PILOT STUDY ON THE IMPACT ASSESSMENT OF ESA EARLY R&D ACTIVITIES

Project CLAIS - Clean Air in Space

know.space

December 2024

Clean air is a health issue, especially in space …

Clean air is essential for healthy human life. Breathing clean air reduces the risk of respiratory diseases (e.g. lung cancer), mitigates respiratory conditions (e.g. asthma, bronchitis which can be exacerbated by particulate matter) and can limit the spread of air-borne bacteria and viruses (e.g. coronavirus that caused the COVID-19 pandemic).

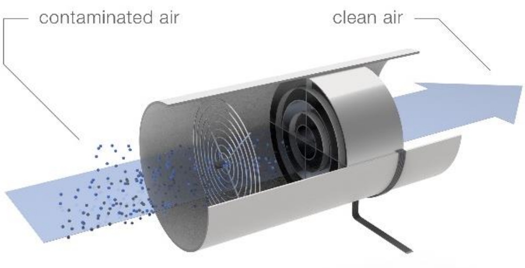
The need for a reliable and safe continuous supply of clean air is even more acute in the enclosed environments of space (spacecraft and habitation units), where the essential oxygen for life is not a naturally occurring gas. Any future long-duration crewed mission will require air to be contained, revitalised (removing carbon dioxide and any harmful particulates), and recirculated as breathable air for astronauts. Therefore, air revitalisation will be an essential life support system to enable the ongoing human presence in space envisaged in ESA's ambitious *Explore2040* space exploration strategy.

… and a new device developed with ESA funding can efficiently and effectively clean air in enclosed spaces …

The *'Innovative Unit for the ECLS System Used for Air Revitalization Focused on Air Disinfection and Cleaning (ADC) - Clean Air in Space (CLAIS)'* is an ongoing project to develop a device to purify air in enclosed spaces. This unit removes fungi, viruses, bacteria, and odours more efficiently than conventional filter systems, leading to a safer and more comfortable environment for astronauts, and preserves operational space assets.

The idea for project CLAIS began when the project team worked on an EU Horizon 2020 project, to develop a terrestrial electrostatic precipitator system for air cleaning. The project team aims to integrate this system with cold plasma technology for use in space, where external air exchange is not possible.

Overview of the technology



Source: bucher.solutions

The European Space Agency (ESA) funded a €100,000 feasibility study under its Discovery programme[1], examining relevant space regulations, risks, and material requirements. The

[1] The Discovery programme, as part of ESA's innovation pipeline, explores new ideas and disruptive technologies by funding early-stage research and development in space technology. Through an open and competitive approach, it encourages risk-taking and collaboration with academia, industry, and innovative SMEs, aiming to identify game-changing concepts for future space missions.

vision of the overall CLAIS project (i.e., beyond the activities funded under this feasibility study) is to deliver a fully tested system for space use.

The project team consists of three SMEs and a university, all based in Austria, with no prior experience in the space sector. There was one prime and three subcontractors:

- **bucher.solutions** (Austria) leads the project as prime. Their core expertise is professional inspections for safety standards and explosion protection, including for electrical and mechanical systems in energy and ventilation.
- **Villinger** (Austria) provides specialist components. They primarily produce ice protection, air decontamination, and heating systems for the automotive, aviation and energy sectors.
- **ionOXess** (Austria) are another subcontractor providing components, who generally work in water treatment, air purification, and pesticide alternatives for plant growth.
- **The Danube Private University** (Austria) is responsible for measuring emissions and air quality. They primarily provide education programmes and undertake research in dentistry and medicine.

… to support safety in human space exploration …

As space exploration and sustained human presence in space expands, so too does the requirement for clean air in crewed spacecraft and stations. The International Space Station (ISS) has spent 25 years in Low-Earth Orbit (LEO), accommodating over 260 astronauts in that time. Several studies have been conducted on the air filtration systems on board the ISS, which have identified potentially harmful chemical compounds and pathogens in the air, posing a risk to the health and wellbeing of the crew on board.[i,ii]

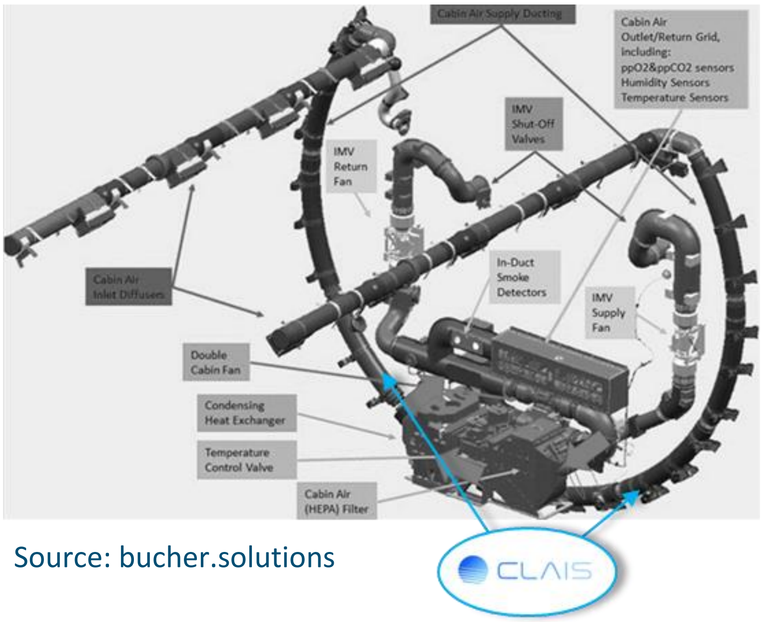
Beyond the ISS, the number of humans in space is also forecast to rise significantly in the coming decades. Future missions, such as the NASA-led Artemis programme, are outlining a roadmap to establish long-term human presence on the moon, in close collaboration with ESA, other international agencies, and industry. Several commercial space stations are planned or in development, such as the Axiom Station (Axiom Space), Orbital Reef (Blue Origin and Sierra Space), Starlab (Nanoracks and Airbus), and Haven-1 (Vast). Future missions will send crews to Mars and beyond.

The health of crew members and enhanced operational life of on-board equipment is essential in ensuring the success of these missions. These ambitions exceed the capabilities of present technologies, and early R&D is essential for developing and maturing new technologies to meet future spaceflight requirements.

Once matured, **the CLAIS technology could purify air to 99.999% and beyond, far exceeding what could be achieved with conventional filter systems.** The key added value of the CLAIS system is the removal and treatment of particles smaller than 300nm, which includes viruses and odour that cannot currently be completely removed. In addition to enhancing the wellbeing and comfort of crew members, this level of purification enhances the operational life of equipment, extending the potential duration of manned missions. The system could also reduce maintenance costs in the longer term.

Contingent on the availability of funding, the project team will look to integrate the CLAIS device into the Advanced Close Loop System (ACLS) of the Columbus module of the ISS, and subsequently the ISS Environmental Control and Life Support System (ECLSS). Following this, the goal is for the CLAIS system to be implemented as standard in future manned space stations and vehicles.

Overview of potential CLAIS integration into the Columbus ACLS



Source: bucher.solutions

… with potential to improve health back on Earth …

The COVID-19 crisis brought renewed attention to the social and economic costs of airborne viruses, and the importance of environmental design for promoting **public health**. Moreover, the project team stressed that the providers of conventional filters face few direct competitors, and there is an opportunity for a new market entrant.

The CLAIS system offers unique functionality in removing all airborne viruses, which is especially useful in closed environments, where air is re-circulated and there is no external ventilation. If the CLAIS system meets stringent space requirements and regulatory standards, this may help to validate the technology for **aviation**, **public transport**, and **medical/pharmaceutical** applications.

The technology could remove airborne viruses from aircraft cabins, buses, trains, trams and subways. Integration of these systems would improve the safety of these closed environments, and would additionally reduce the risk of viruses spreading within and across countries through these vehicles. Therefore, the technology could underpin significant indirect socio-economic benefits, for example, by saving lives and preventing economic contractions associated with global restrictions on travel. The COVID-19 pandemic resulted in a real GDP contraction of over 6% in 2020, more than the global financial crisis.[iii] Improving resilience to future viruses could lead to smaller economic contractions, as a result of better containment of outbreaks and lower risk to public health.

Other terrestrial applications for the CLAIS system are related to healthcare and pharmaceuticals, where highly purified air is essential for patient health and product standards. The system could be integrated into operating theatres, clean rooms, waiting rooms, and production facilities, to reduce the risk of infection or contamination.

… delivering potentially valuable socio-economic benefits

Project CLAIS is still at an early stage, and further technology development, prototyping, testing and commercialisation will be required to unlock the most significant benefits of this R&D. However, **some important benefits have already been realised at this early stage** through the feasibility study.

Promoting spin-in to the space sector

The four contractors participating in this activity had never worked in the space sector, and greatly benefited from ESA's guidance and expertise in helping them leverage terrestrial technologies for space applications.

As mentioned previously, all organisations within the CLAIS project consortium are new entrants to the space sector. ESA early R&D support has unlocked an opportunity for three SMEs and a university to gain exposure to the regulatory, project management, and technical requirements necessary to deliver space-grade equipment. A representative from bucher.solutions stated that the close working relationship with ESA was a key enabler in this process. They noted that the guidance, expertise, and knowledge exchange with ESA was invaluable in ensuring a successful transition into space applications, and would help the consortium to begin future projects and missions more efficiently in the future.

Progressing technology development

This activity enabled contractors to leverage mature terrestrial technologies to develop a new commercial space product, advancing its maturity to TRL1-2. ESA funding helped them pursue innovative and risk-taking approaches, creating valuable background IP, which could have a significant impact down the line.

The key output of this project to date is a feasibility study for adapting two mature terrestrial technologies into a new commercial product for space applications. While the terrestrial technologies were stated to have a TRL of 8, this project started from a nascent concept with respect to the space applicable technology and has since progressed to TRL 1-2. This has been achieved through extensive risk analyses of the materials required to retrofit the technology for space applications, which included simulating defects and playing out scenarios such as safety shutdowns, fail-safe communication, outgassing, and flammability assessments.

These activities have played a crucial first step in the process of developing a mature and flight-proven TRL 9 space device, which is the final objective of the CLAIS project. The funding has provided a pathway for the consortium to build new knowledge, de-risk technologies, and pursue innovative, risk-taking approaches, overall generating new background intellectual property (IP) with high potential impacts. These activities would not be feasible through internal investment alone, especially given the size of the consortium organisations.

Developing new partnerships and strengthening existing ones

This activity helped strengthen the existing collaboration between stakeholders and offered them access to diverse new organisations within the space sector, leading to the creation of new partnerships.

While the consortium has previously collaborated on the development of the terrestrial technology, ESA support has played a key role in sustaining these networks through project work, a trend which is set to continue in future CLAIS phases. The project has also facilitated new partnerships. For the first time, the project team has gained access to ESA stakeholders as a result of the project, unlocking access to a wider array of organisations with existing expertise and space heritage. For instance, the consortium has signed a **collaboration agreement with a large European manufacturer** for the second phase of the project, as well as the Medical University of Innsbruck and other partners.

If successful in receiving follow-on funding, the collaboration with the large European manufacturer will support de-risking of the technology, and enable access to its facilities, contacts and delivery heritage. In the longer term, this collaboration could also position the project team for future mission opportunities. Notably, this will be the first time that bucher.solutions have worked with an international company, raising the global profile of the Austrian SME.

Fostering technical and project management skills

All individuals involved in the project reported learning a lot through this ESA-funded activity, both on the project management side and the technical side. These skills can be leveraged in other space and non-space projects going forward.

Across the consortium, six people have been involved in the project to date, supporting the equivalent of one full-time employee (FTE) over the year, which is significant for supporting the continued growth of the SMEs. The team members, who are relatively senior, have had to adapt to new processes, such as the milestone and deliverable requirements of space missions. They have enhanced their technical expertise – especially in materials – through close knowledge exchange with ESA, and by undertaking evaluation exercises.

bucher.solutions also emphasised the project's importance in developing in-house project management processes. They have played a key role in integrating work packages, which will benefit the organisation in future projects and mission opportunities. Additionally, these skills can be transferred to scale future terrestrial applications of the technology.

Enhancing reputation and visibility

Contractors benefited from an 'ESA stamp of approval', raising their profile, credibility and visibility. This can be leveraged to secure funding in and beyond space, as well as new collaborations such as the one with a large European manufacturer.

As the consortium has not worked in space previously, bucher.solutions regarded ESA support as a key source of validation for their technology, helping to raise the profile of the organisation within the space sector and beyond. The enhanced visibility and reputation associated with the project's affiliation to ESA has already delivered tangible benefits, such as the aforementioned collaboration with a large European manufacturer. Moreover, the project team have been mentioned in local newspapers, and have appeared in two television interviews as a result of the project, helping to further raise the profile of the organisations involved. Outside of the space sector, bucher.solutions also mentioned how customers were interested in the CLAIS project, suggesting there could also be reputational benefits associated with developing space-grade technologies with ESA support, even in terrestrial markets.

Positioning for future contracts and funding opportunities

New to the space sector, the organisations involved in this activity are keen to continue exploring opportunities in space and leverage the emerging heritage they have build through this ESA-funded project to apply for funding and pursue new projects.

By providing early support to demonstrate the feasibility of project CLAIS, ESA has helped to position the consortium to pursue future follow-on contracts and funding opportunities to mature this technology. As already mentioned, all organisations in the consortium are spin-ins to the space industry, meaning this funding has also opened a new sector through which future contracts, revenues and collaborations can be secured. For example, the project team have already applied for ESA General Support Technology Programme (GSTP) funding for the second phase of the CLAIS project (decision pending). In enabling initial access into the space sector, this ESA Discovery support has also strengthened the Austrian space sector supply chain with 4 new organisations (i.e., the four contractors of this activity, bucher.solutions, Villinger, ionOXess, and the Danube Private University, which were not involved in the space sector until this ESA-funded activity).

Potential lucrative future terrestrial market opportunities

The technology developed could, once fully matured, have applications in a range of terrestrial markets, including aviation, pharmaceuticals, medical, and public transportation, representing significant potential revenue streams.

As mentioned previously, there are several terrestrial use cases for the CLAIS technology, with the potential for significant direct and indirect benefits. These markets also represent significant revenue generation potential for the project team.

The project team have outlined ambitions to scale up sales of the technology in both space and terrestrial environments, from 4 units in 2026, to 500 in 2029 – growing sales by a factor of 125 in just 3 years. In the longer term, the technology could disrupt or usurp existing solutions. While it is challenging to project the magnitude of potential revenue for space applications due to the uniqueness of each mission, the project team has estimated potential market sizes of the terrestrial applications, based upon demand and device cost, including:

- **Aviation:** the system could be used to supply cabin air conditioning in aircraft, with a potential global market size of €1 billion.
- **Pharmaceuticals:** the system could be used in clean rooms and production facilities with hazardous substances. With 2,000 pharmaceutical sites in the EU, the

project team estimates a potential market of €45 million, based on an assumption of 5 devices per site.

- **Medical:** the system could be used in operating rooms, clean rooms, and waiting rooms. With approximately 27,000 sites in the EU, 5 devices per site would amount to an estimated market size of over €600 million.
- **Public Transport:** the system could be used to clean buses, trains, trams and subways across the EU, where an estimated 885,000 units represents a potential market size of €1.3 billion.

At this early stage, there are still many steps required before any revenue benefits can be realised. Further development, knowledge transfer, testing, and funding is required to produce the technology. Moreover, an expansion in production capacity and marketing channels is required to obtain significant market shares once the technology is operational.

Would these benefits have been realised without ESA?

Given the crucial role ESA Technical Officers have played in supporting the consortium to spin-in to the space sector, the benefits associated with project CLAIS would not have materialised in absence of ESA support. With respect to future benefits, ESA support (both financially through the Discovery Programme and technically through the provision of expertise) will remain influential in developing the system for future space applications, both on the ISS, and in future missions / spacecraft / space station opportunities.

> *"It is hard to find funding for such early R&D activities, so ESA's support was definitely instrumental for the project and the outputs" – Lukas Bucher, bucher.solutions*

Given the technology already had a high maturity for terrestrial applications, the attribution of benefits associated with applying this technology to non-space markets is more complex. The project team stressed that there are significant benefits associated with leveraging the high standards of space applications to develop leading terrestrial technologies. As mentioned earlier, there are potential use-cases which will benefit from the technology development required to enable the system to operate in hermetically sealed environments.

Moreover, the reputational and visibility benefits associated with ESA support may help to raise the profile of the consortium internationally, helping them capitalise on the terrestrial market opportunities available within the EU and beyond. bucher.solutions mentioned the difficulty in finding funding opportunities for early R&D opportunities elsewhere, suggesting there may be limited avenues to pursue technology development, even for terrestrial applications.

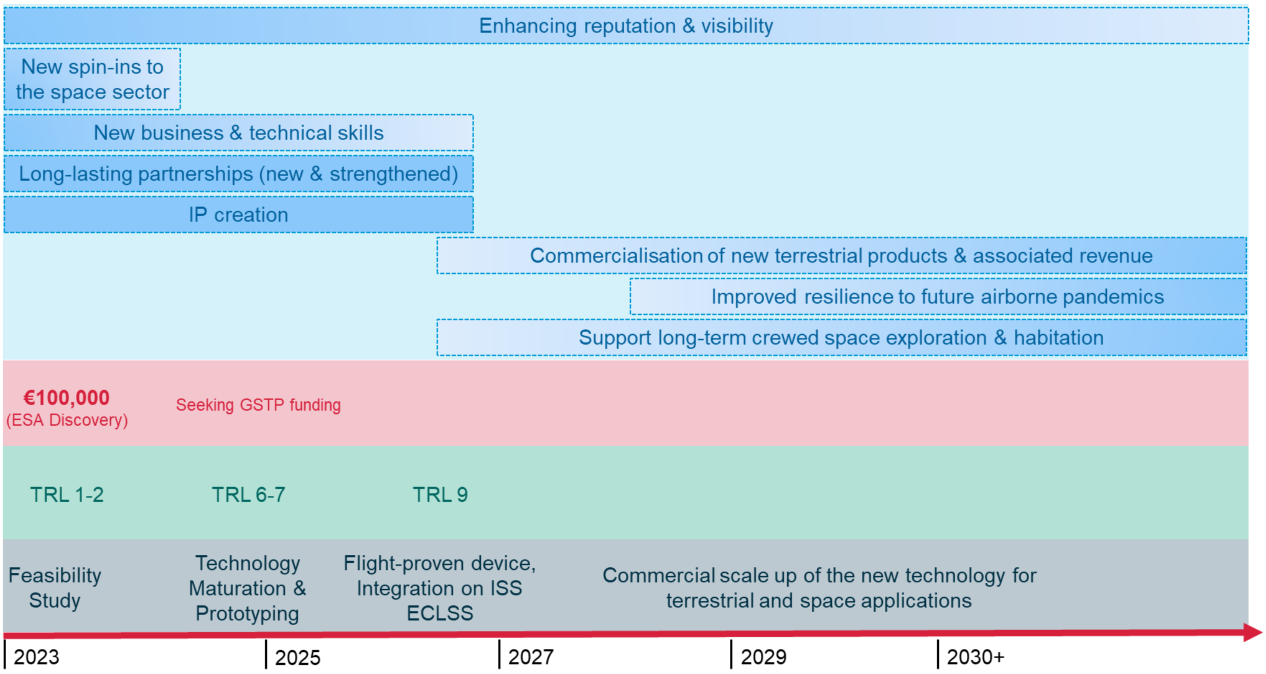
Next steps: Further development, further benefits

As previously mentioned, the most significant benefits from project CLAIS are contingent on further funding to support technology development and commercialisation for both space and terrestrial applications. Project CLAIS has applied for ESA GSTP funding (decision pending) to advance the technology into prototyping and manufacturing stages.

While this funding will likely secure short-term benefits, such as product revenues and increased crew safety, the broader socio-economic impacts that the ESA funding could unlock from terrestrial applications will only be realised in the longer term, once the technology is operational, commercialised, and scaled up.

A preliminary overview of the timeline of the overall CLAIS project and the associated potential benefits is provided below. These next steps and their impact are entirely dependent on the availability and timeliness of funding.

Overview of the timeline of the overall CLAIS project and the potential associated benefits



Source: know.space based on bucher.solutions data

Key priority indicators

Programme	Discovery
Country	Austria (AT)
Activity cost	€100,000
Duration	12 months
Lead contractor	bucher.solutions
Sub-contractors	Villinger, ionOXess, and the Danube Private University
TRL progression	From nascent concept to TRL 1-2 (for the space technology)
Spin-in into the space sector	4 (all contractors)
Jobs supported	6 people involved, equivalent to 1 FTE
New collaboration with ESA	All 4 contractors
Partnerships created	At least 2 (with a large European manufacturer and the Medical University of Innsbruck)
Follow-on funding applied/secured	ESA GSTP funding for Phase 2 of CLAIS (applied, decision pending)

[i] Checinska, A., Probst, A.J., Vaishampayan, P., White, J.R., Kumar, D., Stepanov, V.G., Fox, G.E., Nilsson, H.R., Pierson, D.L., Perry, J. and Venkateswaran, K., 2015. Microbiomes of the dust particles collected from the International Space Station and Spacecraft Assembly Facilities. *Microbiome*, *3*, pp.1-18.
[ii] Harrad, S., Abdallah, M.A.E., Drage, D. and Meyer, M., 2023. Persistent organic contaminants in dust from the international space station. *Environmental Science & Technology Letters*, *10*(9), pp.768-772.
[iii] Verwey, M., Monks, A. 2021. The EU economy after COVID-19: Implications for economic governance. *CEPR*. Available at: https://cepr.org/voxeu/columns/eu-economy-after-covid-19-implications-economic-governance