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Promising pioneering breakthrough technologies and
concepts for Aeronautics and air transport



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Abstract:

This document constitutes the project periodic report of BRAINFLIGHT.

¹ Nature of deliverable: **R** = Report; **P** = Prototype; **D** = Demonstrator; **O** = Other

² Dissemination level: **PU** = Public; **PP** = Restricted to other programme participants (including the Commission Services); **RE** = Restricted to a group specified by the consortium (including the Commission Services); **CO** = Confidential, only for members of the consortium (including the Commission Services).

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Document Authors

Entity	Contributors
TEK	André Oliveira
TEK	David Coimbra

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Table of Contents

Document History.....	2
Document Authors	2
Table of Contents.....	3
List of Tables.....	4
List of Figures.....	4
List of Acronyms.....	5
1 Project objectives for the period.....	Error! Bookmark not defined.
2 Work progress and achievements during the period.....	Error! Bookmark not defined.
2.1 WP2 – Scenarios and Requirements	Error! Bookmark not defined.
2.1.1 Task 2.1 – BRAINFLIGHT CONOPS	Error! Bookmark not defined.
2.1.2 Task 2.2 – BRAINFLIGHT requirements	Error! Bookmark not defined.
2.1.3 Task 2.3 – BRAINFLIGHT validation scenarios....	Error! Bookmark not defined.
2.2 WP3 – Design and Development	Error! Bookmark not defined.
2.2.1 Task 3.1 – Signal Acquisition and Decoder Design	Error! Bookmark not defined.
2.2.2 Task 3.2 – Feedback Mechanism Design.....	Error! Bookmark not defined.
2.2.3 Task 3.3 – Control Laws Assessment.....	Error! Bookmark not defined.
2.3 WP7 – Dissemination and Exploitation.....	Error! Bookmark not defined.
2.3.1 Task 7.1 – Dissemination.....	Error! Bookmark not defined.
2.4 Problems and deviations from planned work.....	Error! Bookmark not defined.
3 Deliverables and milestones tables.....	Error! Bookmark not defined.
4 Project Management	Error! Bookmark not defined.
5 Explanation of the use of the resources	Error! Bookmark not defined.
5.1 TEK.....	Error! Bookmark not defined.
5.2 FCHAMP	Error! Bookmark not defined.
5.3 EAGLE.....	Error! Bookmark not defined.
5.4 TUM.....	Error! Bookmark not defined.
6 Forms C draft	Error! Bookmark not defined.
6.1 TEK.....	Error! Bookmark not defined.
6.2 FCHAMP	Error! Bookmark not defined.
6.3 EAGLE.....	Error! Bookmark not defined.
6.4 TUM.....	Error! Bookmark not defined.

List of Tables

Table 1 – List of acronyms.....	5
Table 2 – Deliverables Table.....	Error! Bookmark not defined.
Table 3 – Milestones.....	Error! Bookmark not defined.
Table 4 – Resources allocated to the project for the reporting period.....	Error! Bookmark not defined.
Table 5 – Major subcontracting, travels and equipment cost items for the reporting period.....	Error! Bookmark not defined.
Table 6 – Major subcontracting, travels and equipment cost items for the reporting period.....	Error! Bookmark not defined.
Table 7 – Major subcontracting, travels and equipment cost items for the reporting period.....	Error! Bookmark not defined.
Table 8 – Major subcontracting, travels and equipment cost items for the reporting period.....	Error! Bookmark not defined.

List of Figures

Figure 1 - Active Two Biosemi 64 channel acquisition system	7
Figure 2 - Topographic scalp plot showing averaged weights of the activation patterns for each defined class in the experience	7
Figure 3 - Testing of the Active BioSemi acquisition system ...	Error! Bookmark not defined.

List of Acronyms

Acronym	Meaning
BCI	Brain Computer Interface
CONOPS	Concept of Operations
EEG	Electroencephalography
GA	Grant Agreement
HCII	Human Computer Interaction International
QMR	Quarterly Management Report
SSSEP	Steady State Somato-sensory Evoked Potentials

Table 1 – List of acronyms.

1 Publishable Summary

BRAINFLIGHT proposes to investigate the application of an emerging technology in Neuroscience and Neuroengineering, as a radical new approach to guide and control an A/C. The question behind BRAINFLIGHT is: "Is it possible to control an aircraft using solely the signals emitted from the human brain, without any other intermediary control devices?" The capability to guide and control an aircraft using the brain is a radically new approach that the consortium believes could eventually decrease the complexity of cockpit environments and the resulting downsides mentioned above. It could enable people currently prevented from piloting to do so, and it might free up capacity to do secondary tasks at the same time. This proposal aims to create a system that allows pilots to learn to control an A/C using brain activity and eventually consolidate it and automate it in such a way that it allows intuitive control and releases the pilot's higher cognitive functions to other activities.

The BRAINFLIGHT objectives for the first year of the project were defined as follows:

- To assess and specify BRAINFLIGHT's concept of operation
- To identify high level operational, functional and technical requirements for the BRAINFLIGHT system in collaboration with aviation actors and end-users
- To design and determine user scenarios to validate the system
- Specify all necessary interfaces between system segments and components
- To perform an iterative process that refines the system architecture including the interfaces and information exchange requirements.
- To design the signal acquisition device and decoder (transformation) for the brain signals.
- To design the user interface and the feedback mechanism (Virtual GUI or tactile) for the BRAINFLIGHT system operator.
- The specification and first testing of the tactile P300 and SSSEP mechanism.
- To formulate new or modified Handling Qualities Requirements for the given interface signals and to design flight control laws and specific command filters providing the abovementioned Handling Qualities for the closed-loop (with pilot on-the-loop).

During this first year of the BRAINFLIGHT project, the consortium has made some progress concerning the contextualization analysis and design of the BRAINFLIGHT concept and a possible BRAINFLIGHT system. Possible aeronautical applications for the BRAINFLIGHT system were presented based on the development of five different scenarios:

- General Aviation (GA) flight under Instrument Flight Rules;
- Commercial Aviation (CA) landing under IFR in low visibility;
- Unmanned Aerial Vehicle (UAV) flight in stressful conditions
- Acrobatic aircraft flight

Three different BCI approaches were defined:

- Active (created from conscious brain activity to try to control);
- Reactive (response to an external stimuli);
- Passive (from non-voluntary control activity from the brain).

A matching exercise between the opinion of interviewed pilots and the application scenarios was performed to assess how and when the BRAINFLIGHT system could be beneficial for the pilots to use during a normal flight mission

The high-level system and sub-systems requirements were defined and the functionalities of the different blocks composing the overall BRAINFLIGHT system were defined, as well as their interfaces and the flows in the system architecture.

Validation scenarios for the BRAINFLIGHT system were defined based on reference flight missions, the fact that BCI concepts pick up various signals including artefacts from muscular activity and possible UAV manoeuvres to be performed in the flight testing phase.

Although the following were not concluded during the first year, the consortium defined and started implementing system components and modules, specifically the signal acquisition pipeline. Coding and optimization of the decoder brain signals was initiated with good preliminary results. A dry electrode was developed and adaptations to the Ground Control System (GCS) from TEK were implemented to comply with the BRAINFLIGHT architecture, where hardware in the loop simulations with the GCS using X-Plane was performed:

- The system is now capable to receive multiple control channels.
- Current state of update of the control is 15ms.
- Direct link from the ground to aircraft is delayed by about 100ms (one way delay)

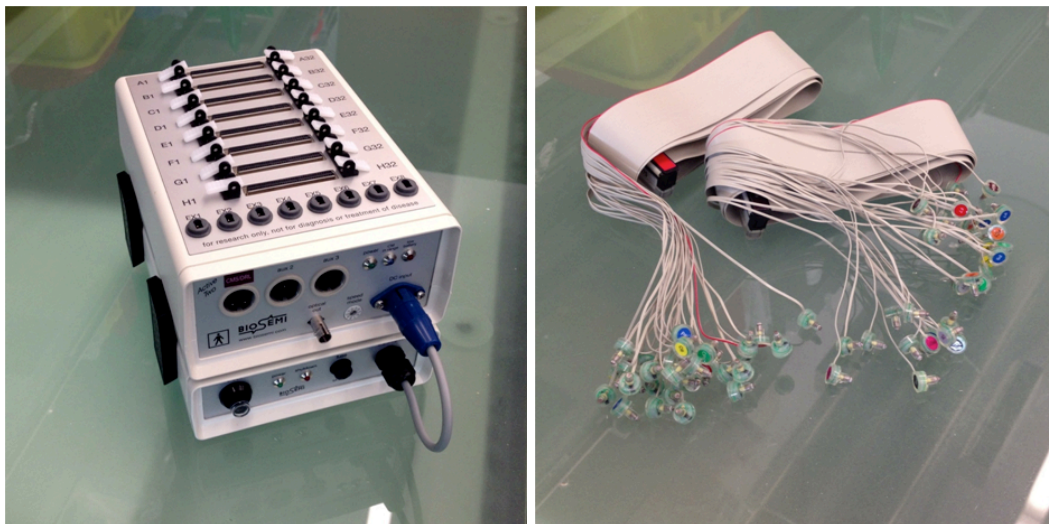


Figure 1 - Active Two Biosemi 64 channel acquisition system

A tactile suit was designed, consisting of multiple straps, and a control module with 16 factors. Some tests were performed in combining tactile feedback with manual control in TUM's flight simulator, which led to improvements in the tactile display design.

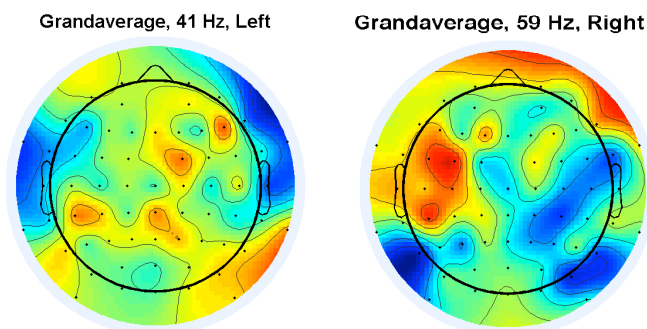


Figure 2 - Topographic scalp plot showing averaged weights of the activation patterns for each defined class in the experience



Based on the analysis of flight handling qualities as defined by the European Aviation Safety Agency's Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes CS-23; the US military specifications MIL-F-8785C and MIL-HDBK-1797, and guidance material from various authors some characteristics of the BRAINFLIGHT flight control system were detailed. Possible command variables were identified and their suitability for brain control in terms of handling analysed. Based on this work a framework for the initial design of two controllers was created:

- The first controller is dedicated to brain control and incorporates a number of unconventional design features
- the second controller is more similar to controllers for manual control.

In terms of dissemination, two scientific papers were published and presented in June and July and the project was presented at the Origin of Innovations conference at Brussels in April 2013.

We believe BRAINFLIGHT will enable people who currently are unable to pilot aircraft to do so still during this century (at least for GA aircraft). Currently, people with physical disabilities cannot pilot commercial aircraft or pilot GA aircraft (although some specific cases might be able to pilot specially adapted GA aircraft). Pilots with physical disabilities are almost inexistent in commercial aircraft because of the simple fact that this would require all aircraft in a fleet to be modified to cater for the pilot's specific disability. Individual owners of GA may and can modify their own aircraft to account for their disabilities. By removing the requirement for common control mechanisms such as centre sticks, control columns or rudder pedals, BRAINFLIGHT can open the door for disabled people to pursue pilot careers throughout Europe, be it at GA level (medium term) or as commercial pilots (long term) and will enlarge the number of people who could get involved in GA traffic. Of course, further studies, in particular concerning safety of both pilots and aircraft and the failure rate of BCI/BMI systems will need to be carried out. BRAINFLIGHT will have a positive impact in providing access to aircraft control to larger groups of people with no need for special physical skills. The feasibility of this impact can be easily demonstrated by running tests with people with physical disabilities that would prevent them from flying a GA aircraft without special adaptation.



**ENHANCED
ACCESS TO
AIRCRAFT
PILOTING**

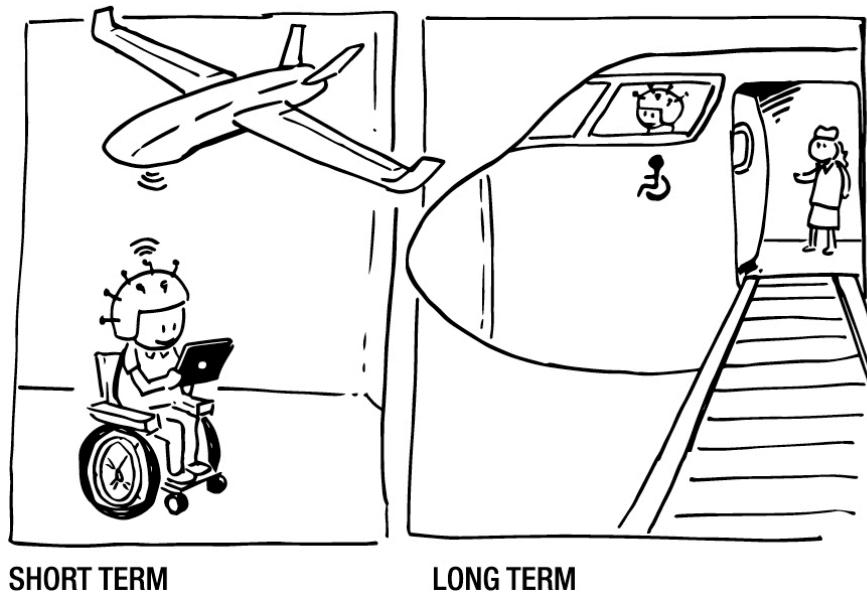


Figure 3 – BRAINFLIGHT impact – enhanced access to piloting.

If successful, BRAINFLIGHT will prove the concept of controlling (either high level control or low level control) an aircraft with neural signals. A large set of human skills is done almost unconsciously by people (e.g. breathing being the most notorious, balancing, walking, etc.) – i.e. people do not need to think about the act of breathing or how they walk to perform these actions. In addition to these basic skills, other more advanced skills can still be learned and trained in such a way they free up higher cognitive functions to focus on other aspects. Perhaps the most obvious example concerns professional sportsmen. These professionals are capable of carrying out their basic game skills (such as dribbling, passing, shooting or tackling) while focusing their attention on the way the game plays out just as fighter pilots can focus on the way dogfights play out without the need to focus on the execution of a particular manoeuvre. The “subconscious” capability enables people to focus their attention and cognitive skills elsewhere.

If the results from the project tests are encouraging, further research, coupled with (extensive) training, could lead to a decrease of pilot basic workload.

BRAINFLIGHT could result in the removal of the need for conventional cockpits altogether or, at least, in the possibility to redesign completely the cockpit paradigms of the future. With the introduction of a brain control device, the pilot is able to control the airplane without needing the conventional feedback devices that are present in the cockpit, but instead use the feedback mechanisms developed within this project. The possibility to remove particular instruments from the cockpit or the entire replacement or re-design of cockpits would need the following steps to be taken by the community.



**COCKPIT
DESIGN
MAY BE
COMPLETELY
CHANGED**

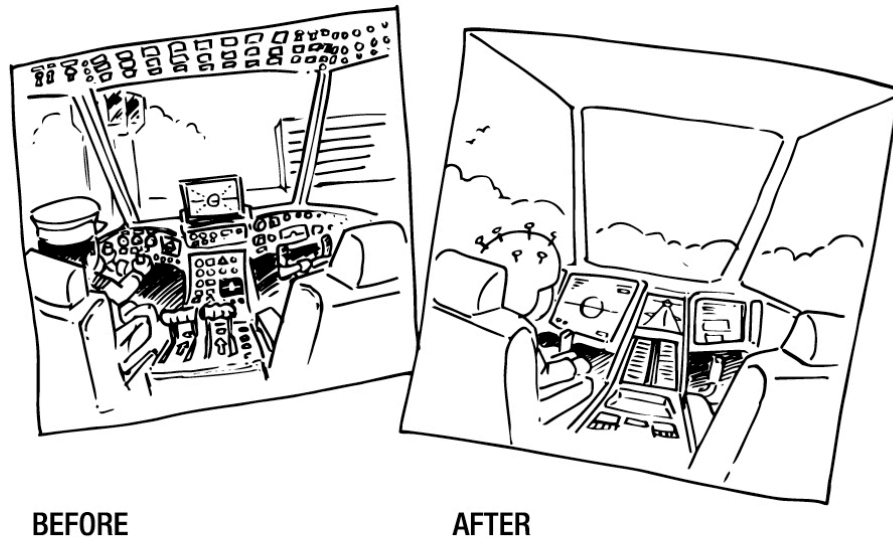


Figure 4 – BRAINFLIGHT impact – cockpit redesign.

Previous research in the field of neuro-sciences have shown positive results in terms of the time required by subjects' brains to naturally learn to use new tools/instruments by an operant process of trial and error (some research has shown that in 2 weeks approximately, 80% efficiency in control using brain signals could be achieved for primates and rodents). If BRAINFLIGHT research corroborates these results, an important impact in terms of pilot training could be achieved. For example, if it's possible for humans to achieve 80% efficiency in control in 2 weeks in a similar way to rodents and primates, then pilot training could be significantly reduced or conversely improved.



**PILOT
TRAINING
TIME
POTENTIALLY
REDUCED**

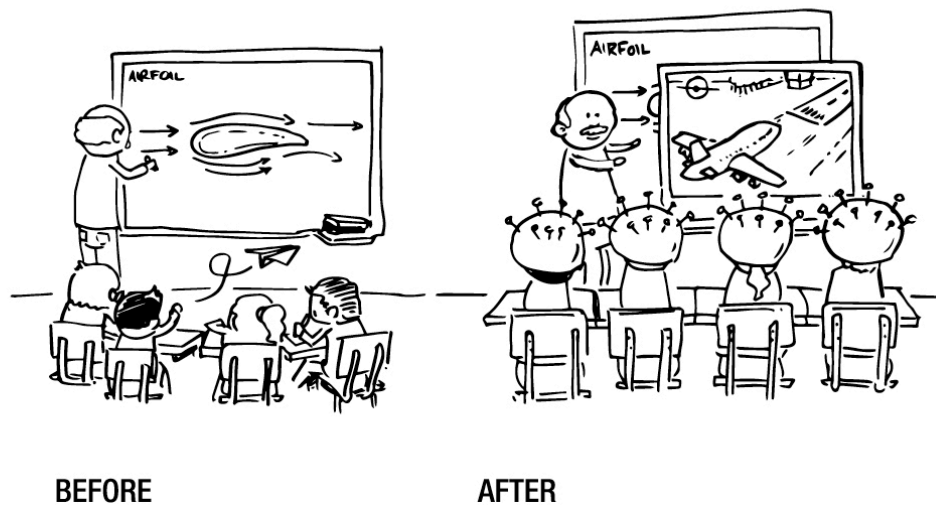


Figure 5 – BRAINFLIGHT impact – reduced training time.