_i ; \frac{\kappa_i}{2} ; \frac{\kappa_i+\kappa_j}{2} ; 0\right\} . F(x) = -\int_{\Omega=\sum \Omega_i} G . S \, dV + \kappa_i \oint_{\Gamma_d} G . \frac{\partial F}{\partial \boldsymbol{n}} - F . \frac{\partial G}{\partial \boldsymbol{n}} dS + \oint_{\Gamma_c} \left[\kappa . G . \frac{\partial F}{\partial \boldsymbol{n}} - \kappa . F . \frac{\partial G}{\partial \boldsymbol{n}} \right]_{ij} dS$$

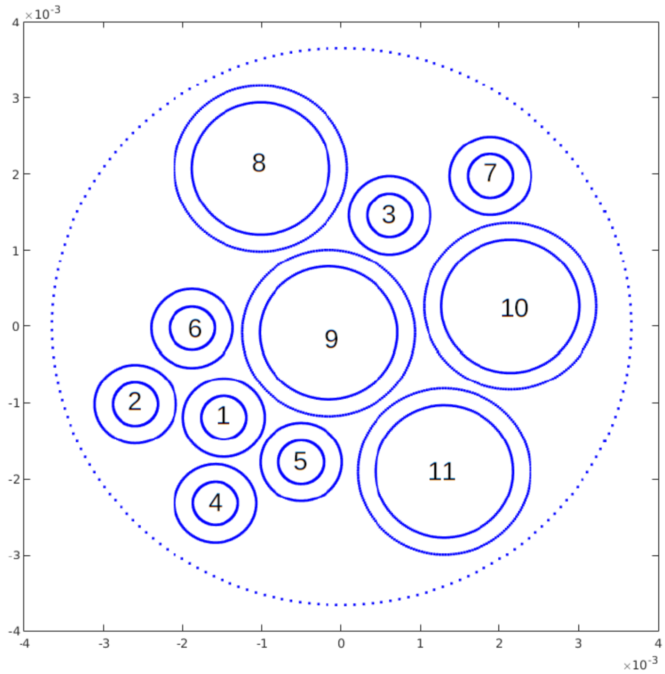


Integral formulation of Poisson's equation. Application to a simplified three-phase cable



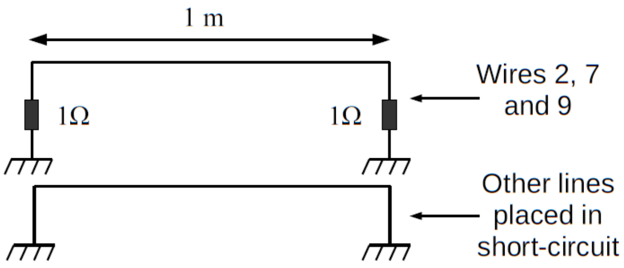
General coupling strategy and optimization loop

An application case has been defined as a bundle of 11 cables inserted into an insulator sheath and placed in free air as illustred by the following figure.



Bundle cross-section and cable numeration

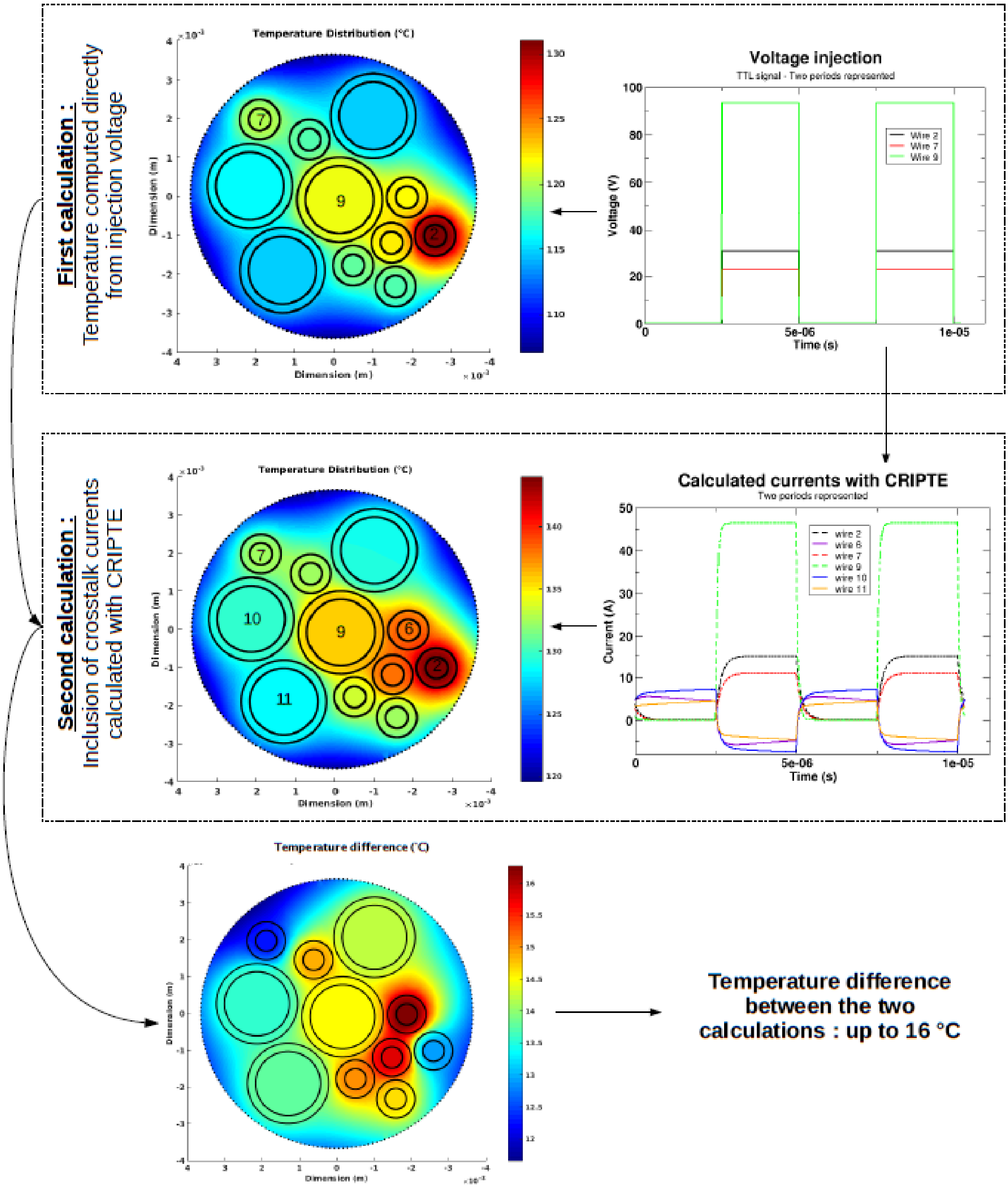
As a first step, topological and geometry description is made using ONERA's EMC software called CRIPTE™. On the unique defined tube, powered cables were connected by 1 Ω impedance to a ground reference plane located 5 centimeters below. The bundle length was set to 1 meter.



Thermal conductivity [W/(m.K)] : 401 (copper), 0.33 (dielectric), 0.1 (sheath)
Ambient Temperature (°C) : 25
Electrical conductivity (S/m) : 59.6e6
Boundary condition : free space convection and radiation→ constant value *h=10 W/(m².K)*

Main characteristics of the studied line

A CRIPTE™ calculation enables us to evaluate the currents on each wire of the bundle. These currents are then averaged and injected in the thermal solver as volume heat source power. Results show an increase of the temperature up to 16 °C, and we can note that this overheating is especially located on wires 1 and 6. Indeed, these ones were placed in close proximity to the two voltage injections (wire 2 and 9).



Test case results

A complete 1D system model developed on AMESim by LMS Siemensis available and approved by ONERA. All activities are on timeis on time.

The main project objective is the definition of an electrical architecture for Flight Control Actuation System (FCAS) capable of controlling the primary flight control surface of an aircraft with the help of electrically operated actuators. This FCAS shall be optimized based on thermal considerations, with a particular focus on heat losses and power dissipation, while taking into account actuators actual duty cycle and the cavity geometry they operate in.

The methodology of the actuation system thermal behavior analysis described implies the wide use of simulation.

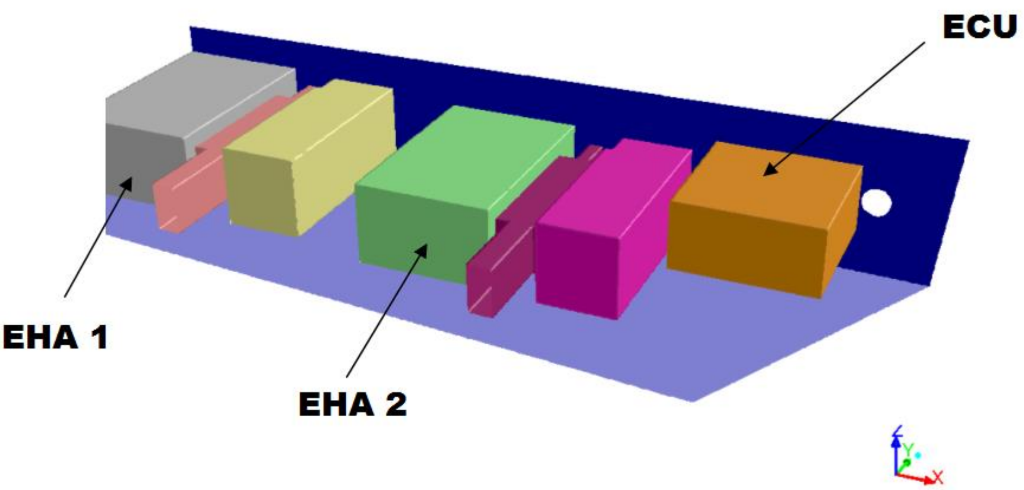
Several approaches may be considered, from costly solutions based on numerous CFD simulations used in a parametric strategy to the use of cheapest nodal or 1D model.

CFD and 1D models must be combined in order to develop a simple and accurate model of a complex system usable as a design tool.

In this study, we decide to combine the both approaches in an iterative process with the help of our partners Siemens, Tsagi and MAI.

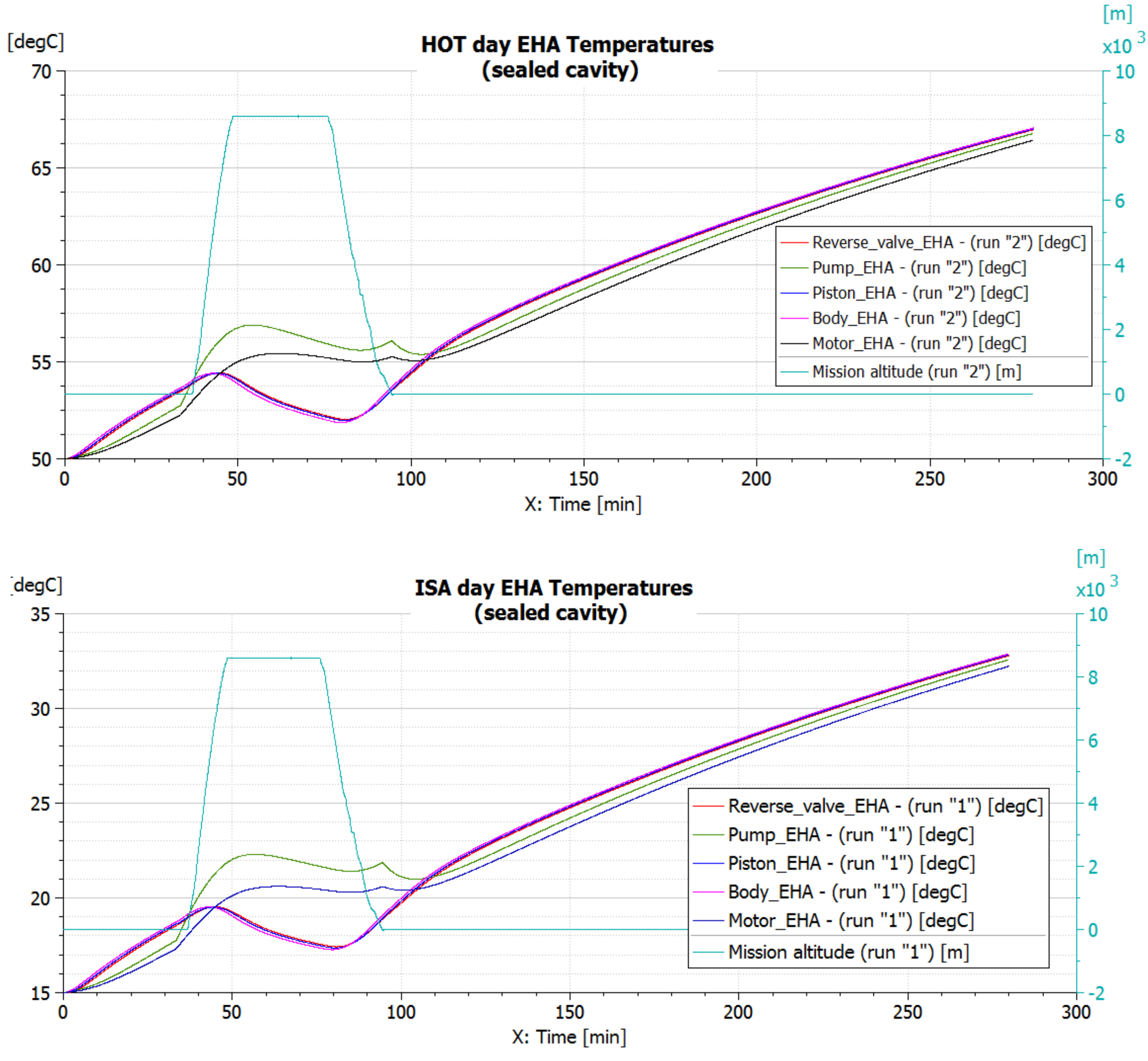
- The first step consists in a simulation of the cavity system thermal behavior in the LMS Imagine Lab Amesim software, over all the flight mission described above. The software uses 1D approach with nonlinear time-dependent analytical equations that represent the system's multiphysics behavior. To be efficient, it needs accurate estimations of the electrical network and of the heat exchange properties.
- According to these first results, several stabilized configurations can be extracted and used as CFD test configurations. High resolution simulation of the aerothermal system leads to an upgrade of heat properties in Amesim

The analysis results described in this report focus on a case which combines two EHAs with an ECU, with no EMA in the cavity. Out of the two EHAs, only one is active during the flight mission (nominal case). However the thermal inertia provided by the second one is accounted for.



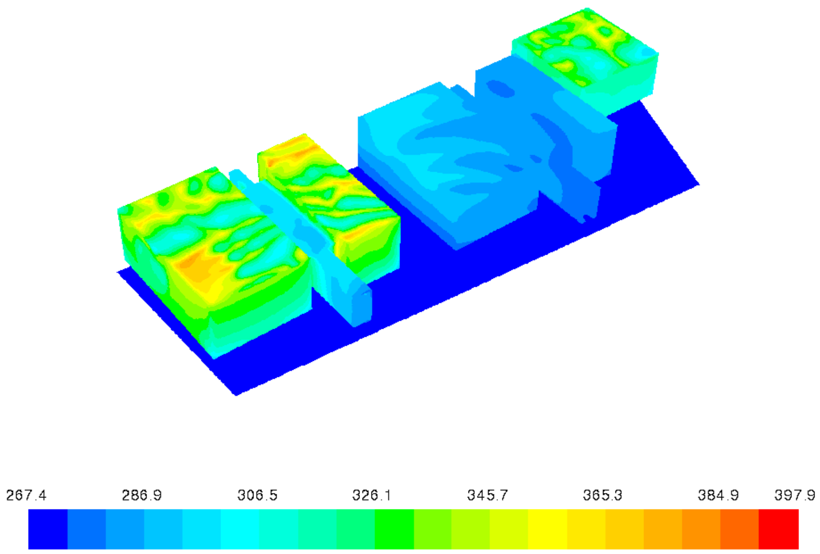
Stabilizer cavity with simplified actuating devices: EHA/EHA/ECU

With the MBSE model, the evolution of the temperature of the active EHA over the whole flight mission is shown below. All temperatures clearly increase during both ground phases as a result of medium to high SAT and low aircraft speeds. On the opposite, low outside temperatures and high aircraft velocities during cruise directly help reduce EHA temperatures. The steeper temperature rise during approach and landing than during takeoff is a direct consequence of the quick decrease of external heat convection following landing.

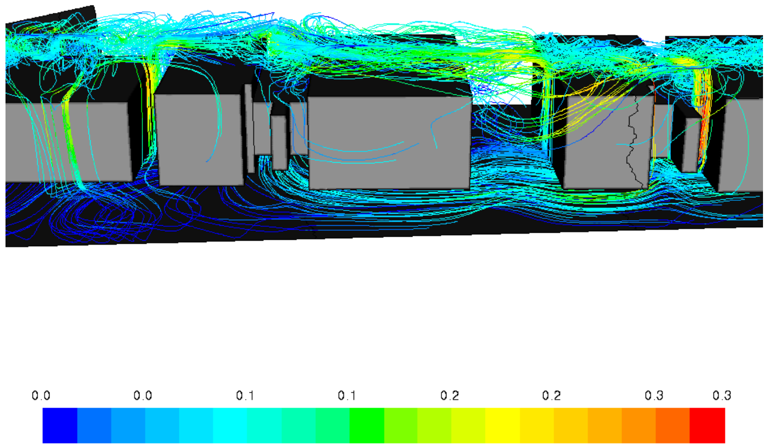


Time profiles of the active EHA lumped temperatures on HOT (top) and ISA (bottom) days, for a sealed cavity (no air ingestion)

The temperatures of the cavity bodies obtained from CFD analysis in an EHA-EHA configuration, on a HOT day, in steady state conditions, are given below as body averages to allow for a comparison with MBSE results.



Wall temperature on each electrical item in the cavity (in K), HOT day, sealed cavity, cruise conditions



Pathlines in the cavity colored by velocity magnitude (in m/s), HOT day, sealed cavity, cruise conditions

End of cruise conditions (t=76,7min) and landing conditions (t=95min) are given and compared with MBSE results in Table 2 and Table 3 respectively.

Temperature (°C)	**CFD**	**MBSE**	**Δ**
Mean EHA	51.9	54.3	**5%**
ECU	47	52.4	**11%**
Cavity	15.1	45	**198%**
Upper panel -internal	--	35.6	**--**

Upper panel -external	-3	-4	**33%**

Table 2 : CFD averaged temperatures (without solar radiation), steady state end of cruise conditions, sealed cavity, HOT day

Temperature (°C)	CFD	MBSE	Δ
Mean EHA	50.7	54.9	**8%**
ECU	59.6	55.8	**6%**
Cavity	50.5	53.6	**6%**
Upper panel -internal	--	53.2	**--**
Upper panel -external	50	50	**0%**

Table 3 : CFD averaged temperatures, steady state at landing conditions, sealed cavity, HOT day

The last part of the study focused on the description of a support to actuator design for thermal point of view.

Task 2.4 Management of EMC environmental aspects

- For T2.4.1 all activities have been done and the report has been delivered in August 2015.
- For T2.4.2 This task activities are also completed and 2 reports were submitted: D2.10 in July 2016 and D2.11 in August 2016.

In these final stages of the project, we have collected and processed data entries provided by TECNALIA and the TsAGI. Respectively, these data consists in functional links and electrical circuits of an ECU connected to an EMA (270 Vdc) and in the other case, functional links and electrical circuits of an ECU connected to an EHA (540 Vdc).

The first step consisted in evaluating from these input data the input/output impedances at pin levels of equipment to obtain an equivalent frequency model z(f) of all impedances.

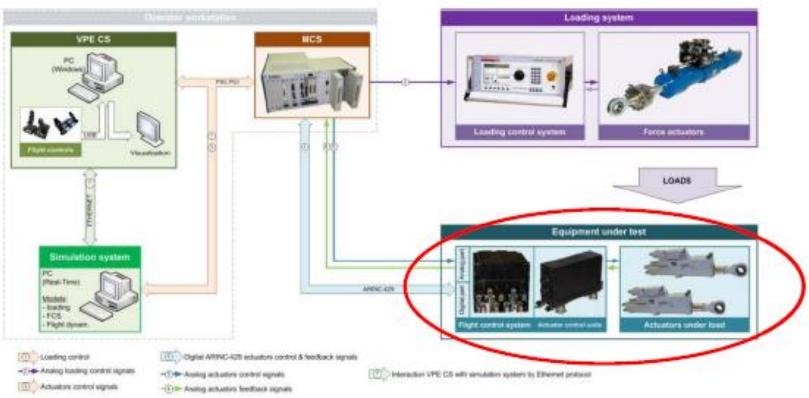


Figure 2 - EHA and ECU from TsAGI

In the diagram in Figure 2, we focused on the links between the ECU and the EHA and especially at the level of the connector of the EHA proposed by TsAGI brushless three-phase motor. We have then determined the equivalent circuit diagram seen from the connector of the 3 phases of the motor supply, as described in

Figure **3**.

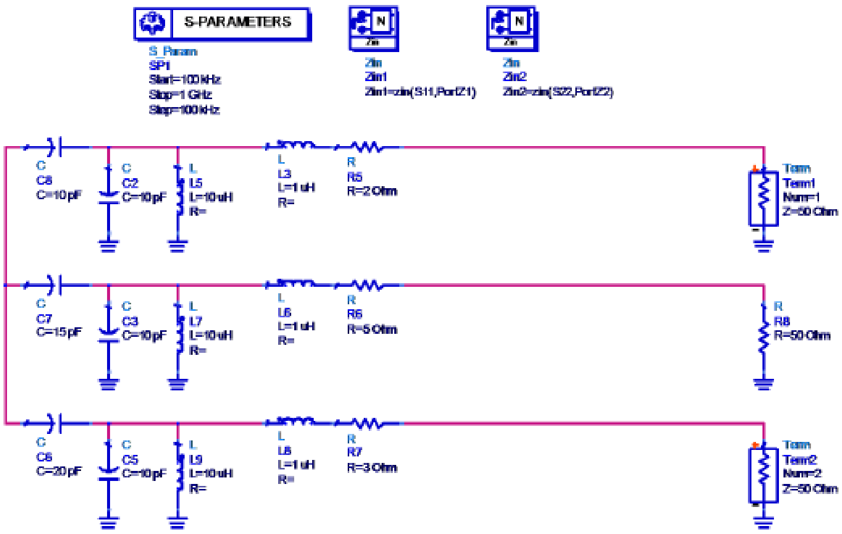
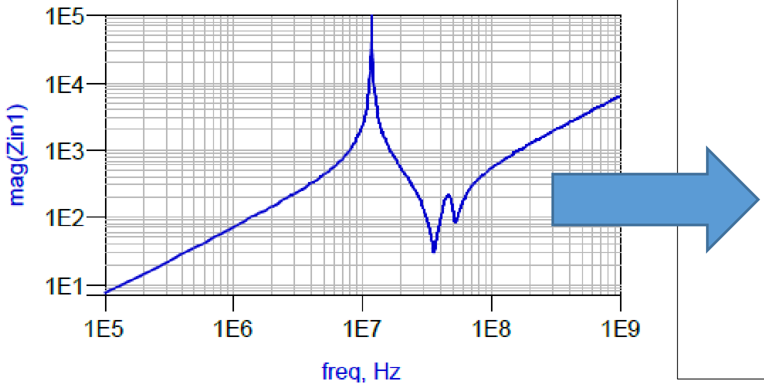


Figure 3 - EHA electric motor schematic for computing z(f) with the electric circuit tool.

In Figure 4, the result of the simulation represents a calculation of impedance versus frequency (f) at pin 1 level. Thus, this result is finally integrated into a scenario of EM calculation in order to compute the functional signals and EMC resulting constraints.



freq	Zin1
100.0 kHz	7.195 / 73.862
200.0 kHz	13.970 / 81.769
300.0 kHz	20.843 / 84.494
400.0 kHz	27.746 / 85.866
500.0 kHz	34.670 / 86.693
600.0 kHz	41.613 / 87.245
700.0 kHz	48.574 / 87.640
800.0 kHz	55.555 / 87.937
900.0 kHz	62.559 / 88.168
1.000 MHz	69.588 / 88.353
1.100 MHz	76.645 / 88.505
1.200 MHz	83.732 / 88.631
1.300 MHz	90.852 / 88.738
1.400 MHz	98.009 / 88.830
1.500 MHz	105.204 / 88.910
1.600 MHz	112.442 / 88.980
1.700 MHz	119.725 / 89.042
1.800 MHz	127.056 / 89.097
1.900 MHz	134.439 / 89.147
2.000 MHz	141.876 / 89.191
2.100 MHz	149.372 / 89.231
2.200 MHz	156.930 / 89.268
2.300 MHz	164.553 / 89.302
2.400 MHz	172.245 / 89.332
2.500 MHz	180.011 / 89.361
2.600 MHz	187.853 / 89.387
2.700 MHz	195.776 / 89.411
2.800 MHz	203.785 / 89.434
2.900 MHz	211.883 / 89.455
3.000 MHz	220.076 / 89.474

Figure 4 – Example of result of z(f) on EHA electric motor (magnitude on pin 1)

The next step has been to define our scenario of study. As explained in the project, only the elevators at tail level have been considered, then we have described the different functional links between the different equipment as shown in Figure 5.

The equivalent topology network has been described and implemented in the Onera tool (CRIPTE) and all inputs as the cross sections of cable bundles have been generated and calculated (see Figure 6). The equivalent impedances, described previously, have been also implemented as junction loads in the EM CRIPTE network. The same work has been performed to define the equivalent source model for the Onera tool (CRIPTE). This source model is classically based on specific measurements of noise source generated by the system. But at the end of the project, the measurements on the test rig could not be performed due to the delay on the availability of the test rig. Consequently, the equivalent source models were not fully completed.

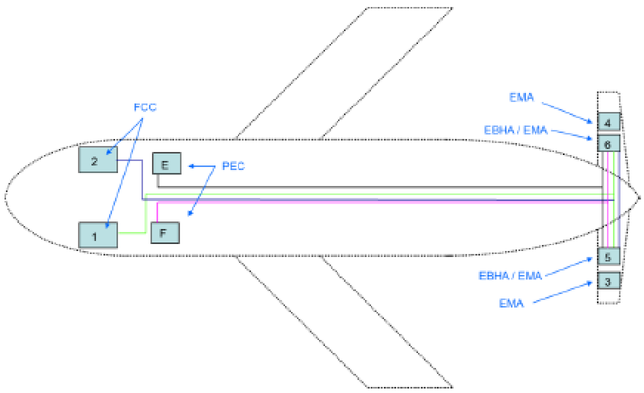
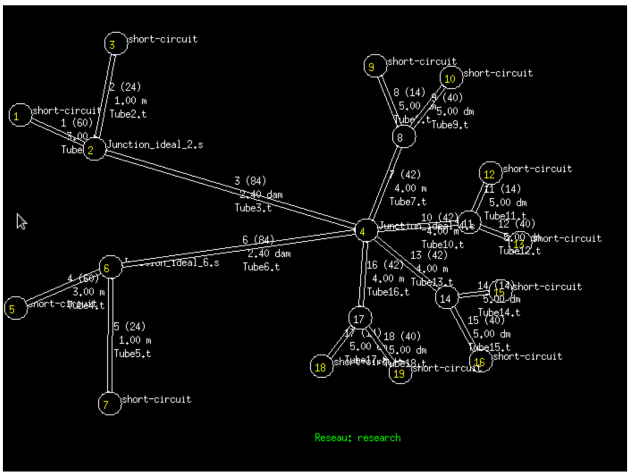


Figure 5 - Description of the studied configuration



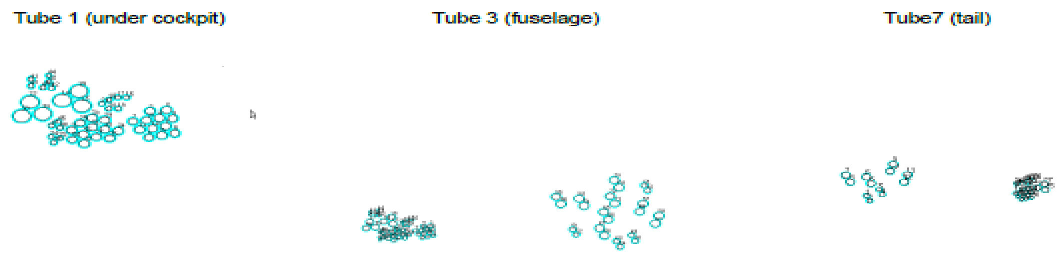


Figure 6 – Description of the equivalent topology network

Task 2.5 A/C with local hydraulic systems with pressure adaptation numerical modelling

The task is completely finished with the only participant TsAGI and two deliverables.

Within this task TsAGI proposed and described the approach (algorithm) of adaptation of pressure in local/zonal hydraulic supply system to the flight regimes. The use of developed algorithm allows to implement «power on demand» concept for hydraulic systems thus reducing power consumption by flight control actuation system..

After performing test simulation with the A/C continuous take-off with one engine failure scenario, the complete flight mission was simulated with SMART local hydraulic supply system operating. This flight mission was prepared by TsAGI with the use of one of its flight simulator for the take-off and landing with s-manoeuvre flight phases through pilot-in-the loop simulation and after that – ascending, cruise flight and descending through software-in-the-loop simulation. Basing on the simulation results and the models description the deliverable D2.13 was prepared at 100% readiness.

To summarize WP progress the main significant results can be described as follows:

1. The final actuators (EMA and EHA) models are developed with Simulink software.

2. The closed loop «aircraft – flight control system – electrical actuator (EMA or EHA)» control quality and stability margins are checked and verified basing on the aerodynamic model of modern A/C and its flight control system and actuators models prepared in Simulink;

3. Complex thermal model of the elevator actuators cavity developed in AMESim;

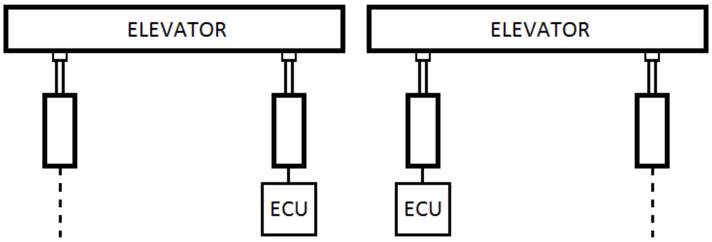
4. Algorithms of hydraulic supply system adaptation to the flight mode of an A/C. The simulation of A/C with SMART local hydraulic supply system operating over the complete flight was performed.

The main reason for the variations between performed and planned simulation activities is the delay in EHA and EMA manufacturing due to underestimated ppms and several managerial issues (for EHA only)..

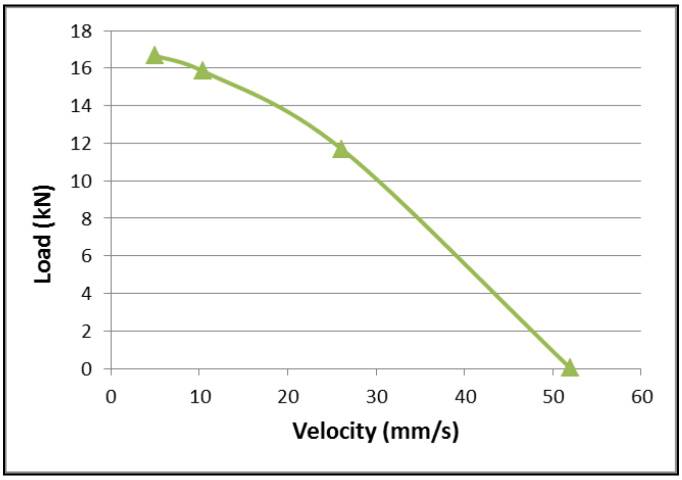
Task 3.1 EMA for flight control applications development

This activity is under CESA leadership and according to the recovery plan presented. All activities have been recovered and actuator and their parts have been manufactured.

As proposed in WP 1.2 (Trade-off and Analysis of architectures), the final choice was an elevator with two actuators both in active configuration. The pitch control is achieved by means of two elevator panels, left and right hinged on a fixed horizontal stabilizer surface.



Some key Performance requirements to be introduced Electro-Mechanic Actuators (EMA) were defined. The loads needed for the elevator surface are based on control surface requirements derived from work package 1.

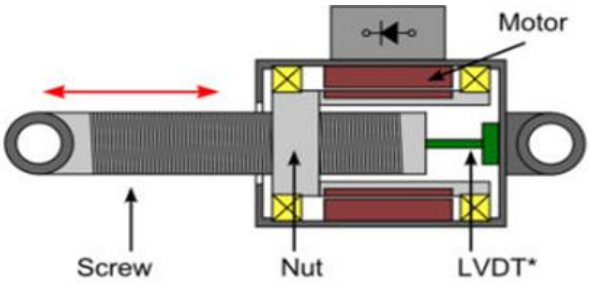


Temperature requirements, electrical characteristics and motor performances were also included.

The final EMA architecture is completely defined. The EMA is based on a direct drive architecture with an inverted ball screw in order to protect the recirculating ball system from external agents as dust, ice or water. Two architectures are studied. Direct drive architecture is chosen over gear drive configuration due to the following advantages:

- Less volume, more compact
- Better resolution
- Less mechanical parts
- More efficiency & less jamming probability

- Less need of maintenance
- Lower weight and space envelope



EMA modes of operation are also studied and as a conclusion the EMA will work under normal, fail-safe or emergency mode. Ballscrew specification (Del 3.4) and BLDC frameless motor specification (Del 3.6) are also in progress but with some delay.

Task 3.2 ECU at Actuator level development

ECU development is under Tecnalia leadership and ECU main characteristics were analysed. The ECU will be based in a modular design, with three independent electronic boards:

- Control board
- Power board
- Anti-jamming system board

Including next sensors:

- Linear position sensor
- Angular position for the motor
- Temperature
- Isolated digital input/output

The ECU hardware for each of the board will contain

- Control board
  - Microprocessor
  - Watchdog
  - Signal conditioning
- Power board:
  - Customized power module
  - 6 IGBTs for 3 phase BLDC motor control

- Precharge DC bus capacitor
- 270Vdc power switch

- Anti-jamming board:
    - Unique PCB for anti-jamming control
    - DSP and power module integrated in this PCB
    - Independent board

While the Software main characteristics are

- Control board software:
    - Safety:
        1. PBIT(Power up built in test),
        2. CBIT(Continuous built in test)
        3. Health monitoring
    - Communications (SECU, data management)
    - Functionality
    - Control algorithm
        1. Three loop architecture: position, speed and torque
        2. Anti-vibration control algorithm
        3. Field weakening algorithm
- Anti-jamming board software:
    - Master and slave activation modes
        1. Master: autonomous activation
        2. Slave: remote activation (control board, SECU…)

- The complete ECU hardware design is closed and consequently, this task is finished. The deliverable 3.9: ECU hardware design report summarizes the task developed.
- From software point of view, the 100% of the software has been implemented as deliverable 3.12 details.

Task 3.3 System Electronic Control Unit for Flight Control applications development

SECU development is under UMBRA leadership. The task is completely finished with the design of a customized hardware and the development of the control software. Control software routines and functionalities were tested on a dedicated test environment built with National Instruments hardware.

The SECU will be designed and developed to implement the following functionalities:

- manage the commands sent by Flight Control Computer (FCC), via a redundant Field Data Bus
- control the position of whole aerodynamic surface according to Force-fighting close loop architecture of all actuators.

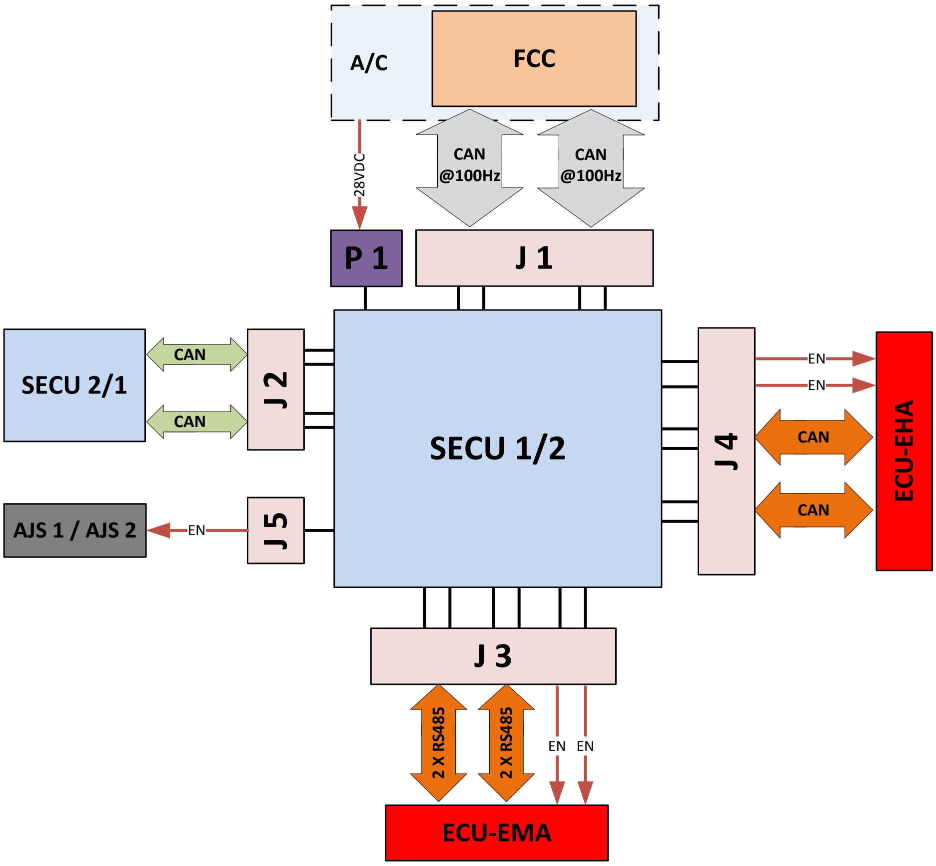


Figure 7 – SECU connections

The main functions of the SECU:

- To control force fighting
- To compare the MON e CON signals received from ECUs
- To manage the HUMS signals received from ECUs.

The SECU is connected to:

- FCC: to receive the commanded position for the surface and to send to FCC the operational mode of SECU;

- Other SECU: to receive the status signals and to send its status signals;

ECU-EMA (or ECU-EHA):

- to receive all the sensors signals to evaluate force-fighting;
- to elaborate HUMS signals;
- to compare the CON and MON signals and evaluate if these values are within a threshold (TBD) to keep the ECU working in Normal mode;
- to command DAMPING or AJ mode if a mismatch (TBD) between MON and CON signal occurs;
- to send the position and velocity commands, the enable commands to start CON and MON signals monitoring and the correction factor for force fighting;
- to send the AJS-EMA (or AJS-EHA) enable signal.

The SECU receives the 28VDC power supply from A/C.

The SECU hardware is composed by the following sections:

- Digital Module: the module includes all the digital logic to perform FF (force fighting) function, MON/CON feedback comparison and HUMS.
- Power Management Module: the module is in charge to generate the local power supplies.
- ECU-EMA Interface: the module is used to adapt and to isolate the signal exchanged between SECU and ECU-EMA
- ECU-EHA Interface: the module is used to adapt and to isolate the signal exchanged between SECU and ECU-EHA
- SECU2 Interface: the module is used to adapt and to isolate the signal exchanged between SECUs.
- FCC Interface: the module is used to adapt and to isolate the signal exchanged between SECU and FCC.
- Monitoring Module: the module is in charge to monitor power supply and internal voltages and send the conditioned signals to the Digital Module

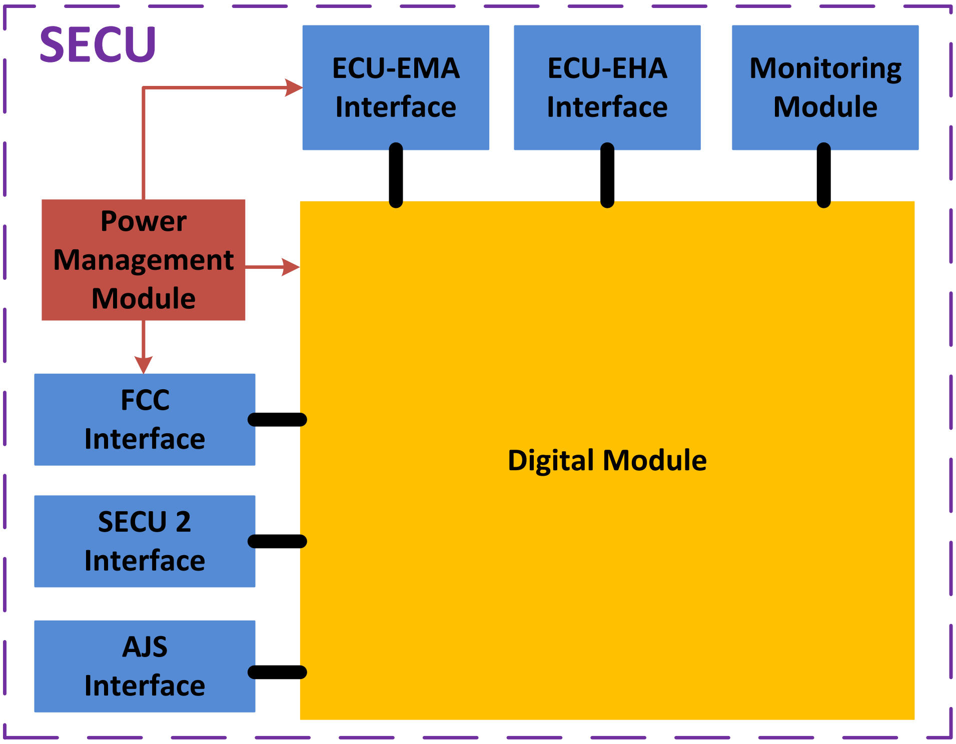


Figure 8 – SECU Architecture

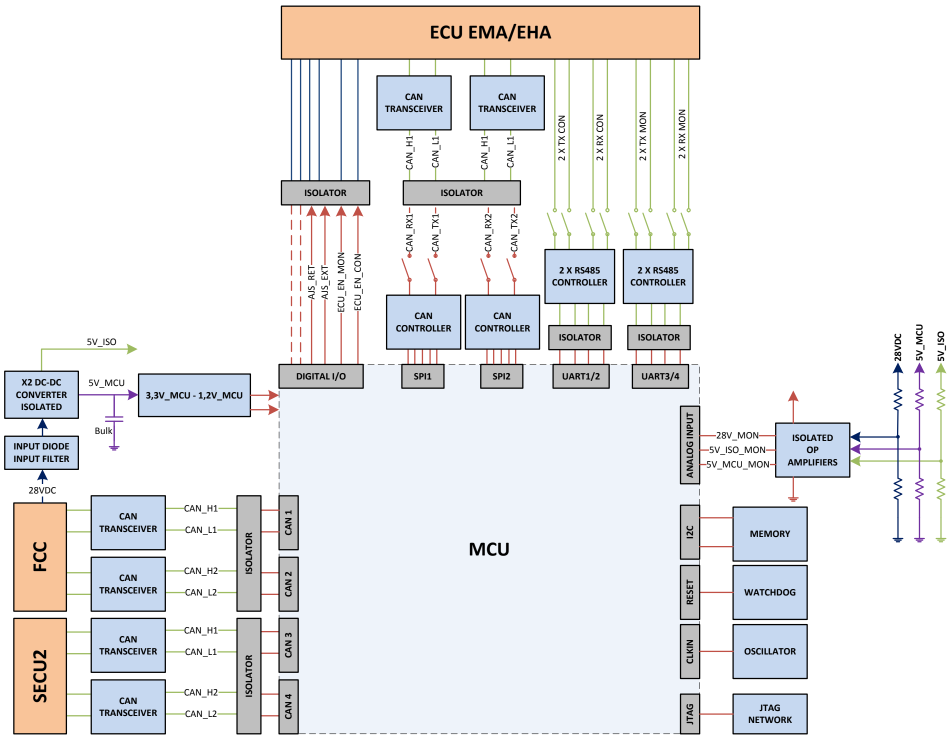
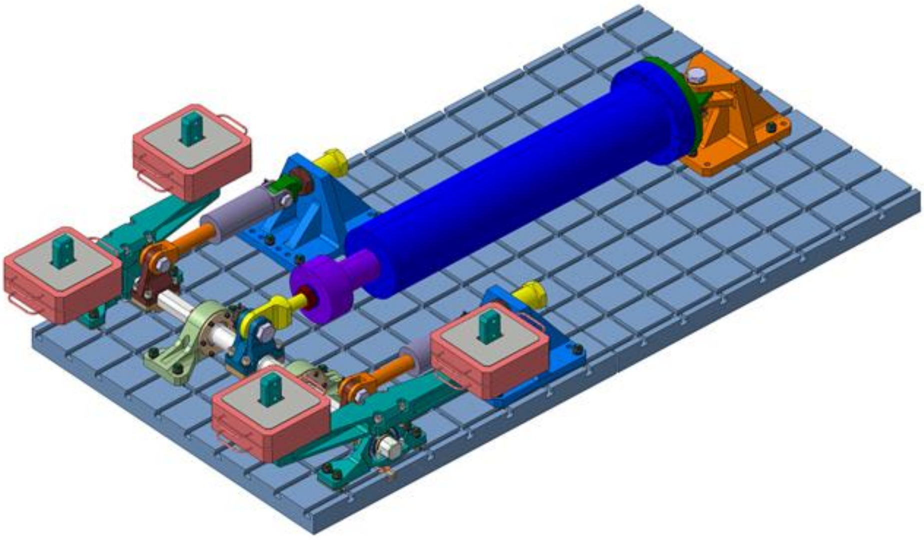


Figure 9 – SECU Hardware Scheme

Detailed description of SECU hardware and software design is provided in the document D3.11.

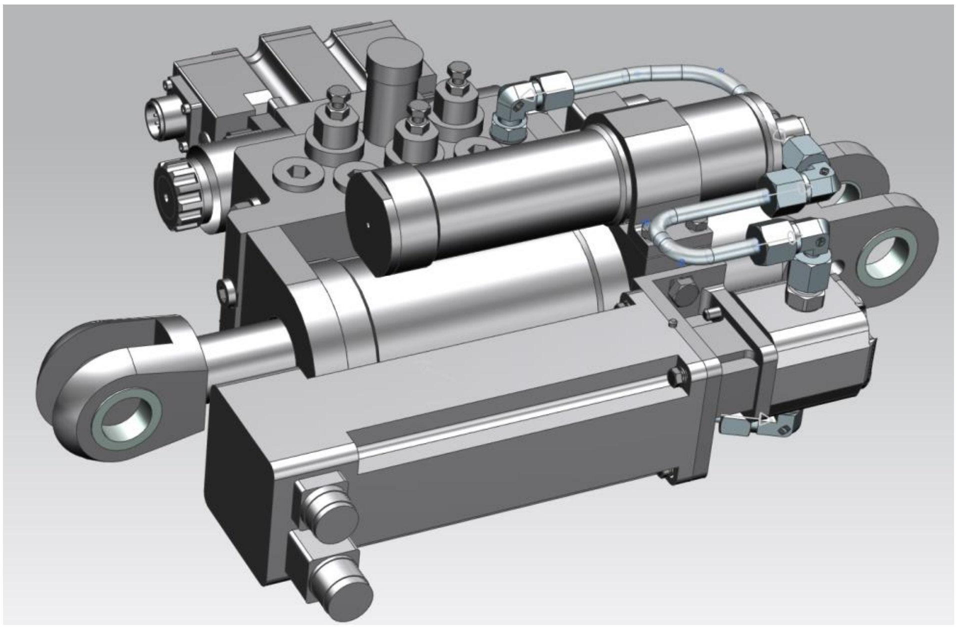
Task 3.4 Test Rig module design

Basing on several draft designs for the test-rigs proposed and discussed inside the consortium the selection of final test bench equipment was done (task 3.14) and the corresponding deliverable D3.14 with the detailed description of the test-rig components was prepared. The test-rig of TsAGI principal scheme is shown below.



Task 3.5 EHA with combined control development

Basing on the conceptual and draft design of EBHA for elevator control system developed by MAI the activity continued with the detailed design of the actuator. Its overall view is presented in the figure below.



The EBHA manufacturing was started in 2016 despite the activity was not planned to be done in the frame of RESEARCH project and it’s expected to be delivered to TsAGI till the end of the year.

Work Package 4 – Components, systems and rigs manufacturing and verification

Task 4.1 EMA manufacturing and validation

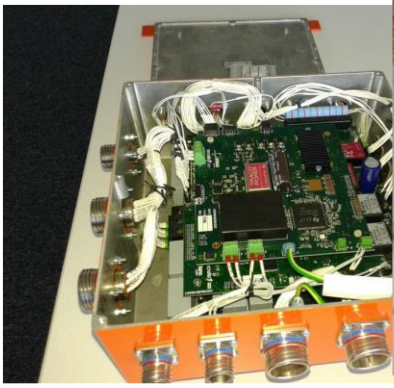
A demonstrator similar to the final EMA actuator have been used in order to complete the integration with the ECU system. After system assembling the EMA/ECU has been validated. EMA and ECU set works properly. The main target of the project: to develop, tune and validate a complete EMA + ECU set capable of applying movement to a primary control surface in a medium range aircraft, in terms of control and dynamic has been achieved.

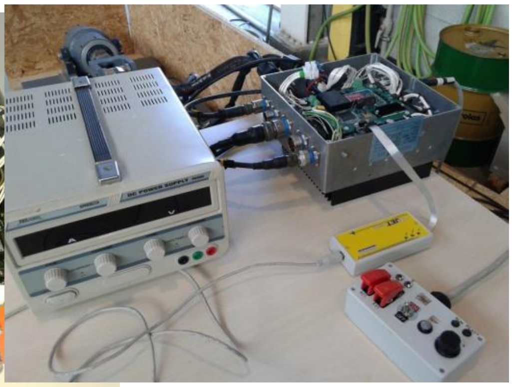
Based on the obtained results, it can be concluded that system works at a frequency up to 1Hz for displacements up to 10mm. Maximum amplitude of displacement is 30 mm at a frequency up to 0.15Hz.

All intended tests were performed although some of them were failed showing undesired current peaks that limits the achievement of full performances. Future works for system improvement will be oriented to current peaks reduction by means of using pre-filter, signal saturator implementation, or other solutions implemented in hardware of ECU.

Task 4.2 ECU manufacturing and validation 100%

The complete ECU system made up of three PCBs and electronic cabinet or box has been manufactured. After system assembling the ECU has been validated.

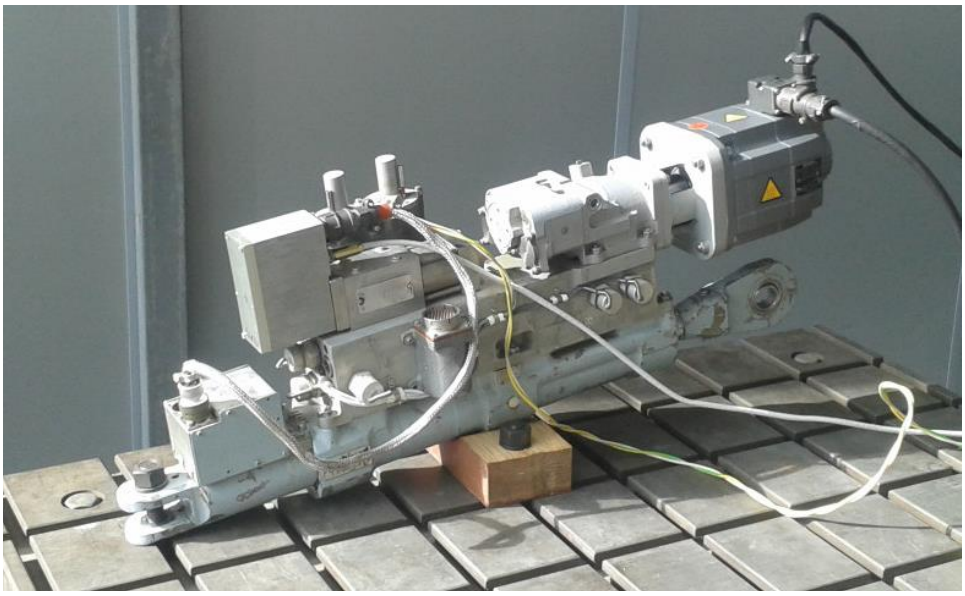




The complete ECU validation process and results are detailed in deliverable 4.2.

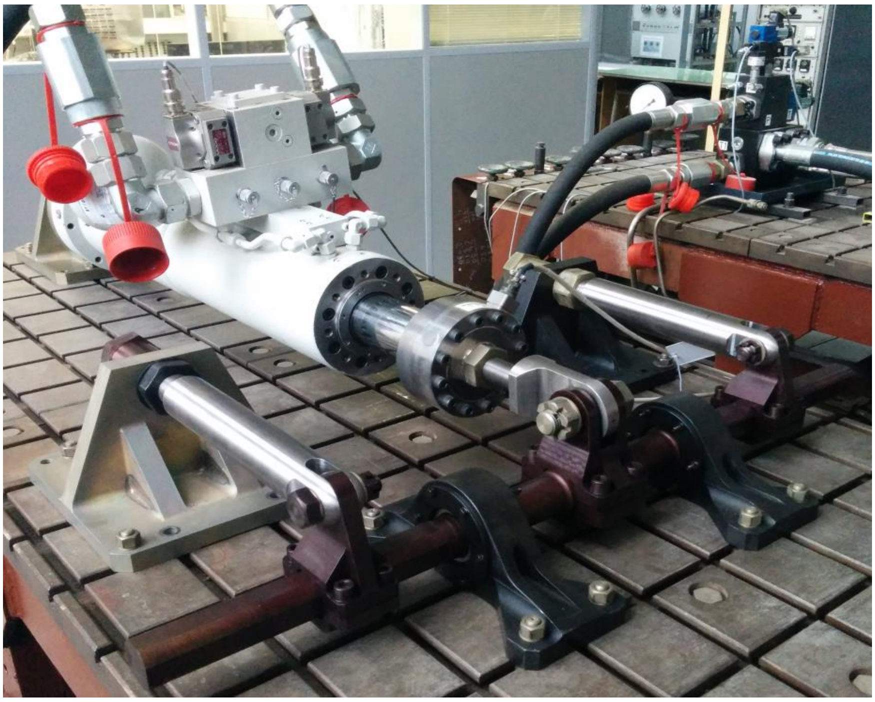
Task 4.4 EHA Demonstrator Unit

The EHA demonstrator unit was upgraded by Voskhod factory (TsAGI's subcontractor) as it was originally planned. The actuator was delivered to TsAGI in the mid 2016 after preliminary testing and tuning of its electronic control unit at Voskhod. The delay of the delivery of the actuator was due to the motor-pump assembly fault with the necessity to replace it before the delivery. The overall view of the actuator on the TsAGI facilities is shown below.



Task 4.5 System test-rig manufacturing and set-up

Basing on the test-rig design one test-rig was manufactured and assembled in TsAGI (task 4.5). The figure shown below contains the view of the test-rig but without installed inertial elements on the ends of the twisting shaft (see the figure with the design (task 3.4)).



The second test-rig was planned to be delivered to CESA from Umbra but the activity was cancelled.

Work Package 5 – System validation and assessment

Task 5.1 Validation test plan and procedure

The task is completely finished with two deliverables submitted to EC: D5.1 in June 2015 (10 months delay to original schedule and 3 months delay to recovery plan) and D5.2 in February 2016 (3 months delay to the original schedule).

The D5.1 delivery delay to the recovery plan appeared due to negotiations about the test-rig and testing location which was closed by the decision to use the Umbra's test-rig in CESA facilities.

In addition the 2nd issue of the D5.2 was released in March 2016 with some additional changes, but the overall agreement on the testing campaign and test parameters are archived by the partners.

.

The deliverable covers main aspects of testing flight control actuation system which was under development within RESEARCH project. These tests can be briefly described in the following way:

- Acceptance test procedures & testing of performances (separate for EMA and EHA);
- HUMS testing;
- Safety testing on actuator level;
- System testing:
  - Force fighting;
  - Safety testing on system level;

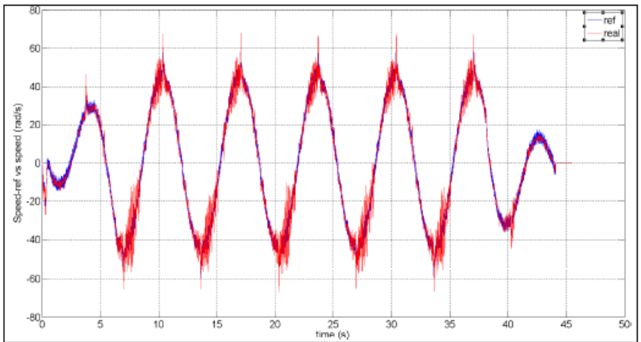
The main reason for the deliverable D5.1 delay is the difference in expectations of partners from the validation campaign as well as not taking into account in very detailed way all the aspects of system testing in the beginning of the project.

Task 5.2 System Test Execution, Validation and Demonstration phase

Based on extensive testing in the laboratory the EMA and ECU performance has been tested without SW limitation. First off all, the maximum current which controls the torque production has been increased to 100A. In normal operating conditions the required current to achieve the nominal torque must be lower than this value.

The following conclusions can be drawn from the acquired data:

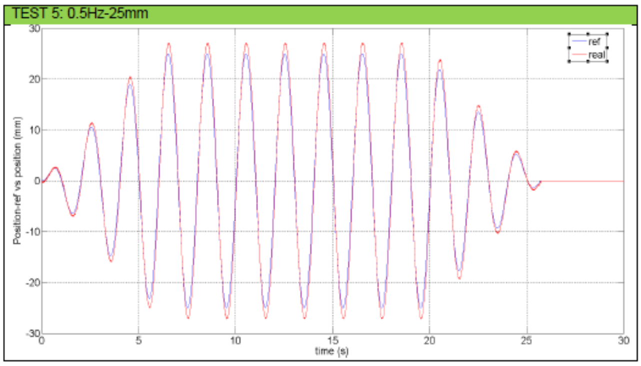
- As can be seen in current and Dc bus measurements a considerable amount of noise is captured, these noise generate alarm in the control system due to current measured by the DSP goes beyond the maximum current limit. At the present the causes of the noise are unknown. In some graphs (not always), the noise appear when the position value reach zero position which is the maximum speed operating point of the EMA.
- Modifications in control allows the improvement of performances achieved by actuator in two times. Better adjustments of control achieving higher effective current in motor could also improve the performance in actuator.
- At low frequencies, 0,25Hz and 0.5 Hz, the control based on current and speed loops works quite good. The current response could be increase improving some HW components to increase the rms current demand up to 40 Arms in motor.
- At higher frequencies, 1Hz and 2Hz, the control based on current and speed loops works good. The positions response has a maximum phase lag of 20 degrees and overshot of 20%, this response is limited by the performances of motor by the maximum rotational speed command.



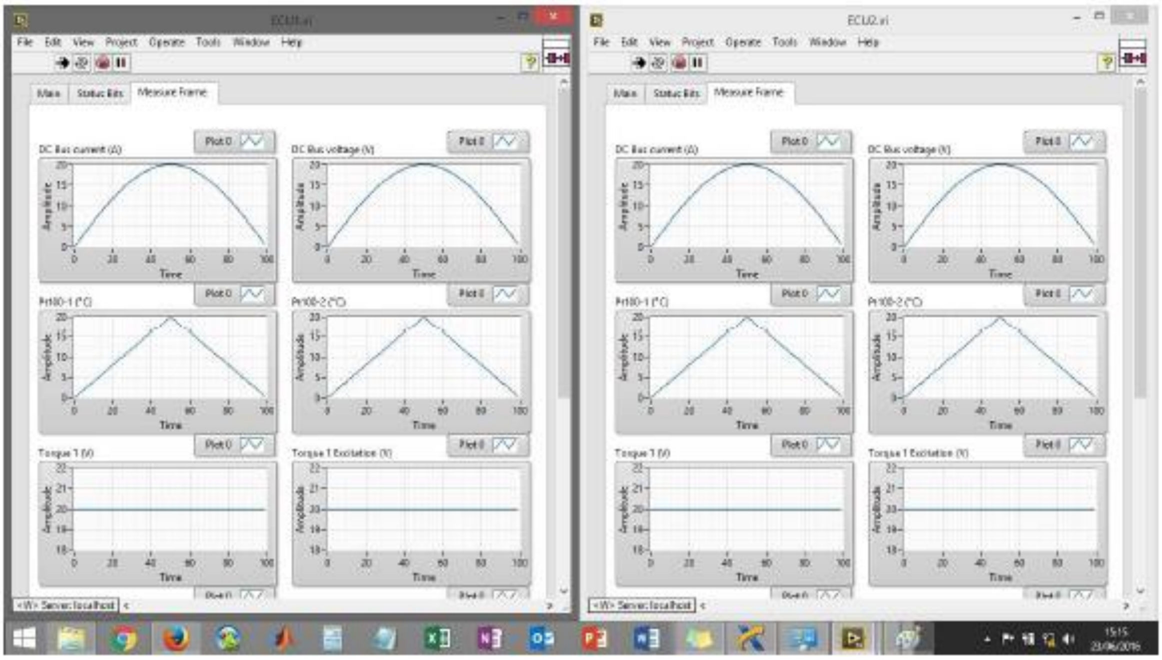
Comments:

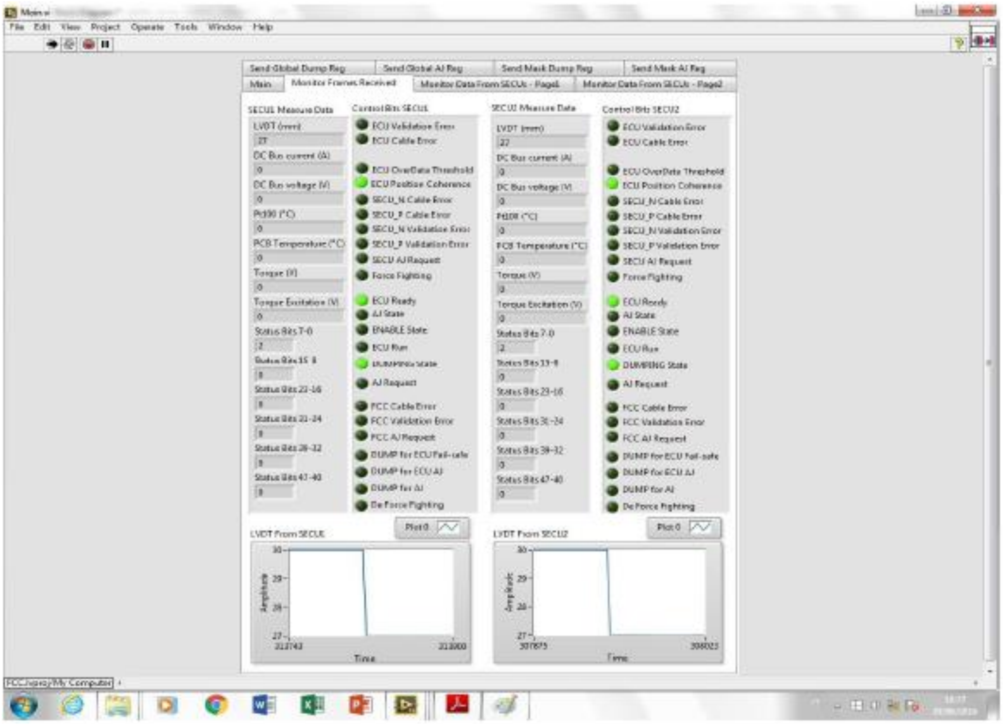
As is shown, satisfactory results are obtained.

TEST 5: 0.5Hz-25mm



SECU was tested to send to command to the whole system. The FCC creates and send the position setpoint, that is sent by SECU to ECU which sends the measurement data to SECU. On the same time the two SECUs continue to exchange data.





Task 5.3 Results analysis and conclusions

The feasibility of the two different architectures of EMA or EHA driven elevators has been evaluated based on the development reports of WP3 and 4. The feasibility analysis takes also into account the safety analysis of D1.5, the A/C motion analysis of D2.6, the thermal analysis of D2.8, and the electromagnetic analysis of D2.11 and also includes a rough A/C weight estimation analysis. The test results of D5.3 are mentioned, but could not be integrated into the overall evaluation due to its late delivery.

Work Package 6 – Dissemination and Exploitation

Both tasks (6.1 and 6.2) are completed in three planned deliverables

- 6.3 - Final version of the Awareness & Dissemination plan
- 6.4 - Exploitation plan
- 6.5 – Project website was started at the following address: www.research-project.aero

4.1. Potential Impact

The Reduction of fuel burn has become a priority for most aircraft (A/C) operator due to environmental and cost implications. Such interest has made the aerospace industry have to look for some sources to minimize fuel consumption, concluding that the approach towards a more electrical aircraft, i.e. use of electricity to operate the consumers, could provide some benefits.

RESEARCH project offers a great opportunity to enhance the European economy making it more innovative, productive and competitive using fewer resources, reducing environmental impact and combating climate change. It will also contribute to developing new technologies that will enable European industries to compete in a global market as the aeronautical one, create jobs and support growth of EU economy. **RESEARCH** project will contribute in several ways to fulfill the expected impacts described below.

- **Strengthening the European competitiveness**

Global Market Forecast states that order book value will be driven by producing ecoefficient aircrafts, which will involve producing highly efficient aircrafts, engines, actuators and feed-drives. Therefore, it will be crucial for the Companies involved in the Aeronautical Value Chain to conduct reliable and efficient components and undergo deep validation tests on the new developments for those eco-efficient aircrafts, and the cornerstone for that efficiency will lie in having safe, and reliable technological prototypes and validation tests for those aircraft components.

In this global scenario, the RESEARCH project concepts will have a remarkable impact on the Competitiveness Position and Sustainable.

The technologies presented will open the door to high performance, environment friendly and economic aircraft operation by better exploiting available weight reduction potentials of new design philosophies without compromising the existing, high aerospace safety requirements. These technologies are also enabling contributions to sustain or even improve safety of aircraft operation by means of more affordable and efficient integrated sensing / actuating technologies. Through these new technologies and respective products, Europe will become more independent from North American aeronautics industry.

- **Improving innovation capacity**

The specific innovation capacities of each technology to be developed under the framework of RESEARCH will radically shorten the gap between concept and product.

This effort will give as results new and innovative products that will be based in Europe and will help to increase European competitiveness.

To address the industry competiveness, RESEARCH will enable the European aero-equipment industry to provide the solutions that in turn enable the European aero-

SYSTEMS industry to provide air framers with new systems of significant gains in acquisition, operation and maintenance costs.

- **Protecting the environment and the energy supply**

Dealing with environmental impact, a significant contribution is expected from the manufacturing phase energy consumption reduction, and the decrease of the thickness reduction of metallic components.

Ecological production will also be a side-effect of the developed technologies, as the substitution of trial by the use of simulation-based design as well as the reduction of waste materials and products will reduce the energy consumption related to these processes (as well as the associated energy costs). In this manner, RESEARCH project will contribute to achieve the objectives of reducing the aircraft operational cost and reducing the environmental impact by providing manufacturing capabilities to fabricate metallic system and equipment components and structures. IATA figures show that if an aircraft reduces its weight by 100 kg, it will save four kg of fuel in each flying hour, and that every kilogram of fuel saved reduces CO_2 emissions by 3 to 3.3 kg, that is, 0,12kg CO_2 emissions are produced per kg of weight of the aircraft and flying hour.

- **Ensuring safety and security**

The electrical components used in this project, allow a higher integration of sensors for their monitoring, providing a better view of their performances and structural integrity (from a safety point of view) or achieving an improved degree of "intelligence" improving the integration within the controlling system or aircraft (this feature facilitates its use in UAVs, which are required to be able to take decisions based on the information received from the integrated sensors).

The goals mentioned above will be developed through improvements in the **Flight Control Actuation Systems** by:

- Development of efficient, reliable and safe electromechanical systems that will impact their market entry into the more electric aircraft;
- The development of smart actuation will help to ensure reliability and safety of the aircraft industry;
- Highly integrated actuation systems able to alleviate loads at any stage will positively impact the efficiency of the aircraft with less fuel burn and less CO_2 emissions;
- Electromechanical Actuation system is a vital company strategic line for I4A cluster. Therefore, the project will have a strong impact on their businesses.

- **Development of international (EU-RU) partnership for further scientific and industry collaboration**

The RESEARCH is the first collaborative project between European Union and Russia in the field of technologies development for More Electrical Aircraft. On the one hand such multinational (and so multicultural) projects include lots of additional inter-cultural barriers so leading to additional project risks. At the same time in case of successful managing these risks and overcoming barriers mentioned, it potentially leads to good outcomes basing on synergy effect of two different aerospace engineering schools.

4.2. Use and dissemination of foreground

Dissemination of Foreground

This section outlines the dissemination activities carried out by project partners. It provides an outline of what is planned and what has been done. Main activities centre around the participation in fairs, exhibitions and specific events, preparation of papers and articles as well as meetings with companies mainly from the aeronautical sector.

Concretely, the aims of Dissemination are to communicate the objectives and results of the project and increasing public awareness and interest to plan and facilitate the transfer of knowledge to the Aeronautical and Space community, showing the details of the strategy that will be followed during the project period, in order to present the results achieved in the various activities in which the project is involved to the public (ex. Potential users, beneficiaries, etc.).

Diverse dissemination activities have been pursued: from distribution of brochures in renowned conferences, to the submission of results to leading journal/conferences in the area.

To obtain as much diffusion of the project as possible, across all areas, several forms of dissemination media were used to achieve the objectives:

- Brochures and Presentations
- Related deliverables
- Papers
- International conferences and workshops
- Preparation of articles for specialized media and newsletters

Image 1. EMA actuator displayed in UNVEX16 exhibition

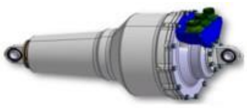
Image 2. EMA actuator displayed in Farnborough International Airshow 2016, and the poster that decorated the stand

Image 3. Poster that decorated the stand in Aerospace Defense & Meetings Sevilla 2016.

Image 4. EMA actuator displayed in Le Bourget 2015

4.3. *EXPLOITABLE KNOWLEDGE AND ITS USE*

CESA has actively participated in several EMA development and industrial projects apart of Research project that will help to better ensure exploitable activities. The most relevant are highlighted in the following table.

Project Name	Description	TRL	Role
ArmLight (Clean Sky – FP7)  EU Contract 298176	EMA for the main landing gear of the Green Regional Aircraft. Main characteristics are: -Linear direct drive electromechanical actuator. -One DC power supply for normal extension/retraction operation. -A built in test (BIT) is implemented within the ECU with self-monitoring capability. -Anti-jamming system located inside the rod.	Current TRL3 and will be TRL4 at the end of the project (2015)	Development, manufacturing and testing of EMA and ECU
ACTUATION 2015  EU grant number 284916	Develop and validate standardized, modular and pooled EMA for the first time for all airframe systems (flight control, high lift, main landing gear, nose wheel steering, door locks, thrust reversers) and all types of airframes (business, regional and large aircraft and helicopters.	TRL5	New material /coatings and Regenerated Power Management
SINTONÍA (Spanish National R&D CENIT) 	EMA to extend and retract the door of the Nose Landing Gear. Main characteristics: -Single electric motor -Linear actuator with single screw architecture and an anti-jamming screw system. -Anti-jamming system	TRL3	Development, manufacturing and testing of EMA and ECU
PROSAVE[2] (Spanish National R&D CENIT) 	Actuator for aircraft cargo door -Two electromechanical actuators. The system can operate with both EMAs simultaneously or just one EMA. -Equipped with sensors for current, voltage, applied load, motor and ECU temperature. -Equipped with a normally closed brake to leave the system locked in the case of power supply	TRL3	CESA Development, manufacturing and testing of EMA and ECU

Project Name	Description	TRL	Role
	absence.		
HOIST (AiM MRTT boom system) 	EMA to lower and raise the Tail Boom (a telescopic rigid beam refueling device) of the A330-MRTT (Airbus Defense and Space) -Redundant electric motor of 10 kW each. -Differential and two stage reduction gearbox with an alternative manual drive mechanism and position sensing capabilities to transfer torque to a wire rope cable installed in an output drum.	A330-MRTT	CESA: Design, manufacturing and qualification of EMA.
ERA (AiM MRTT boom system) 	Extension-Retraction actuator for the Tail boom (a telescopic rigid beam refueling device) of the A330-MRTT (Airbus Defense and Space) -Redundant electric motor of 10 kW each. -Differential and two stage reduction gearbox linked though bevel gears with an alternative manual drive mechanism and position sensing capabilities to transfer torque to a double chain installed in a sprocket output.	A330-MRTT	Design, manufacturing and qualification of EMA
Emergency Unlock Actuator - A400M 	The EMA is an electrical element composed by two motors connected by a gear box to have only one output shaft. The gear box is designed to allow the sum of the speeds and to keep the torque when one or two motors are running. To allow the irreversibility, one electromagnetic brake is mounted in each motor.	A400M	Development of EMA and ECU.
M1 positioners for the GTC telescope. 	-Linear actuators used for Active Stabilization Subsystem of the Primary Mirror GTC telescope. Output Load = 1800 N, Total Stroke= 1.6 mm, Resolution = 1.2 nm -Electromechanical stage and Output hydraulic stage to reduce the displacement of the electromechanical stage and amplify the output force.	Operating in Grantecan Telescope	Design, manufacturing and qualification of EMA and ECU of M1 positioners
EELT positioners	“Soft” actuator, based in a dual stage design, Output Load = 880 N, Total Stroke = 15 mm,	TRL4	Design and manufacturing of the EELT positioner

Project Name	Description	TRL	Role
	Resolution = 1.7 nm, Precision = 5 µm -A high bandwidth actuation device, VCA (Voice Coil Actuator). -A gravity off-loading device to remove the static force.		prototypes

In addition to the experience on EMAs for Primary flight controls, CESA meets the skills required for the systems to be implemented into a flight demonstrator.

The companies of the consortium have new opportunities in both European and local research and development programs. Thanks to the development made within this project new opportunities have been opened for the partners in Cleansky2. In particular CESA is responsible of the development of 4 EMAs for ailerons, spoilers, winglet tabs and flap tabs.

The project aims to develop complex and highly integrated flight control systems for an innovative new wing of the Turboprop Regional Aircraft that will bring significant progress beyond the current state of the art.

Finally, the project development had a significant impact on consortium technical knowledge and background, providing new commercial opportunities not only in the European market, but also in emerging economies markets.

Section A (public)

This section includes two templates

- Template A1: List of all scientific (peer reviewed) publications relating to the foreground of the project.
- Template A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[5] (if available)	Is/Will open access[6] provided to this publication?
1	*Electromechanical actuator with anti-jamming system for safety critical aircraft applications*	*Andrés Jiménez, Eva Novillo, Francisco Aguado, Esteban Morante*			*Recent Advances in Aerospace Actuation Systems and Components (R3ASC14) conference*	*Toulouse, France*	*2014*			yes
2	*Health and Usage Monitoring System (HUMS) Strategy to enhance the Maintainability & Flight Safety in a Flight Control Electromechanical Actuator (EMA")*	*Ricardo de Arriba, Alberto Gallego*			*Third European Conference of the Prognostics and Health Management Society*	*Bilbao, Spain*	*2016*			
3	*Electro Mechanical Actuators for Aircraft eRudder and Landing Gear Including Innovative Anti-jamming Solution*	*Andrés Jiménez, Eva Novillo, Francisco Aguado, Joseba Lasa, Iñigo*			*Recent Advances in Aerospace Actuation Systems and Components (R3ASC16) conference*	*Toulouse, France*	*2016*			

[5] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[6] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

		Eguizabal, Iraide Lopez								
4	*Electrified FCAS architectures weight and safety analysis*	*Anton Steblinkin, Alexey Skryabin, Vladimir Kuvshinov*			*Aviation and Space Technologies (MAI international conference*	*Moscow, Russia*	*2014*			
5	*Safety & Energy Efficiency Research on Advanced More Electrical Flight Control Actuation Systems for Short/Middle Range Passenger Aircraft*	*Anton Steblinkin, Vladimir Kuvshinov, Evgeny Erofeev, Leonid Khaletsky*			*More Electric Aircraft 2015 Conference*	*Toulouse, France*	*2015*			
6	*Research of Aircraft Flight Dynamics Peculiarities Due to the Using of Electric Actuators in Control System*	*Vladimir Kuvshinov*			*More Electric Aircraft 2015 Conference*	*Toulouse, France*	*2016*			
7	*RESEARCH project*	*Ricardo Arriba, Alberto Gallego*			*Aerodays London*	*London, UK*	*2015*			
8	*Local hydraulic system with adaptive pressure control for long-haul aircraft*	*Evgeny Erofeev, Anton Steblinkin, Roman Terekhov*			*Hydraulics conference (Bauman Moscow State Technical University conference)*	*Toulouse, France*	*2016*			
9	*Aileron actuator housing bay flight mission thermal integrated analysis*	*Gregoir Lenoble, David Donjat, Anton Steblinkin, Andres Jimenez*			*Recent Advances in Aerospace Actuation Systems and Components (R3ASC16) conference*	*Toulouse, France*	*2016*			
10	*Research of Aircraft Flight Dynamics Peculiarities Due to the Using of Electric Actuators in Control System*	*Vladimir Kuvshinov*			*Recent Advances in Aerospace Actuation Systems and Components (R3ASC16) conference*	*Toulouse, France*	*2016*			
11	*Local hydraulic system with adaptive pressure control for long-haul aircraft.*	*Evgeny Erofeev, Anton Steblinkin, Roman Terekhov*			*Hydraulics conference (Bauman Moscow State Technical University conference)*	*Moscow, Russia*	*2016*			yes

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[7]	Main leader	Title	Date/Period	Place	Type of audience[8]	Size of audience	Countries addressed
1	*Conference/Forum*	*Tecnalia*	*More Electric Aircraft*	*February, 2015*	*Toulouse*	*Research/Industry*		
2	*Fairs and Exhibitions*	*Tecnalia*	*Interntational Paris Airshow, Le Bourget*	*June, 2015*	*Paris*	*Industry*		
3	*Conference/Forum*	*Tecnalia*	*Aerodays*	*October, 2015*	*London*	*Research/Industry*		
4	*Conference/Forum*	*Tecnalia*	*R3ASC International Conference on Recent Advances in Aerospace Actuation Systems and Components*	*March, 2016*	*Toulouse*	*Research/Industry*		
5	*Fairs and Exhibitions*	*CESA*	*Interntational Paris Airshow, Le Bourget*	*June, 2015*	*Paris*	*Industry*		
6	*Fairs and Exhibitions*	*CESA*	*Farnborough International Airshow*	*July, 2016*	*Hampshire*	*Industry*		
7	*Fairs and Exhibitions*	*CESA*	*Aerospace & Defense Meetings*	*May, 2016*	*Seville*	*Industry*		
8	*Conference/Forum*	*CESA*	*UNVEX – IV CONGRESS OF UNMANNED VEHICLES*	*May, 2016*	*MAdrid*	*Research/Industry*		
9	*Conference/Forum*	*CESA*	*Aerodays*	*October, 2015*	*London*	*Research/Industry*		
10	*Conference/Forum*		*Third European Conference of the prognostics and health management Society 2016*	*July, 2016*	*Bilbao*	*Research/Industry*		
11	*Conference/Forum*	*Tsagy*	*MAKS air show in*	*August 2015*	*Zhukovsky near Moscow*	*Research/Industry*		

[7] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[8] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

4.4. Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	
Title of Project:	
Name and Title of Coordinator:	

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	NO
2. Please indicate whether your project involved any of the following issues (tick box) :	NO
RESEARCH ON HUMANS	
• Did the project involve children?	NO
• Did the project involve patients?	NO
• Did the project involve persons not able to give consent?	NO
• Did the project involve adult healthy volunteers?	NO
• Did the project involve Human genetic material?	NO
• Did the project involve Human biological samples?	NO
• Did the project involve Human data collection?	NO
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	NO
• Did the project involve Human Foetal Tissue / Cells?	NO
• Did the project involve Human Embryonic Stem Cells (hESCs)?	NO
• Did the project on human Embryonic Stem Cells involve cells in culture?	NO
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	NO
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	NO
• Did the project involve tracking the location or observation of people?	NO
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	NO
• Were those animals transgenic small laboratory animals?	NO
• Were those animals transgenic farm animals?	NO

• Were those animals cloned farm animals?	NO
• Were those animals non-human primates?	NO
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	**NO**
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	**NO**
DUAL USE	
• Research having direct military use	NO
• Research having the potential for terrorist abuse	NO

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1 (CESA)	1 (TsAGY) 1 (UMBRA) 1 (UAC)
Work package leaders		3 (CESA) 1 (TsAGY) 2 (ONERA) 1 (UMBRA) 1 (UAC)
Experienced researchers (i.e. PhD holders)	1 (CESA) 1 (ONERA)	4 (TsAGY) 3 (ONERA) 1 (UMBRA) 11 (MAI)
PhD Students		1 (CESA) 3 (TsAGY) 3 (MAI)
Other	1 (CESA) 2 (TsAGY) 1 (UMBRA) 1 (UAC)	7 (CESA) 2 (TsAGY) 18 (UMBRA)

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	1 (CESA)

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ ⦿	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

⦿ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

● No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

● No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

● Main discipline[9]: 2.3 AERONAUTIAL ENGINEERING

○ Associated discipline[9]:1.1 Mathematics and computer sciences | ○ Associated discipline[9]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ ●	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

● No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

[9] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ⦿ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ⦿ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise **Environment** External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy **Research and Innovation** Space Taxation **Transport**	

13c If Yes, at which level? ○ Local / regional levels ⦿ National level ○ European level ○ International level	

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**0**
To how many of these is open access[10] provided?	
How many of these are published in open access journals?	
How many of these are published in open repositories?	
To how many of these is open access not provided?	
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[11]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**0**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	

17. How many spin-off companies were created / are planned as a direct result of the project?	**0**
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

⦿ Increase in employment, or	❑ In small & medium-sized enterprises
❑ Safeguard employment, or	❑ In large companies
❑ Decrease in employment,	❑ None of the above / not relevant to the project
❑ Difficult to estimate / not possible to quantify	

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*

[10] Open Access is defined as free of charge access for anyone via Internet.
[11] For instance: classification for security project.

Difficult to estimate / not possible to quantify	

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ⦿ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ⦿ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	⦿	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
⦿	Brochures /posters / flyers	❑	Website for the general public / internet
❑	DVD /Film /Multimedia	⦿	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	⦿	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine

5. SOCIAL SCIENCES
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

4.5. *FINAL REPORT ON THE DISTRIBUTION OF THE EUROPEAN UNION FINANCIAL CONTRIBUTION*

This report shall be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.

Report on the distribution of the European Union financial contribution between beneficiaries

Name of beneficiary	Final amount of EU contribution per beneficiary in Euros
1.	
2.	
n	
Total	