4.1 Final publishable summary report

1- Project Executive summary

The TESTHEMAS project will design, manufacture and tune an innovative and smart Test Rig for linear actuators that will be capable of conducting synchronized tests on three assemblies of Helicopter linear Electro Mechanical Actuators (HEMAS) while applying different counterloads on them. This functionality will be controlled and monitored by means of a local control, command and data monitoring system. On the other hand, the Test Rig will incorporate an Adaptation Kit able to be inserted in a global test bench simulating an aircraft network called Electrical test Bench (Copper Bird) in such a way that the Test Rig can be operated remotely including a very versatile data transfer capacity

This actuator Test Rig will be based on a modular, eco-efficient and adaptive concept by integrating easily exchangeable hydraulic and mechanical components with sensors and control strategies that will allow automatic and autonomous safe operation that will assure optimised lifecycle costs and environmental impacts during HEMAS tests. This innovative concept of actuator test bench will mean thus a positive impact on the safety and working conditions of the end users of the Test Bench as well as a reduction in the time and costs associated to testing linear actuators together with an increase in the quality and reliability of said tests.

The TESTHEMAS system will be tested and validated at several stages: Virtual validation at model level and final experimental validations of the complete system. These sequential and complementary validations will assure thus a reliable, safe and efficient performance of the prototype and will provide data for a deep concept evaluation

2- Description of project context and objectives

The TESTHEMAS project will design, manufacture and tune an innovative and smart Test Rig for linear actuators that will be capable of conducting synchronized tests on three assemblies of Helicopter linear Electro Mechanical Actuators (HEMAS) while applying different counterloads on them. This functionality will be controlled and monitored by means of a local control, command and data monitoring system. On the other hand, the Test Rig will incorporate an Adaptation Kit able to be inserted in a global test bench simulating an aircraft network called Electrical test Bench (Copper Bird) in such a way that the Test Rig can be operated remotely including a very versatile data transfer capacity

This actuator Test Rig will be based on a modular, eco-efficient and adaptive concept by integrating easily exchangeable hydraulic and mechanical components with sensors and control strategies that will allow automatic and autonomous safe operation that will assure optimised lifecycle costs and environmental impacts during HEMAS tests. This innovative concept of actuator test bench will mean thus a positive impact on the safety and working conditions of the end users of the Test Bench as well as a reduction in the

time and costs associated to testing linear actuators together with an increase in the quality and reliability of said tests.

The TESTHEMAS system will be tested and validated at several stages: Virtual validation at model level and final experimental validations of the complete system. These sequential and complementary validations will assure thus a reliable, safe and efficient performance of the prototype and will provide data for a deep concept evaluation.

TESTHEMAS includes the the following objectives corresponding to their specific packages:

Work Package	**Objectives**
WP1 - Specifications and Requirements of the Test Rig and Adaptation Kit	• Define in detail with the CSJU Topic Manager the specifications and requirements associated to the HEMAS Test Rig and Adaptation Kit system
WP2 Test Rig and Adaptation Kit Conceptual design	• To develop simplified models (electrical, mechanical,...) of the Test Rig • To integrate the models of the concepts of mechanical and control components for validating the global concept of the Test Rig in a virtual manner • To identify potential physical implementations and to simulate electrical and mechanical behaviour • Selection of the optimal solution to be implemented • To develop the concept of the Graphical User Interface
WP3 - Test Rig and Adaptation Kit Detailed Design	• To design in detail the mechanical, hydraulic, electric/electronic components of the Test Rig and Adaptation Kit • To design in detail the control, monitoring and communication SW for the Test Rig and Adaptation Kit
WP4 - Test Rig and Adaptation Kit Manufacturing, Integration and Tuning	• To manufacture and assemble the Test Rig parts and components defined during the detailed design stage • To commission the TESTHEMAS system and to tune the drive and control parameters once the test bench has been assembled
WP5 - Validation and Acceptance tests	• To define Test Rig acceptance Test Plan and Procedure. • To test and validate the TESTHEMAS Test Rig. Execution of the Test Rig Acceptance test programme • To analyse the results and compare them with the predicted results obtained in previously performed simulations. Model correlation and Test Rig and model final fine adjustment. • To final approve the complete TESTHEMAS system at laboratory level.
WP6 - Delivery and	• TESTHEMAS Test Rig delivery to end user's site. Provide Assembly installation and operational support.

support	• TESTHEMAS Test Rig delivery to Copper Bird site. Provide Assembly installation and operational support
WP7- Dissemination and Exploitation	• To communicate, share and transfer relevant knowledge about the technologies developed in the project to the European market of technology providers and end users. • To define an internal exploitation strategy for the TESTHEMAS system.
WP8 – Project Management	• In this Task TECNALIA will establish an appropriate governance structure for assuring an effective project direction and management. This structure will define roles, responsibilities and activities within the organization and people involved in the Project as well as decision rules. More details about this Management structures and procedures will be provided in Chapter 2.1

3- Main S&T results/foregrounds

Work package 1:

As starting point of the project, the Topic Manager provided TESTHEMAS TECNALIA's work team a range of preliminary specifications and requirements. A helicopter electro mechanical actuator model or family of models needs to be addressed for the study. Actuators' service conditions need also to be delimited to allow Test Rig design and analysis.

As a first approach, the call of proposal establishes numerous already known requirements. These requirements were detailed more deeply in a document specified by the topic manager and another document ("Test cases") gathered all the performance test cases that should be carried out in the HAK.

This work package is basically aimed at fixing the specifications and requirements for the system with the Topic Manager: Load cycles, endurance tests cycles to be performed, duration of cycles, strokes, ground and in-flight available space, environmental constraints, etc.

These documents were not closed in month 2, it was reviewed after the PDR due to a lack of information related to the attachments stiffness and inertial masses and even later, after manufacturing the test bench, the test cases were reviewed because the emergency test cases had not been included in the test cases document. These changes have introduced a delay in the overall schedule.

Work package 2:

In this task, the overall Test Rig system configuration was defined, and schematics, diagrams, and layouts of the Test Rig were provided.

TECNALIA developed different 3D models, which were assessed until one of the architectures was selected finally and validated by the Topic Manager in the PDR

meeting. Different architectures were evaluated in order to identify the optimum solution taking into account different cost functions. Thus, the results of the simulations combined with other relevant criteria such as technology availability and reliability, mechanical and electrical constraints conducted to the selection of an optimal solution to be deeply developed and implemented in subsequent work packages. This optimal solution selection was accomplished with the total involvement of the Topic Manager team and constituted an important milestone of the project.

A preliminary sizing of all the subsystems was completed as a result of the simulations carried out.

This task demonstrated that the preliminary design met all system requirements and established the basis for proceeding with detailed design. As a final stage within the preliminary design task a review (PDR) was performed to show that the correct design options were selected, interfaces were identified, and verification methods were described.

After a previous analysis, it was concluded that a hydraulic test bench allows more load control possibilities than an electromechanical bench design. In addition, the hydraulic solution ensures steady loads in high dynamic load curves, as well as in static load applications, whereas the load control in an electromechanical test bench is not stable enough for static load applications. The proposed hydraulic test bench is conceived as a standalone facility, which will need only electrical power to function. The bench will include its proper hydraulic compression unit allowing the system to operate isolated from any other hydraulic circuit.

Technical description reports, conceptual design details were included in the Design Report and mechanical and electrical interface control documents were elaborated and delivered 2 weeks before the preliminary design review (PDR) meeting.

The PDR meeting took place on September 25th, 2013(Month 6).

Work package 3:

This work package produced the design of a laboratory test bench able to simulate service conditions of a HEMAS. Once the Test Rig conceptual design was defined, TECNALIA proceeded with the design in detail of the test bench.

The concept of the Test Rig and Adaptation Kit was developed in detail according to the design, material and components selection, manufacturing and assembly needs identified during the conceptual design stage. Calculations for ensuring the mechanical integrity of the structure and the correct operation mode of the test bench according to the specifications were conducted. The software used for Test Rig design (CAD), 3D design of assembly and different parts and 2D drawings was CATIA V5 R19, for structural calculation (CAE) by FEM (finite element method) NX, and MSC NASTRAN was used, whereas vibration calculation (CAE) was carried out with ACTRAN software.

Documentation to be generated within the task: Assembly and detailed part drawings, a Commercial off the shelf part list, detailed electrical schemes, the definitive interface control document and the controlling software. This task finished with a critical design review (CDR) where full-scale Test bench fabrication, assembly, integration and test

were validated by the Topic Manager. To comply with this objective, the simulations obtained from running the mathematical model were reviewed.

The availability of a complete mathematical model enables the possibility of simulation of the tests prior to the manufacturing stage and allows the development of the detailed control software in a safer and more accurate manner instead of evolving the system control by trial and error activities. The mathematical model of the HAK was coupled to the HEMAS model developed by the SGO memberships and TECNALIA has worked with them in this integration. TECNALIA and SGO memberships in charge of the HEMAS development have had a really fluid communication that has been a key factor for the satisfactory design of the HAK.

The PDR meeting took place on February 27th, 2014(Month 11)

Work package 4:

After detailed design, off-the-shell components were ordered, non-commercial components were machined and all subsystems assembled. TECNALIA adjusted the drive and control parameters as well as the load control by means of the mechatronic simulations that were conducted during Task 3.2.

TECNALIA worked very hard to achieve the goals established in this work package. The test cases stablished in the first work package was very exigent and we had to involve our hydraulic supplier experts to fulfil the requirements stated. TECNALIA developed also a specific Simulink model of the HAK which was coupled with the HEMAS model and several simulations were run to tune the control strategy of the HAK.

This WP finished in July 2014 (Month 16).

Figure 1 – HEMAS Adaptation Kit in TECNALIA facilities

Work package 5:

This WP is devoted to the analysis, definition and execution of validation, commissioning and acceptance tests to be conducted at TECNALIA's site prior to the TESTHEMAS delivery to its respective installation sites. The aim is to confirm that specifications set in WP1 are fulfilled.

The first part of this task was to define the tests to be performed to demonstrate Test Rig specifications fulfilment. This acceptance test plan ensured performance and functionality of the Test Rig to carry out the EMA test plan validation. The plan involved the following tests:

- hydraulic actuator performance (load, stroke, speed…),
- control performance (position curves, alarms, start/stop, data exchange, data storage…).

As starting point, TECNALIA set-up and start up the Test Rig system, verifying that system did not show any vibration or noise and that the desired speed-load profiles were achieved in an accurate and dynamic mode.

Once the driving systems were running properly, programmed acceptance tests were conducted for verifying that the specifications and requirements defined in WP1 were fulfilled in an efficient, safe and reliable manner. Tests results were compared to the results obtained from simulations to evaluate the real Test Rig behaviour.

The Test Plan was executed in accordance to the procedure set in the specific deliverable produced in task 5.1. A report with the test results was elaborated (deliverable produced in task 5.2).

The Acceptance test report (5.2) was presented to the Topic Manager and the SGO members in a Workshop in Liebherr-Lindenberg on October 28-29th, 2014. The results were really satisfactory and the delivery of the HAK to the first site (Ottobrun) was approved.

Work package 6:

On 20-01-2015 TESTHMAS test bench was installed in AGI facilities. The test bench was set-up and tested. In order to improve some software changes and GUI modifications have been done after the initial assembly and set-up.

TECNALIA has been for many weeks working in Ottobrun in AGI facilities advancing the TESTHEMAS test rig and HAK set-up and integration with the aim of delivering the TESTHEMAS equipments totally validated and with the functionalities open to cover future HEMAS integration as there is not a final foreseen date for HEMAS availability.

TECNALIA has also given training courses to AGI operators and modified equipment communications with HEMAS to perform better with the SPCC. At least five workshops have been conducted together with people of AIRBUS for both training and on-site system modifications.

TECNALIA has also attended the group meetings whenever it was necessary and delivered all the technical and support documentation and deliverables. Telephone and remote desktop support has been performed when AGI operators requested it.

Due to several issues with the HEMAS control and motors and several delays in other HEMAS development projects affecting TESTHEMAS, the topic manager decided to remove site 2 (Cooper Bird) HAK (HEMAS Adaptation Kit) integration from the tasks of the project.

Figure 2 – HEMAS adaptation kit in AGI facilities

Work package 7:

Tecnalia has developed a dissemination and exploitation plan for the TESTHEMAS test bench and the results of the project. Three conferences have been attended and two articles have been presented. The conferences where Tecnalia has published the results of the projects are:

- **Greener Aviation International Conference in Brussels 2015**
- **R3ASC International Conference on Recent Advances in Aerospace Actuation Systems and Components in Toulouse 2016**
- **2015 IEEE International Conference on Industrial Technology in Seville.**

The target groups of the dissemination have been European aeronautic sector: end users of actuators test bench and European test bench builders. The dissemination was planned to be done by means of the following actions:

- Direct proactive communications. Participation in Fairs
- Direct proactive communications. Virtual and physical demonstrator.
- Workshops that will be held at Tecnalia with participation of Industrial Companies potentially interested in TESTHEMAS project results.
- Presentations of the project in Forums, such as the Clean Sky Joint Undertaking General Forum.
- Contributions in specialized Conferences or Journals.

Tecnalia has done a presentation of the project in the CLEANSKY SGO annual review.

Tecnalia has taken part in several fairs and exhibitions where the project results where shown:

- More electric aircraft Toulouse 2015
- ICIT Seville, 2015
- Le Bourget Paris Airshop 2015
- Aerodays London 2015
- Greener aviation Brussels 2015
- R3ASC Toulouse 2016

Tecnalia has also meet with companies in the aeronautical sector:

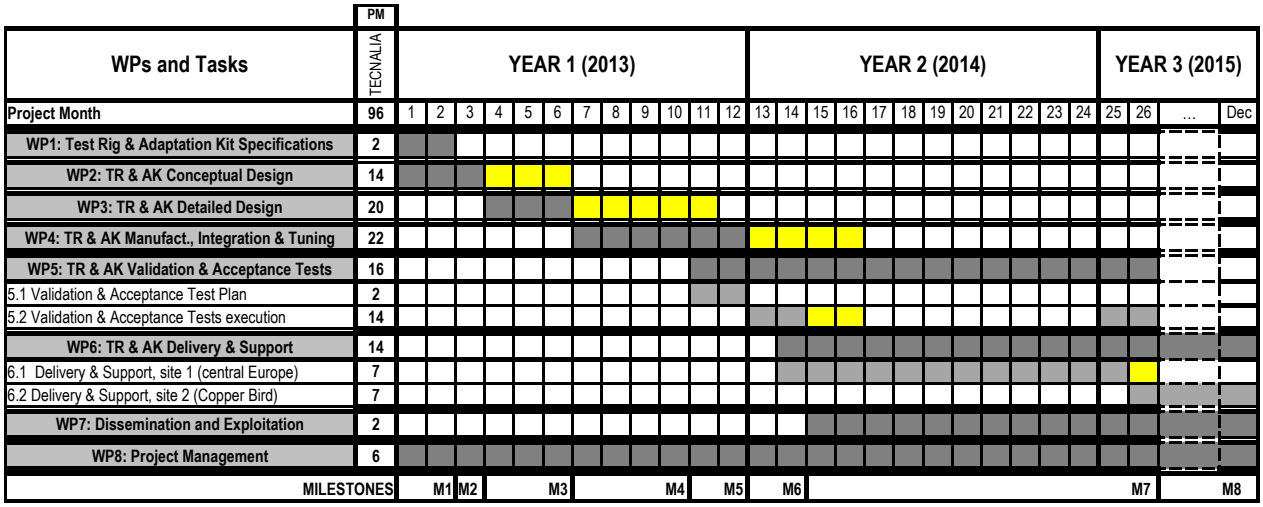
- CESA
- Glual Hydraulics
- Nottingham University
- Axon
- HINE
- Amcro
- Obeki
- Flavia
- Ikusi
- Alfa-MIM
- Grindel
- Airbus Helicopters France

Work package 8:

As part of the management activities of the project TECNALIA has been in constant contact with the SGO membership in charge of the HEMAS development and taken part in the follow up meetings.
TECNALIA and SGO memberships in charge of the HEMAS development have had a really fluid communication that has been a key factor for the satisfactory design of the HAK.
TECNALIA has been involved in the SGO HEMAS meetings and is attending to the follow-up meetings that take place every three months. In this way, the integration of the HEMAS in the HAK will be much more safety, we have foreseen future problems and we are trying to solve them. TECNALIA is even implementing new partial redesigns in the HAK to anticipate these possible future problems.

The unforeseen new test cases introduced in the specifications after HAK manufacturing have introduced an important impact in the schedule. Instead of sending the HAK to the first site in July 2013, it has been rescheduled and the new date is February 2014. An important modelling work has been performed and a partial redesign of the HAK approved to respond to the new requirements

Planning rescheduled



- List of project meetings, dates and venues;

Kick-off meeting	Topic Manager-Tecnalia	Airbus-Helicopters Getafe	08/05/13
Preliminary design review meeting	Topic Manager-Tecnalia-SGO HEMAS project coordinator	Airbus-Helicopters Getafe	25/09/13
Pre-Critical design review(follow-up) meeting	Topic Manager-Tecnalia	Airbus-Helicopters Getafe	
Follow-up meeting 1	Topic Manager-Tecnalia-SGO HEMAS project coordinator	Liebherr-Lindenberg	06/02/14
Critical design review meeting	Topic Manager-Tecnalia-SGO HEMAS project coordinator	TECNALIA Donostia	27/02/14
Follow-up meeting 2	Topic Manager-Tecnalia-SGO HEMAS project coordinator	TECNALIA Donostia	1-2/07/14
Follow-up meeting 3	Topic Manager-Tecnalia-SGO HEMAS project coordinator	Liebherr-Lindenberg	28-29/10/14
Follow up meeting 4	Topic Manager-Tecnalia-SGO HEMAS project coordinator	Liebherr-Lindenberg	28-29/10/14
Follow up meeting 5	Topic Manager-Tecnalia-SGO HEMAS project coordinator	University of Nottingham	28-29/01/15
Follow up meeting 6	Topic Manager-Tecnalia-SGO HEMAS project coordinator	AGI, Munich	28-29/04/15
Follow up meeting 7	Topic Manager-Tecnalia-SGO HEMAS project coordinator	AGI, Munich	22-23/06/15
Follow up meeting 8	Topic Manager-Tecnalia-SGO HEMAS project coordinator	AGI, Munich	17/09/15

Tecnalia has also a long list of teleconferences and ECM documents exchanged with the Topic Manager and the SGO HEMA project members

4- The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

Contribution of TESTHEMAS System to enhancing the Competitiveness of the European Aeronautic Industry

Reduction of time and costs associated to testing of Helicopter Electro-Mechanical Actuators (HEMAs)

1) The modular and reconfigurable concept of the Test Rig will allow having different testing positions, covering from testing one single actuator to three actuators each of them consisting of two EMAs sharing one output ram.

2) This modular and reconfigurable conception of the Test Rig will allow easy adaptations to future variations in the requirements of the testing processes, thus allowing for example to use in the future the counterload actuators to load a swash plate, thus reducing the costs associated to assembly and disassembly operations for bench upgrading operations above 25%.

3) The TESTHEMAS Test Rig will be equipped with force and velocity sensors that will gather very valuable lifecycle information about the Test Rig. Indeed, the data mining techniques that will be integrated in the Local Control System will allow end users to implement predictive maintenance operations and thus to save both diagnosis time and machine-down time. This predictive maintenance combined with the ease of assembling and disassembling components of the Test Rig, will allow reducing the maintenance costs above 15%.

Improved knowledge-base of manufactures and users of HEMAS

The TESTHEMAS Test Rig will allow measuring with accuracy several physical parameters related to the use stage of HEMAS, mainly dynamic and thermal parameters. These measured data will allow an accurate characterization of the performance of HEMAS and also a correlation of the numerical models that have been developed at design stage. By means of these correlations, HEMAS developers will gain an improved knowledge-base about the lifecycle performance of their manufactured products, what will allow improving that performance in an increased manner and by extension, will improve the competitive position of both manufacturers and users of these optimised HEMAS

Concerning dissemination activities the following figures are highlighted:

- 2 papers
- 3 lectures at international technical conferences
- 5 dissemination activities to the public in general (news, poster, media, etc..)
- Scientific/technical workshop with relevant international experts and researchers

5- Project Website