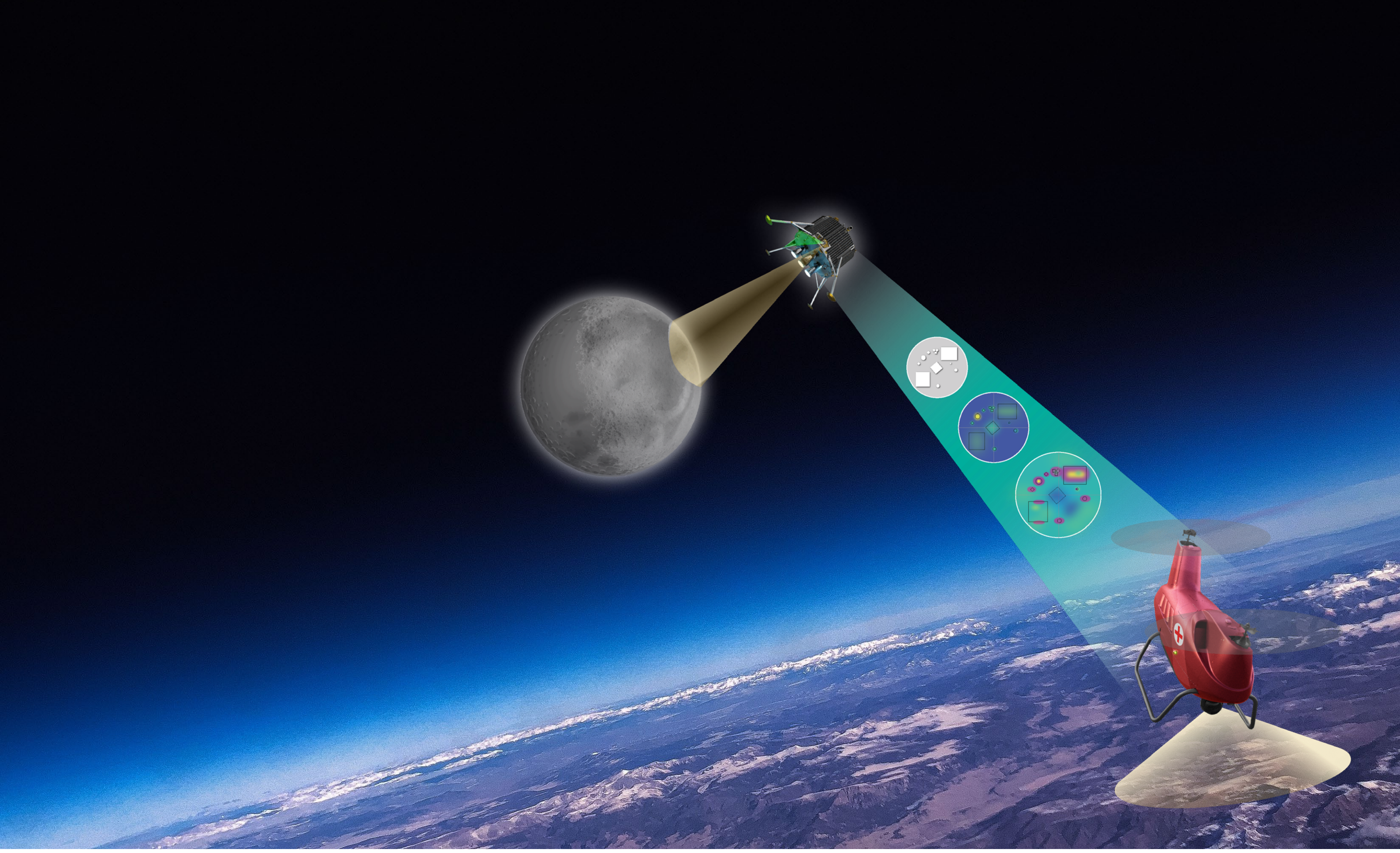

Socio-economic benefits from ESA Technology Transfers

A report for esa

CASE STUDY: Landing Zone Assessment for Drones

know.space

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Landing zone assessment using Lidar: space technology to enable a new class of drones

Successfully reaching the surface of an extra-terrestrial body, whether the Moon, Mars or a comet, entails significant risk in selecting a landing site and guiding the lander safely to the surface. Even with advanced mapping of the lunar or planetary surface, hazards such as boulders or steep slopes can risk the mission before it touches down.

Historically, landing in a precise area has entailed a slowed descent using thrusters (and parachutes where there is a significant atmosphere) and relied on flat expanses to minimise hazards. However, this significantly limits potential landing zones and omits many areas of high scientific interest where the terrain is less predictable. To enable safe landing in a broader range of potential landing sites, autonomous systems that can identify and guide towards safe landing sites are required.

A new Lidar-based approach to Hazard Detection and Avoidance (HDA) for planetary landing craft is now being applied to Landing Zone Assessment (LZA) systems for large autonomous unmanned aerial vehicles (UAVs or drones) on Earth.

Hazard detection and avoidance: a shared challenge

Lidar (Light Detection and Ranging) is a remote sensing method using light in the form of pulsed laser in order to measure variable distances to Earth; these can then be used with other data to generate precise three-dimensional information about the Earth's surface characteristics.

HDA technology automatically identifies roughness, slope and shadow hazards, then recommends safe landing sites to planetary exploration Landers. In real time it fuses the information from the Lander's navigation system, Lidar, and a camera to reconstruct the terrain topography, building hazard maps and directing the Lander to the safest site that is reachable. The technology was originally planned for use on the Luna-Resurs landing mission.

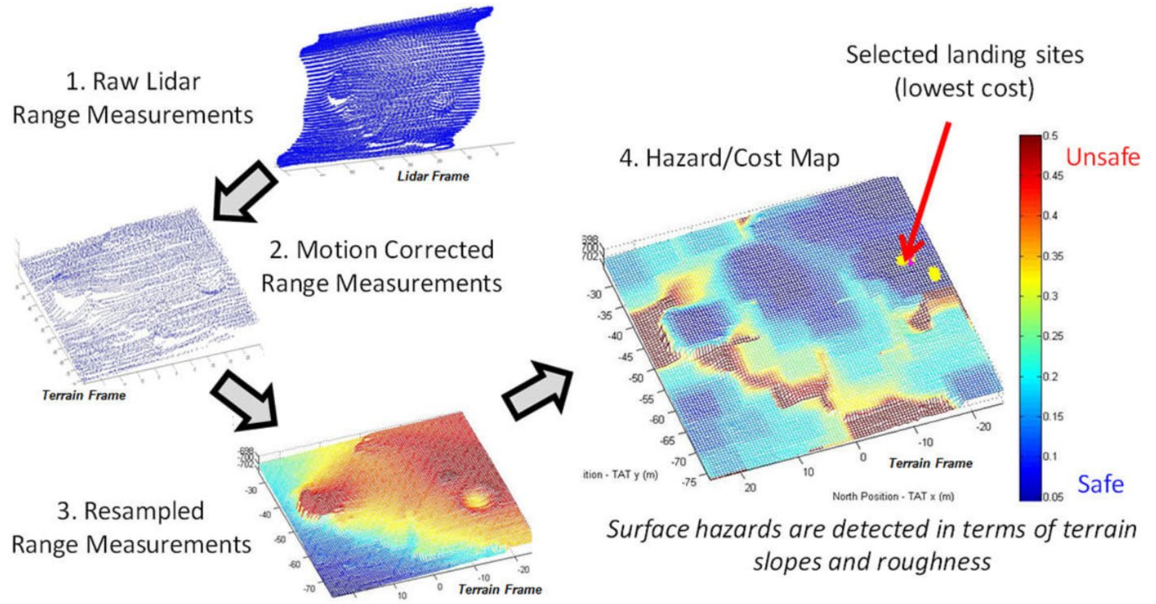

Image: NGC Aerospace

On Earth, there are similar challenges for autonomously landing UAVs, with potentially greater risk in terms of dynamic landscapes and populated areas. As in space, LZA for drones enables landing in unknown or unstructured environments by autonomously identifying hazards and recommending a safe landing site.

Successful deployment of this technology would open a **broad range of new applications** for UAVs, and **greatly mitigate risk in emergency situations** for larger UAVs operating in populated areas. Larger UAVs resemble unmanned helicopters and have wide-ranging potential from precision agriculture to monitoring forest fires. It is expected that **autonomous LZA will be required in the future to meet regulations** around beyond-visible-line-of-sight (BVLOS) operation of larger UAVs, making this technology critical to realising the full potential of UAVs.

Space technology brought down to Earth …

NGC Aerospace, a Canadian high-tech SME, are recognised for their design and deployment of artificial vision, guidance, navigation and control systems for autonomous vehicles in space, in air, and on the ground.

NGC met Laflamme Aero, a Quebec-based company that develops UAVs, at an international drone conference, and have collaborated for several years in the development of autopilot systems for one of the largest UAVs in the world – a 550kg tandem-rotor helicopter, LX300, designed by Laflamme.

Through the ESA technology transfer programme, NGC and Laflamme are collaborating on developing an LZA capability for Laflamme's remotely piloted LX300 helicopter. Laflamme have a range of complex requirements for operation, considering customers' needs and potential regulations surrounding the use of large UAVs in populated areas.

The technology has already undergone the first stages of testing. After an initial proof of concept phase that tested the LZA technology in a simulated environment, a second phase tested the system on a small UAV in a real environment. Now NGC and Laflamme are working with ESA to demonstrate the technology in an operational environment on Laflamme's full-size UAV, scheduled for summer 2022.

… enabling a new class of drone to fly

Adapting the software for UAVs on Earth is a complex task. The drone will be moving fast, changing altitude, dealing with wind and other weather, and at different trajectories and velocities compared to a Lander. Yet the rewards are significant, since **this type of technology is essential for the entire large-drone industry.**

Due to their size, larger UAVs are associated with a high degree of 'air risk' - colliding with objects in the air – as well as 'ground risk' - the risk of hurting people or damaging assets on the ground. **A reduction in ground risk will be vital to achieving compliance with emerging and future regulations on the use of UAVs**, especially when operating BVLOS. Large UAVs, classified as those greater than 25kg, are currently restricted to operating within visual-line-of-sight (VLOS), outside populated areas, and with case-by-case flight permits given.

Existing landing systems are based on radar and GPS, which further restricts landings to structured and known-to-be-safe locations, due to the limited achievable accuracy in hazard detection. Other solutions being worked on for the UAV industry are camera-based, but Lidar has significant potential advantages over these systems, as outlined in the sections below.

Potential for significant socio-economic benefits

Although the technology is still in development, some early benefits have already begun to emerge. The largest socio-benefits will come from the technology's successful commercialisation, as this solution potentially provides two huge opportunities for the sector: it **mitigates ground risk to enable BVLOS operation of larger UAVs**, and it **broadens the range of feasible applications** for large UAVs to those where the landing site is not necessarily known in advance. This will in turn generate wide-ranging and substantial socio-economic benefits.

Unlocking commercial opportunities

Enabling new UAV applications

"This **technology is critical** to enable beyond-line-of-sight operation of large drones"
David Neveu, Vice-President, Aerial Systems, NGC Aerospace

The LZA solution is a **significant step forward from existing landing systems for UAVs**, which restrict landing zones to pre-selected, safe and static sites. The use of Lidar instead of radar or cameras broadens applications to low visibility situations and can quickly assess unstructured or dynamic environments to identify and automatically land in a safe landing spot. Without this level of risk mitigation, large UAVs will not be permitted to fly beyond the operators' line of sight, or autonomously overpopulated areas. As such, this technology has **the potential to open new markets for large drones and their associated applications**. These applications are further explored below.

A clear opportunity in a fast-growing market

The global UAV market is forecast to grow from **€24bn in 2021 to €51bn by 2026**.

This technology is not currently commercially available, so this is an **opportunity to be a first mover in the global market** with an affordable system utilising state-of-the-art technology for LZA. The market for UAVs is growing fast, with forecasted growth from €24bn in 2021 to €58bn by 2026, and the commercial segment of the market is expected to grow fastest, at a compound annual growth rate of 28%[1]. Though Laflamme and NGC are focused on large drones only, there exists a substantial potential market for systems that enable wider applications of these UAVs, with many potential applications reserved for the largest types of drone, e.g. where a large payload is required.

Laflamme Aero are one of only a few players in the world addressing the large UAV segment. The firm sees the **potential to be market leaders in security and commercial applications**, becoming commercially competitive with manned aircraft.

Job creation

NGC have **expanded their workforce** as a direct consequence of this project, alongside **upskilling their existing workforce**, with employees gaining pilot certifcation. At Laflamme, a number of existing employees have had the opportunity to work on this exciting project and the company estimates one new employee has been taken on to cover the work associated with this

[1] Markets and Markets (2021) *Unmanned Aerial Vehicles Market* Available at: https://www.marketsandmarkets.com/Market-eReports/unmanned-aerial-vehicles-uav-market-662.html

project. The development of this technology has directly contributed to the Canadian employment landscape.

Expanded operations and investment

NGC Aerospace have grown their operations as a result of their increasing focus on terrestrial applications, brought about by the technology transfer. The firm has engaged in **increased flight testing activity**, investing in a **new fleet of drones**, alongside testing equipment. In the future, NGC hope to secure further investment to bring their product to commercialisation.

With technological advantages over existing systems

Overcoming poor visibility

Lidar **can operate under complete darkness** and in **poor visibility**, including snow and fog.

Other solutions being worked on for the UAV industry are camera-based. Cameras may operate well in perfect visibility, but **a key advantage of Lidar is its capabilities under poor visibility**. Lidar can complete LZA in darkness, poor lighting conditions, or limited visibility caused by snow or fog. This is **essential for a reliable LZA system**, which operators can be confident will work regardless of the situation. Furthermore, this opens up a far wider range of potential applications, such as monitoring forest fires, which necessarily entails poor visibility, or search and rescue in snowy conditions.

In practice, NGC have removed the camera sensor present in the space technology from the terrestrial application, as the planetary Lander requirement to identify shadow was not a factor for UAVs, and so the design could be simplified. As a future evolution of the product, the addition of a visible or infrared camera is being considered to **complement the Lidar capability**.

Flexible landing

Many potential landing zones, including those that have been used before and could be used routinely, also have other purposes – for example, building roofs (where helipads are common) or carparks. These environments could have unexpected or unpredictable obstacles such as people, vehicles, or other objects on or around them, meaning a guided or aborted landing would be necessary.

The LZA system would be able to detect and avoid these objects or people. This could **greatly increase the range of available landing sites**, opening up more opportunities for drone usage, **without the need for new or specialised infrastructure**.

Real-time detection

NGC's system is capable of performing UAV motion correction and landing zone detection and tracking in real time. This **minimises the need to hover in place or make multiple passes** before landing, commonplace with other solutions. This in turn increases the speed of landing, which is always useful, but may be vital in certain applications, particularly emergency situations.

In addition, landing quickly reduces fuel consumption, generating both cost savings to the operator and a positive environmental impact.

Saving valuable time

Currently, each UAV mission involves flight time, available working time, and return flight time. In some instances, end-users may like to have additional working time, but this could only be achieved (without changing the UAV) by reducing the weight of any payload to reduce fuel consumption. With the LZA system, the **return flight time could be re-purposed as working time**, with the UAV then automatically finding a safe landing site until it could be recovered at an appropriate time. This could be particularly useful in search-and-rescue or disaster management situations.

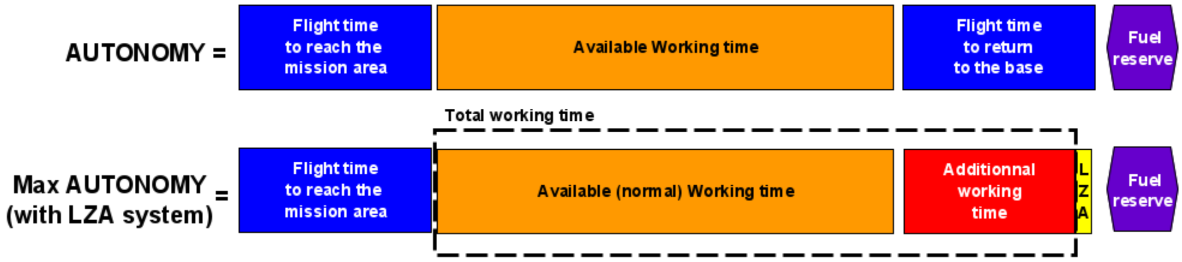

Image: NGC Aerospace

Wide-ranging compatibility

The system's **modular architecture** means it will be **compatible with a wide variety of sensors** which can be interchanged depending on the application. This was key in enabling the transfer from space to terrestrial applications, and means the software is more easily adaptable for terrestrial sensors and the alternative scan patterns and interfaces required for terrestrial landings.

Generating wider benefits to society

Enhanced safety for the general public

A key concern of airspace regulators for large drones is the high degree of ground risk in the case of a malfunction or loss of contact with any remote pilot or ground station. Such an incident could lead to a crash and cause serious injury, death, or destruction, putting the general public at risk. Of particular concern in sparsely populated areas is the potential for fires as a consequence of such crashes.

The LZA system could **dramatically reduce these risks by enabling the UAV to perform an automated emergency landing without injuring people or causing any damage** on the ground or to the aircraft itself.

Taking pilots out of harm's way

UAVs have the **potential to replace manned helicopters in dangerous situations**, such as firefighting, eliminating the associated risk to human life for the helicopter pilot. Of the 298 wildland firefighter fatalities in the US between 2000-13, 26.2% were aviation-related fatalities, with the leading causes of death being aircraft failure and pilot loss of control[2]. Therefore, introducing more UAVs could significantly reduce the fatalities associated with wildfire fighting by removing the requirement of having a pilot onboard.

Overcoming resource constraints

[2] Centers for disease control and prevention, 2015. *Aviation-Related Wildland Firefighter Fatalities – United States, 2000-2013*. Available at: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6429a4.htm

There is currently a **shortage of qualified drone pilots globally**, and also in civil aviation. This is likely to continue as the market for drones grows rapidly. The use of LZA enables fully-automated UAV operations, negating the need for a pilot and so mitigating against this constraint.

Reduced fuel consumption

UAVs consume **10-20% less fuel** than manned flights.

UAVs consume significantly less fuel than manned flights – Laflamme estimate between a fifth and a tenth of the total amount. This is due to their ability to operate with **one system engine instead of two**. It will also be easy to implement an electric version in the future when such technology is available.

Enabling many new applications

The **breadth of applications the LZA solution offers is vast**, spanning multiple sectors

Broad governmental potential

There is an **enormous breadth of potential applications of this technology**, ranging from **tackling emergency situations**, such as natural disasters and medical emergencies (e.g. transporting organs) to **carrying out routine inspections**, e.g. ice monitoring. Large UAVs with the BVLOS capability have a range of possible applications where large payloads to unknown or unstructured landing zones can be common. There exists potential for their application in border security, or search and rescue, where the landing site is not known in advance and may be in unstructured environments

Large UAVs also have the **potential to replace manned helicopters in certain situations**; for example, in providing crucial information on the spread of forest fires, helping authorities to map their spread and react quickly and effectively without putting human pilots at risk.

Enabling deliveries

In delivery missions without a pre-determined landing zone, the only existing option is to 'air-drop' the cargo. However, this is not feasible for some types of cargo, such as certain medical supplies, or anything that could be damaged by the drop. The **LZA system would enable the UAV to identify a safe landing zone close to the target to deliver such goods**. This is most likely to be applicable to missions with a moving target, or search-and-rescue missions where the target location is not known in advance.

Assisting agriculture

Laflamme believe that agriculture has the potential to benefit hugely from the use of large, unmanned UAVs enabled by their technology, and this could become a significant part of their business over the next 10-25 years. Large UAVs could be used in **precision agriculture, scanning crops and identifying areas for treatment**, reducing the costs to farmers associated with lost crops or unnecessary treatment, as well as benefitting the environment through reduced use of unnecessary chemicals.

Laflamme recognise that their technology would probably be out of reach of most individual farmers, so envision a cooperative model, whereby groups of farmers could share a large drone between them. The LZA technology would be critical in enabling such applications, mitigating the risk surrounding the use of large drones over populated areas, particularly as the drones move between farms.

Would these benefits have been realised without ESA?

This was Laflamme Aero's first experience of working with ESA, and it had a bigger impact on the project than they expected. ESA didn't just view the work as an R&D project, instead **being there at every step, challenging thinking and bringing new ideas**, making sure that the project was really addressing the challenges faced and that the solution would meet the requirements. The funding and support ESA offered through its demonstrator programme enabled both NGC Aerospace and Laflamme Aero to prioritise this project and work on it in parallel with other strands, instead of doing everything sequentially, which could have added years to the timeline, by which point it may have been too late to bring a competitive solution to the market. In this sense, ESA's help may prove vital to the technology's commercial success.

> "This kind of support is **critical** for the industry – without it, we would not have addressed this challenge now."
>
> *David Laflamme – Co-founder and Chief Technology Officer at Laflamme Aero*

… with further development and benefits to come

NGC and Laflamme are still developing their technology and hope to secure further finance to **commercialise their system** soon. They foresee a **broad range of potential customers**, initially focusing on governments, but in the future selling their systems to civil industry also. Since the technology is so new, there are a range of potential market scenarios, but it is possible that drones may become available for hire, similar to car hire at present, or owned cooperatively, for example between groups of farmers. All of **this will depend on future regulation** surrounding the use of large UAVs, but the enhanced safety promised by this technology should help to alleviate concerns from regulators and the general public surrounding large drone use.

LZA technology is also considered as key to the safe deployment of optionally piloted and electric vertical take-off and landing (eVTOL) aircrafts that are under development worldwide, with significant potential benefits from the technology's application to this area. Organisations involved in the development of such aircrafts have **already demonstrated clear interest** toward LZA to enable a range of delivery-focused and time sensitive missions.