HARAS – High Availability Redundant Actuation Systems

Project Partners: Triumph Integrated Systems (Lead), NEMA Ltd., Kugel Motion

Project details:

The Highly Available Redundant Actuation Systems (HARAS) project directly addresses five topics, encompassing areas of technology for a more electric aircraft, and specifically targets unmanned vehicles and their electrical actuation systems. A key objective of the program was to investigate the development of high availability, fault tolerant electrical actuation solutions suited to emerging Unmanned Vehicle Aircraft (UAV) and similar next generation platforms.

A notable use-case, is a flight control surface which has a requirement for combined functionality (such as combined aileron, elevator and rudder) with restrictions in maximum component diameter, but with available space across the length of the surface. The programme's output is a demonstrator that is suited towards an aircraft of MTOW 7-10 tonnes, that provides a basis for development in technological areas such as fault-tolerance, health monitoring, advanced motor design, and maintenance-free (for life) fitting. The project is 3 years long and comprises a consortium of electric actuation (Triumph), motor (NEMA) and linear transmission (Kugel Motion) specialists.

The HARAS project follows on from a previous ATI project EMMAS (No. 101802), which was largely technology focused as opposed to application based. EMMAS (Electro-Mechanical Magnetic Actuator Systems) addressed the trend of moving away from hydraulic actuators to EMA's and focused on motor control technology incorporating a magnetic gear component within an EMA design for a rudder. HARAS has focussed on developing the technology for a specific problem in small platform design, associated with narrow space constraints for control surface actuation, as well as increasing redundancy and therefore aircraft utilization.

Table 1: Summary of the project grant details

Project	Funding	Lead Partner	No. of Partners	Partner Composition	Duration
101374 HARAS	Total: £1.0m Grant: £0.5m	Triumph Aerospace Operations UK Ltd	3	1 Large company, 2 SMEs	Nov 2015-Apr 2019

Table 2: Summary of the project focus areas

ATI Value Streams		ATI Enablers		ATI Attributes		Strategic Horizon	
Whole Aircraft		Aerodynamics		Safety	X	Secure	
Structures		Manufacturing		Cost		Exploit	X
Propulsion		Materials	X	Environment		Position	
Systems	X	Infrastructure		Fuel Burn			
		Process and Tools	X	Operational Needs	X		
				Passenger Experience			

Technology Achievements:

Triumph Integrated Systems Actuation & Control coordinated the project with the support of NEMA Ltd for bespoke motor development, and Kugel Motion Ltd for the development of high load, light-weight, minimal envelope linear motion components. The project work package achievements were as follows:

Systems architecture study (WP1)

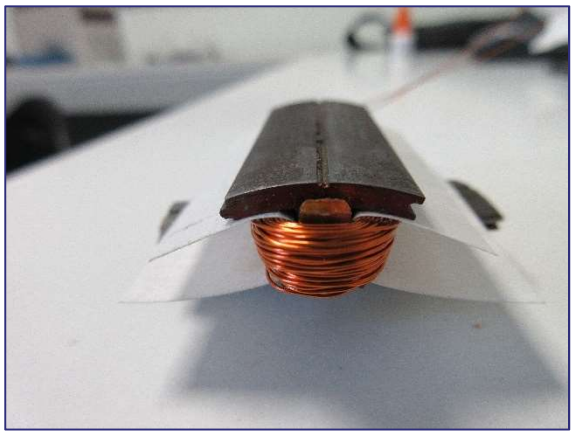
This focused on the requirements study and technology review, assessing current requirements, current technology, and common areas for development. This work package highlighted targets, such as size, weight, and performance, to ensure relevance to future needs. The aim is to use a greater number of simple actuators to achieve higher availability with no weight impact. This study highlighted the fact that multiple actuators in this proposed system did not have an impact on weight, that is, using a distribution of smaller units does not add up to the mass of an alternative single larger unit. Further, a novel design concept has been created and enables EMA (Electro Mechanical Actuator) disconnect so that the rest of the system EMA's can continue to operate. In addition, the operating case is satisfied by 6 actuators, but there are an extra 2 for redundancy purposes. Therefore, 2 actuator failures are tolerable which has positive implications for platform operability.

Advanced motor design and development (WP2)

This work package focused on the development of advanced motor components to drive the actuators, following directly from WP1 and preceding WP3 (EMA design) and WP4 (Electronic Controller). Based on previous project experience, attempting to define the motor in parallel with the EMA causes suboptimal design.

This advanced motor development utilises brushless PM (permanent magnet) design and progressed the motor with segmented lamination technology towards TRL6. Segmented laminations have been proven to enable thin diameter and low inertia motors, and therefore faster response for more responsive controls. The use of PEEK (Poly-Ether Ether Ketone) slot liners has been tested, along with various other materials, and proven to improve heat removal. Together these technologies contribute to a smaller and more lightweight component.

The motors have been fully designed and evaluation motors have been developed, with a lab demonstrator at atmospheric conditions being built. New motor test equipment for advanced duty cycle testing and loading has been set up for the HARAS project; a good example of substantial capital investment because of ATI funding.



Motor - Segmented Lamination

segmented lamination

High Availability EMA (Electro-Mechanical Actuator) Design and Development (WP3)

This work package focuses on the design and topology of a multi-structure, high availability actuator and its associated mechanical architecture, including gearbox and/or screw components. Both rotary and linear actuators were evaluated in a multi-actuator setting and incorporating the concept motor designs from WP2.

The design is currently at concept level (PDR), moving into detailed design and manufacture. There is currently a case for adjusting requirements and taking previous electronics technologies to address future more electric aircraft (MEA) requirements.

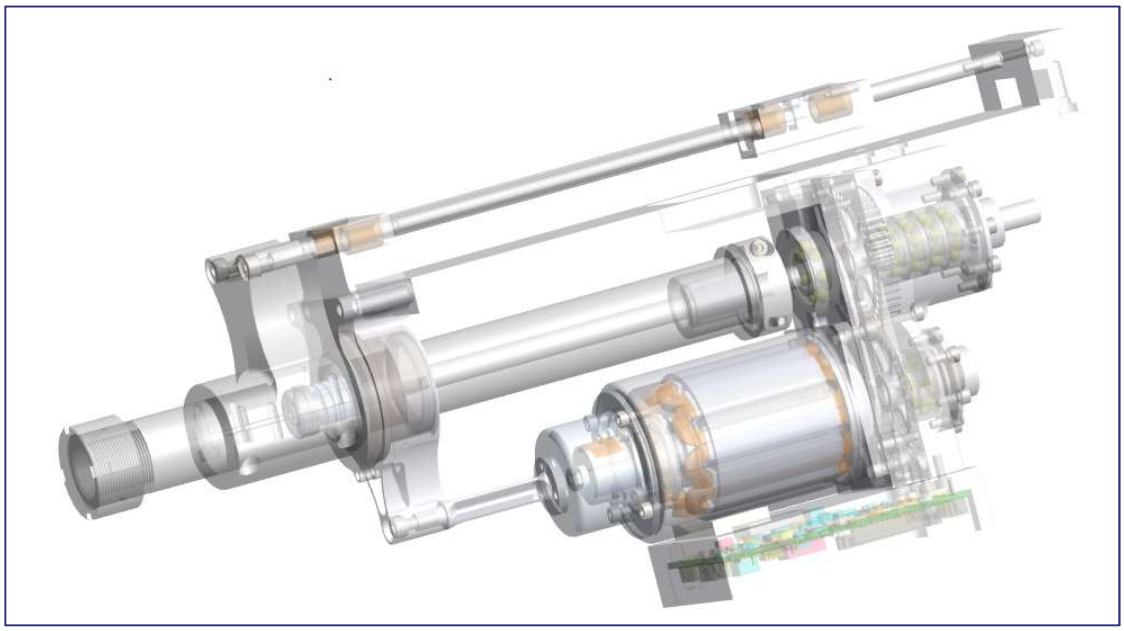
High Availability ACU (Actuator Control Unit) Design and Development (WP4)

This work package focuses on the electrical power and control aspects of the project. There are particular topics of research to be considered including power distribution, multiple motor control and EMA performance monitoring.

Currently there has been approximately 50% progress on the design and development of the actuator (WP3) & Electronic Controller (WP4). Designs need to be finalised to build the required prototypes, and then consider the system level design and demonstrator integration.

Table 3: Summary of the technology achievements

Project	Performance Improvements	TRL Progression
101374 HARAS	• Capacity to tolerate 2 single failures (mechanical or electrical) without affecting performance. • Aiming for limited maintenance / downtime ➢ No grease ➢ Potential for long service intervals ➢ Opportunity for condition monitoring • High density motor design	• EMA tech and EMA disconnect to TRL 4-6 • Motor design / technology as whole to TRL 4-6 • Segmented lamination to TRL 4-6



Developing EMA Design for HARAS

Economic Impact:

The HARAS project is primarily aimed at the UAV market however will have benefits to the wider aerospace component supply chain; the UAV market continues to grow dynamically within the aerospace sector. The overall UAV market was predicted significant growth to $8.2 billion in 2018, and approximately $10 billion in 2023[1]. As UAVs are emerging into civilian applications, this is expected to increase further and may lead to significant changes within the market. Civilian UAVs are also anticipated to evolve in market sectors such as communications, energy, environment and disaster relief.

The global market for advanced actuation systems will remain prominent in coming years due to the nature of the system being indispensable as actuators play a crucial role in aircraft design improvements. The global actuator market is estimated at $2,900 million by 2014 and is expected to reach $3,800 million by 2019. If actuator systems comprise 6% of a UAV, and if flight actuation is considered 15% of this 6%, this translates to a market of approx. $0.1 billion to capture by 2023[2]. In addition, the European commercial aviation actuator system market is estimated at $1,400million in 2014 and is expected to reach $1,600 million by 2019[3].

Triumph Integrated Systems Actuation & Control has expanded in the UK over the past 4 years currently consisting of 3 sites: Staverton near Gloucester, Deeside in Flintshire and a facility in the Isle of Man. The aim is to grow the capability of the design teams based at Deeside and Staverton to support the development of products and systems for the More Electric Aircraft market. A key enabler to this growth is the Innovate UK and ATI research projects. By Triumph establishing relationships with SME suppliers such as NEMA, Kugel Motion, Triumph would expect to increase the revenue and sales of these companies, allowing them to increase in size, and have a route into the aerospace market.

At Triumph, the HARAS project has safe-guarded 3-4 FTE (full time equivalent) roles, in design engineering and project management. NEMA expects to hire 2 production engineers and 1 researcher, as well as safeguarding 1 role because of this project. Also, the project and funding helps both Companies keep pace with developments within the industry and remain competitive.

If the proposed design is successful, the HARAS project technology will reduce aircraft / platform downtime or inactivity due to the ability to tolerate failure, or to plan in scheduled maintenance due to the capability to detect and operate with failures. The increased fault tolerance and safety aspects of the technology has potential to provide greater confidence in electric actuation to all stakeholders. Environmentally there are potential benefits enabling slimmer flight structures with more compact actuation systems that reduce aircraft drag thus saving fuel.

The technology is applicable within the UK's defence sector through unmanned and manned aircraft, with potential customers identified for UAV applications. There are also potential applications on emerging platforms such as the compound rotorcraft X3 Airbus Racer (high speed helicopter). The motor design, specifically learning around segmented lamination and PEEK slot liners, have other high voltage applications e.g. power transmission, electric cars with motors up to 1200V and submarines/navel up to 600V and increasing.

[1] Qi3 Insight: Unmanned Aerial Vehicles Growing Markets in a Changing World.
[2] http://www.4-traders.com/GLOBAL-MARKET-GROUP-LTD-10860448/news/Global-Market--Actuator-Systems-Market-in-Aviation-Market-Analysis-Commercial-Aviation-and-Defen-19538451
[3] http://www.marketsandmarkets.com/PressReleases/aviation-actuator-system.asp

The ATI project has supported the creation of strong collaborative relationships, reinforcing that of Triumph and NEMA, and fostering the collaboration between NEMA and Kugel Motion. NEMA and Triumph have previously worked on challenging product development schedules, and having a dedicated project team helps create a focus in a non-competitive environment.

Table 4: Summary of the economic impact

Project	Value created	Employment
101374 HARAS	Value attributed to project £1.01m Capital investments / equipment – Approx. £50K $0.1b UAV actuator market opportunity by 2023	Jobs created: 3 Safeguarded: 5

"The project has allowed us to investigate higher spec materials that are available to our industry by advanced technologies for laminations and magnets."

Andrew Wilding, Managing Director, NEMA Ltd.

"The ATI / Innovate UK framework is a highly effective way of accelerating technology development in a collaborative environment that builds long term relationships and partnerships with SME's and Universities to benefit the economy and product development for aircraft systems."

Graham Reeves, Engineering Director of Triumph Integrated Systems – Actuation and Control

Next Steps:

The HARAS project followed on from a previous ATI project called EMMAS and focuses on technology application. The technology is very promising, and if funding is available, it has a lot of scope for progress and many commercialisation opportunities.

The HARAS project technology has direct commercial opportunities on UAV platforms across civil aerospace and defence. There is also great potential for small diameter actuation systems with superior availability, on future more electric commercial platforms. as wings get thinner to improve efficiency, and platform utilisation continues to be a focus. Specifically, the technology developed for the new advanced motors may also have applications in other industries that require compact high voltage motors, such as electric cars and the maritime industry.

Kugel Motion, through the HARAS project have been introduced to the aerospace supply chain and have been exposed to new opportunities for their capabilities in custom ball screw and roller screw manufacture. Triumph are building a strong relationship with Kugel in R&T off the back of the HARAS project due to their potential as a UK based supplier and their unique UK capabilities.

Some of Triumph's existing OEM Customers have expressed an interest in the outcome of this project and discussions are happening continuously throughout the project regarding future Customer interactions.

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