ARL-TR-9999 ● OCT 2024

DEVCOM ARL Technology Assessment (Tech Assess) 2023 Participant Feedback Report: Auterion Government Solutions/KEF Robotics

by Marshal Childers, John Millemaci, and Luis Hernandez

NOTICES

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REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	3. DATES COVERED END DATE
October 2024	Technical Report	2 November 2023	2 November 2023

4. TITLE AND SUBTITLE
DEVCOM ARL Technology Assessment (Tech Assess) 2023 Participant Feedback Report: Auterion Government Solutions/KEF Robotics

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
Marshal Childers, John Millemaci, and Luis Hernandez

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
DEVCOM Army Research Laboratory ATTN: FCDD-RLA-JC Aberdeen Proving Ground, MD 21005	ARL-TR-9999

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES
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14. ABSTRACT
Tech Assess 2023 provided an operationally relevant environment and problem set that enabled technology developers to demonstrate new technologies and apply existing technologies in innovative ways. It also provided a means for the government to assess and provide feedback on the performance of technologies for known gaps and emerging needs. The primary objective of Tech Assess 2023 was to identify and assess technologies that can accelerate solutions relevant to US Army modernization priorities. Auterion, KEF Robotics, and the US Army Combat Capabilities Development Command Army Research Laboratory gathered at the Robotics Research Collaboration Campus at Aberdeen Proving Ground, Maryland, to demonstrate and evaluate autonomous mobility and navigation in a GPS-denied environment.

15. SUBJECT TERMS
autonomous mobility, GPS denial, unmanned aircraft systems, UAS, technology assessment, Military Information Sciences

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	C. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	24

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER *(Include area code)*
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STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

We thank the following individuals that participated in and supported Tech Assess 2023 as technology performers from Auterion Government Solutions (AGS) and KEF Robotics:

- Aaron Dahl (AGS)
- Robert Struck (AGS)
- Thomas Stastny (AGS)
- Daniel Mesham (AGS)
- Trent Siggard (AGS)
- Kerry Snyder (KEF Robotics)
- Fraser Kitchell (KEF Robotics)

Executive Summary

On 2 November 2023, Auterion Government Solutions (AGS), KEF Robotics, and the US Army Combat Capabilities Development Command Army Research Laboratory gathered at the Robotics Research Collaboration Campus at Aberdeen Proving Ground, Maryland, to demonstrate and evaluate unmanned aircraft system (UAS) technologies for autonomous mobility and navigation in a GPS-denied environment. This report describes the site, scenarios, assessment methods, and provides feedback on performance of the technology, including performance observations and needs that were identified during the event.

The Free Fly Astro was running AGS's Skynode, an AI node combined with third-party software that supports the system's higher-level functions. The platform also contained KEF Robotics' Tailwind hazard detection and avoidance modules. AGS's goal is to ensure that their products are interoperable across a variety of platforms.

KEF Robotics is a small business whose Tailwind product is deployed on a variety of UAS platforms. The integrated KEF Robotics technologies applied visual inertial odometry to enable GPS-denied flight. Although a fixed camera was used on the Astro, these technologies are also compatible with gimbal-mounted cameras, which typically tend to be at a lower technical readiness level than fixed cameras.

1. Introduction

1.1 Technology Assessment (Tech Assess) 2023

The purpose of Tech Assess 2023 was to inform US Army modernization efforts through innovation, discovery, demonstration, and experimentation of autonomy technologies. The intent of this assessment was to accelerate the delivery of innovative capabilities to the Warfighter.

Tech Assess 2023 provided an operationally relevant environment and problem set that enabled technology developers to demonstrate new technologies and apply existing technologies in innovative ways. It also provided a means for the government to assess and provide feedback on performance of technologies for known gaps and emerging needs. The primary objective of Tech Assess 2023 was to identify and assess technologies that can accelerate solutions relevant to Army modernization priorities. Tech Assess 2023 presented a venue to examine and understand Army challenges and provide assessment data to participants on how their technologies address these challenges.

1.2 Purpose

The purpose of this report is to provide Auterion Government Solutions (AGS) and KEF Robotics an evaluation of the performance of their autonomous mobility and GPS-denied navigation technology during Tech Assess 2023 held at the US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) Robotics Research Collaboration Campus (R2C2) facility on 2 November 2023.

2. Facility Description

R2C2 supports Army research in the areas of robotics, AI, autonomy, and teaming. The facility provides ARL and collaborators with the opportunity to conduct transformational research critical to multidomain operations and science and technology in an operational environment. As a facility with rich terrain features, the ability to present relevant scenarios, and a plethora of engineering facilities, it poses as an ideal location to perform technology assessments.

The site is located on a peninsula and consists of approximately 700 acres of woods, vegetation, shoreline, and infrastructure (Fig. 1). There are semi-improved paths through the vegetation with some cleared paths with undergrowth (Fig. 2). The infrastructure consists of a 600-ft-diameter gravel pad with a Military Operations on Urbanized Terrain (MOUT) configuration, an unmanned ground vehicle (UGV) mobility course (Fig. 3), and various other operations buildings.

Fig. 1 R2C2 facility

Fig. 2 Vegetative environment at R2C2 (this environment was not used during this demonstration)

Fig. 3 Configurable MOUT structures (top); UGV terrain course (bottom)

3. Assessment Process

3.1 Objective

The assessment provided an opportunity for the companies to demonstrate technologies in scenarios and terrain that are relevant to the Army. It is understood that the performance achieved was based on the technology configurations that were applied, the scenarios, and how they were administered. The primary objective of the assessment was to evaluate the capabilities of these technologies considering Army needs. We acknowledge that further research and development work is required to provide robust solutions for the Army, and our desire is that the findings of this assessment will contribute towards that goal. Secondary objectives included the generation of ideas by the performers and attendees on how to leverage the shown capabilities and identify potential collaborative efforts to build upon them. Figure 4 shows the AGS/KEF Robotics team briefing the demonstration attendees.

With regards to AGS and KEF Robotics, the primary objective was to demonstrate the ability of the Free Fly Astro (running AGS's Skynode and flying KEF Robotics' Tailwind) to navigate autonomously and in GPS-denied environments.

Fig. 4 AGS and KEF Robotics representatives demonstrate the Free Fly Astro for the attendees

3.2 Scenarios

The integrated technologies were demonstrated against two primary scenarios:

- One run consisted of an autonomous mission using waypoint planning (Fig. 5).
- The other run (GPS denial) consisted of turning off GPS as part of the navigation system on the UAS and the platform being flown manually. The display showed two tracks: the yellow line indicates the track determined by the GPS coordinates while the red line represents the track calculated using the onboard Visual Inertial Navigation system (Fig. 6).

The demonstration activities were conducted in the vicinity of the MOUT site (Fig. 7).

Fig. 5 Autonomous mission using waypoint planning

Fig. 6 Manual flight with GPS turned off

Fig. 7 Location of scenario activities with the MOUT site

4. Demonstrated Configuration

The UAS that was demonstrated was a Free Fly Astro running AGS's Skynode, consisting of an AI node and third-party hardware that uses an RV3 processor (Fig. 8). AGS does not manufacture robotic systems but makes products such as the AGS operating system (OS) that can run on a variety of platforms. This capability has enabled AGS to build partnerships with original equipment manufacturers of drones.

Fig. 8 Free Fly Astro platform

The UAS contained a Visual Inertial Navigation system, which uses visual inertial odometry (VIO) and conventional object detection to achieve terrain-relative navigation.

The technology recorded detailed logs of each flight conducted. An example flight log is shown in Fig. 9.

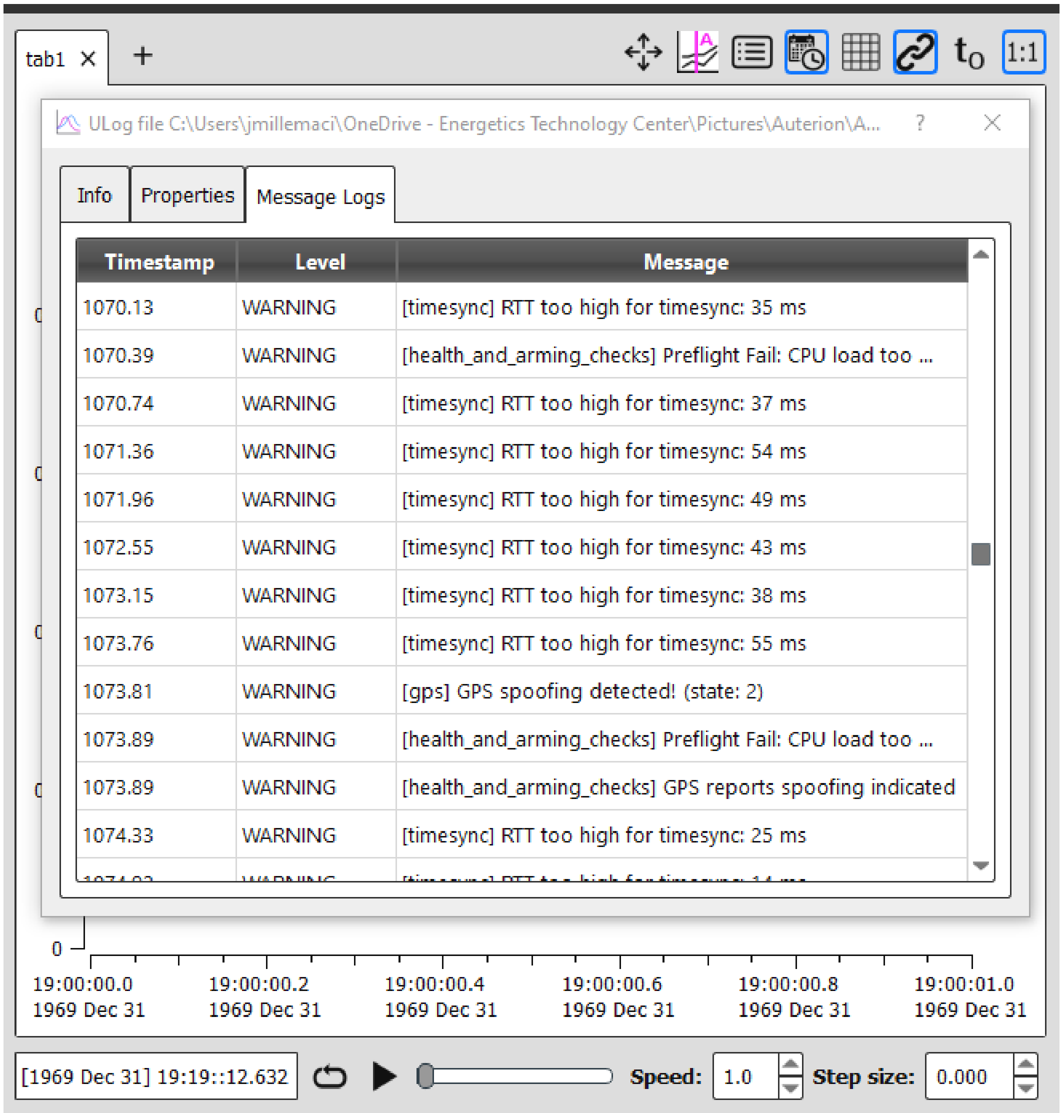

Fig. 9 Example of an Astro flight log

The focus of the AGS/KEF Robotics demonstration was the performance of the Astro UAS in a GPS-denied environment.

Figure 10 shows the Free Fly Astro in flight.

Fig. 10 Free Fly Astro in flight

5. Results

In this section we present a summary of observations and graphical results of the various scenarios that were undertaken by the vehicle (i.e., how this was collected).

Feedback is organized into the following eight categories:

1) Functionality (In what ways did the technology appear to be functioning for the scenario and environment?)

2) Relevance (How relevant was the performance to the scenario?)

3) Adaptability (In what ways is the technology adaptable to military operations?)

4) Concerns (What, if anything, about the performance is of concern and/or needs improvement?)

5) Effectiveness (Describe the effectiveness of the technology for the given activity.)

6) Viability (How is the technology useful for ARL and Army Futures Command [AFC] objectives?)

7) Specific feedback

8) Collaboration opportunities

5.1 Functionality

AGS's approach for standardizing an OS for UAS provides an approach for an optimized solution to many issues in the areas of UAS and other unmanned systems (UxS) adaptability and compatibility across platforms. They were able to demonstrate VIO dead reckoning of a UAS as it flew around the site using only a camera, inertial measurement unit, and altimeter. A custom sensor package was integrated on the UAS platform, but the Visual Navigation application could be integrated into any system running the AGS OS with the appropriate sensors.

Based on the demonstration scenarios, the GPS tracker and VIO were relatively accurate. The demonstration was adequate although limited by the actual flight conditions and the limited extent of the flight area (mainly confined to the MOUT site). It would have been valuable to see a demonstration over a larger flight area to see how much drift might accumulate.

The Astro performed without problems in a teleoperated mode, although both manual and autonomous flights were performed. The user interface appeared user-friendly and easy to understand.

5.2 Relevance

The platform performed well over a variety of terrains (i.e., gravel, buildings, and forest). Flight safety protocols required that line of sight to the aircraft be maintained. Although the flight area over which the demonstration was performed was relatively small, AGS flew the Free Fly over multiple loops to enable accumulation of errors as might be experienced over longer flight distances. Also, the demonstration of obstacle avoidance and autonomous navigation using VIO would have enhanced the demonstration for the evaluators.

KEF Robotics' VIO capability appeared relevant to the scenarios. Application outside of the target purpose would benefit from some form of closed-loop drift correction, especially for longer flight distances.

The accuracy of the VIO for the demonstration was not specifically measured, but KEF Robotics reports less than 2% error, relative to GPS, for other tests. However, visual observation of the separation of the two tracks appeared to indicate an error greater than 2% during the demonstration.

5.3 Adaptability

The requirement for flight in fully denied global navigation satellite system-denied environments is essential for a variety of military operations. Although the technology seemed to perform adequately, sometimes it did not appear to be very accurate (see the chevron position differences in Fig. 11).

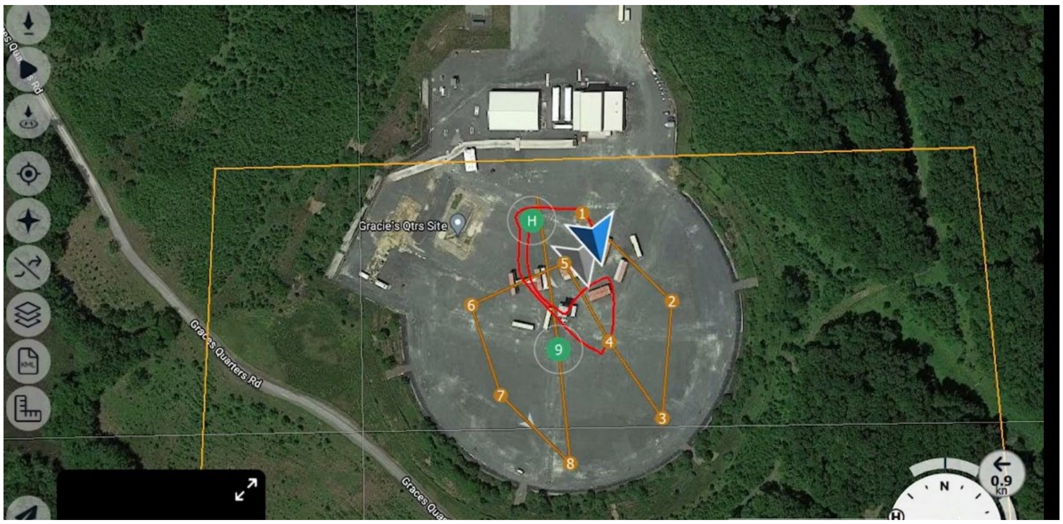

Fig. 11 Screenshot of the chevron positional differences during the demonstration

AGS has strived to ensure the AGS OS has wide potential application across all areas of UAS with potential across all UxS. The autonomy stack and standardization of software interfaces lend themselves to applicability to new autonomy capabilities. KEF Robotics' VIO is more limited in application & platform, but similar in adaptability to a variety of UAS.

The Visual Navigation solution is adaptable to a variety of UAS platforms, adding the ability to fly in GPS-denied environments to a multitude of platforms, including flying at low altitudes. KEF Robotics' VIO seems to be dependent on AGS OS, but since AGS OS is platform agnostic, that would enable KEF Robotics' VIO to run on multiple platforms as well.

5.4 Concerns

The assessment raised questions of accuracy over longer distances/flight durations, which influences the applications for which the system can used.

Since AGS is not a hardware vendor, solutions requiring more than software many take more integration time.

It would be beneficial if the AGS OS were to support all UxS in the future, to include air, surface, underwater and ground (both quad/legged and wheeled) platforms. KEF Robotics' capability would be useful in a similar, above platform, support level. It appears that the VOI method is fundamentally limited to aerial applications.

The KEF Robotics VIO requires a sensor suite to execute GPS-denied navigation, which might make implementation on a very small UAS problematic.

5.5 Effectiveness

The demonstration showed the technology to be effective to within a few meters (based on the limited flight area over which the demonstration took place) given the operating parameters of low altitude and low speed. Ground truth was provided by GPS for error estimation against the flight path determined by the KEF Robotics VIO system. However, a fielded capability should include map-based localization, which KEF Robotics stated they have but was not demonstrated. The effectiveness of the KEF Robotics system was easier to assess than the AGS OS, the evaluation of which required some experience with integrating platforms and developing ROS tools, applications, and modules.

5.6 Viability

The demonstrated technology would likely be viable for navigation in the battlefield and particularly for intelligence, surveillance, and reconnaissance under conditions where GPS hardware may fail or GPS jamming/spoofing is being applied.

The AGS OS ecosystem that supported the VIO demonstration is viable for use on a variety of UAS platforms. A single OS that would be common across all autonomous aircraft would have advantages. There is a ROS 2 interface to AGS OS, which offers a pipeline for ARL/AFC to transition algorithms to fielded systems.

5.7 General Feedback

If the accuracy of the technology could be improved, it could be used for dropping payloads in a GPS-denied environment.

KEF Robotics may want to consider the following license package options (prices are only for illustration purposes):

- Method 1: Offer standard perpetual license and low-cost, short-term expiring option. Examples are standard ($100) or 6 month ($45).
- Method 2: Offer standard perpetual license and low-cost access tokens (with bundle discounts). Examples are standard ($100), tokens ($5 each) (12 hours/token), or bundle ($350 for 100 tokens).
- Method 3: Offer standard perpetual license and high-cost, limited transfer option. Examples are standard ($100) or limited transferrable ($350) for up to five transfers.
- Cost should not be the only consideration. Ease of licensing would be an important factor as well.

The applicability of the KEF Robotics VIO solution could be increased by making the payload (sensors) smaller to be compatible with smaller UAS. Also, testing in inclement weather (e.g., rain) would be informative to assess how weather might affect the accuracy of the VIO.

The benefits of a single OS across multiple types of autonomous aircraft makes sense ("any camera, any computer, any aircraft").

5.8 Opportunities for Collaboration

Several ARL researchers expressed interest in collaborating with AGS/KEF Robotics. The names of those individuals will be provided directly to AGS/KEF Robotics.

The fact that the AGS OS ecosystem seems to offer a promise of modular upgrade capabilities in software packages makes it attractive for use on ARL and customer robotic platforms.

If AGS OS becomes widely accepted, collaboration is imminent. The KEF Robotics technology is likely applicable to some of ARL's customers' mission styles, dependent on its ability to close specific capability gaps.

6. Conclusion

The demonstrated UAS technologies showed success in the given scenarios for autonomous mobility and navigation in GPS-denied conditions. Feedback on the performance is provided by ARL in eight categories. The demonstration showed a rather seamless integration of AGS OS with the KEF Robotics VIO hardware solution. The ability of AGS OS to be implemented on a variety of UAS platforms attests to its ability to be integrated and positions AGS to be a dominant solution provider. During the demonstration it was difficult to gauge the magnitude of positional differences between the VIO-determined path and the GPS-determined path; therefore, further quantitative assessment, including over representative distances, is recommended.

List of Symbols, Abbreviations, and Acronyms

AFC	Army Futures Command
AGS	Auterion Government Solutions
AI	artificial intelligence
ARL	Army Research Laboratory
DEVCOM	US Army Combat Capabilities Development Command
MOUT	Military Operations on Urbanized Terrain
OS	operating system
R2C2	Robotics Research Collaboration Campus
ROS	robotic operating system
UAS	unmanned aerial system
UGV	unmanned ground vehicle
UxS	unmanned systems
VIO	visual inertial odometry

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