DESIGN OF A LOCAL AREA INTEGRATED DRONE, AIRCRAFT, VEHICLE, AND ASSET MANAGEMENT SYSTEM (LAIDAVAMS)

Charlie Wang, Lance Sherry

Center for Air Transportation Systems Research at George Mason University, Fairfax, Va.

Abstract

Campuses, such as military bases, airports, and industrial parks, include multiple transportation, energy, water, and agricultural infrastructure and facilities. Tenants on the campus can improve productivity and increase safety by using drones for inspection and surveillance of these infrastructure and facilities. Campus owners, operators, and Facility Managers would like to facilitate the use of drones but will need to coordinate and track drone operations along with all the other dynamic assets at the campus such as aircraft, ground vehicles (e.g. security, fuel trucks, baggage), and portable assets (e.g. construction equipment).

The paper describes the results of the application of the System Engineering Process (i.e. SE-V) for the design of a Local Area Integrated Drone, Aircraft, Vehicle, and Asset Management System (LAIDAVAMS). The system design includes: vehicle mounted transponders, ground-based receiver network at the campus, data processing and storage, data analytics, and visualization.

Introduction

Campuses, such as military bases, airports, and industrial parks, include multiple transportation, energy, water, and agricultural infrastructure and facilities. Tenants on the campus can improve productivity and increase safety by using drones for inspection and surveillance of their enterprises. Campus owners, operators, and Facility Managers would like to facilitate the use of drones but will need to coordinate and track drone operations along with all the dynamic assets at the campus. At an airport campus, this would include drones, aircraft, ground vehicles (e,g, security, fuel trucks, baggage), and portable assets (e.g. construction equipment).

The paper describes the results of the application of the System Engineering Process (i.e. SE-V) for the design of a Local Area Integrated Drone, Aircraft, Vehicle, and Asset Management System (LAIDAVAMS). The system design includes: vehicle mounted transponders, ground-based receiver network at the campus, data processing and storage, data analytics, and visualization.

The paper is organized as follows: The next section describes the Enterprise, Process, and Stakeholders. This is followed by the Concept-of-Operations for the LAIDAVAMS, the Requirements, and the Design/Functional Architecture for the LAIDAVAMS. The paper concludes with final comments and future work.

Context: Enterprise, Process & Stakeholders

This section describes the enterprise, process, and stakeholders. For the purpose of this paper, the description focuses on an airport, however, this description should be generalizable for other types of campuses.

Enterprise

Campuses, such as military bases, airports, and industrial parks, include multiple transportation, energy, water, and agricultural infrastructure and facilities. Examples include cell phone towers, power generation stations, water, and sewage treatment plants, quarries, railroad stations, railroad tracks, marinas, and waterways. An example of this type of campus is an airport. Airports tend to serve as transportation hubs connecting highway, marine, and rail with air transportation. Airports also have less expensive land that is attractive locations for quarries, sewage treatment, power generation, and agriculture. For example, a GIS study of 66 Virginia airports identified nineteen small and medium-sized airports with more than 20 infrastructure, facilities, and agriculture within 5 nautical miles of the airport [1].

Drones, also known as Small Unmanned Air Systems (sUAS), provide significant efficiency and productivity improvements for infrastructure inspections, aerial surveillance and reconnaissance, and aerial photography and surveying. Infrastructure inspections include powerline, cell phone towers, and railroad inspections.

These inspections can be conducted with higher frequency, less time, and lower cost than manual hands-on inspection [2]. The use of drones also significantly improves safety by avoiding inspectors having to climb structures [3]. Aerial photography and surveillance are conducted for quarries, mines, agriculture, and forests providing detailed digital surveying data not available through traditional means [4].

Campus owners, operators, and Facility Managers are incentivized to provide campus tenants the opportunity and infrastructure to operate drones on the campus. This may not be as onerous as it sounds. With appropriate procedures and technology, airports can safely operate vehicles in close proximity including parallel approaches, land-and-hold-short, taxi, and queuing. There is no reason why *cooperative* drones cannot also be operated in the safe proximity of airports. Note: protection against *non-cooperative* drones is a separate topic.

Process

Campus owners, operators, and Facility Managers will need to coordinate and track drone operations along with all the dynamic assets at the airport including aircraft, ground vehicles, and portable assets. Coordination and tracking can be done by having detailed information of planned and current simultaneous operations on the campus. Not only can the manager assist in deconflicting drone operations and drone-ground operations, but also keep track of drone, vehicle, and assets involved in operations, identify hotspots, and quickly address marginally safe operations.

The inclusion of drones along with campus vehicle and asset coordination and tracking is made possible by recent changes in drone standards that require drones to be equipped with receivers to transmit location and other information with a specified communications protocol (ASTM: F3411 − 19). When drones, ground vehicles (e.g. construction, security, maintenance, firefighting, etc.), and portable and fixed assets (e.g. portable signage, construction generators, portable lights, etc.) can be synchronized with this standard communications protocol, an enterprise-wide management system can improve productivity, efficiency, and safety to the overall enterprise.

Stakeholders

Campus tenants would like to use drones for inspections and surveillance to reduce costs and improve safety (e.g. manual inspection of smokestacks).

Campus Managers have potentially conflicting objectives of enabling their tenants to maximize their operations, yet minimize the risk of accident (of any type) but especially through the interaction of tenant operations.

Campus Managers are beholden to the campus owners such as municipalities or airport authorities for revenue generation. Indirectly these authorities are staffed by elected officials whose constituents want the best of both worlds: low cost, efficient, secure, and safe transportation access, without noise, congestion, and environmental hazards. Campus Managers must also meet local, State, and Federal regulations and support local law enforcement. Campus Managers must also manage insurance costs that are determined by the perceived risks.

With regards to drone operations, the Drone Operators, either employed by the tenants or outsourced by the tenant, must comply with Federal regulations regarding vehicle and vehicle operations. They must remain compliant with procedures for airspace operations including airspace Air navigation Service Provider (ANSP) Universal Traffic Management (UTM) systems, such as the Low Altitude Authorization and Notification Capability (LAANC).

As is the case for all technological systems the balance between safety and efficiency/productivity must be established and maintained in the presence of changing conditions.

Problem/Need Statement

The LAIDAVAMS will be used by campus property owners and facility managers to coordinate multiple simultaneous, safe drone and ground operations. In some cases, drone operations may be in proximity to manned flight or other ground operations. In addition, to drone operations, LAIDAVAMS can also be used to track campus surface vehicles (e.g. firefighting, law enforcement, fuel trucks, maintenance vehicles) as well as portable and fixed assets (e.g. portable signage, construction generators, portable lights, etc.)

The LAIDAVAMS includes drones, aircraft, vehicle, and asset-mounted transmitters and a network of ground-based receiver gateways. It also includes data processing and storage, data analysis, visualization, and report generation. In many cases, such as campuses on private property, it may not be feasible or appropriate for a government Air Navigation Service Provider (ANSP) to install and operate the ground-based receiver gateways for the surveillance system. When an ANSP does provide surveillance infrastructure, it may also make sense to have a ground-based receiver gateway independent of the ANSP surveillance system. It may also make sense to integrate two or more transmitter/receiver surveillance systems to reduce costs.

In the same manner that Airports monitor and improve airport operations by installing and operating surface tracking surveillance systems alongside air traffic control surveillance, LAIDAVAMS is designed to operate alongside government air traffic systems such as UTM and provide the campus facility manager detailed operational information.

The LAIDAVAMS will interface with government airspace Universal Traffic Management (UTM) systems, such as the Low Altitude Authorization and Notification Capability (LAANC). LAIDAVAMS can be also configured to provide ground-based detect-and-avoid for drones, vehicles, and assets, as well access to secure areas.

LAIDAVAMS Concept-of-Operations

LAIDAVAMS Concept-of-Operations is described in three phases: (1) Approval and Registration Process, (2) Day of operations, and (3) Monthly/Quarterly/Annual Reporting. The description below refers to Campus Tenants operating drones. The same process would apply to tenants using other mobile assets including fuel trucks, security vehicles, construction equipment, etc...

Approval and Registration Process

1. Campus Tenant decides to use drones (or other vehicle or portable assets) for inspections
2. Campus Tenant submits a request for drone operations to Campus Manager. The request provides details of the type of drone operations, frequency, time of day, location, …etc.
3. Campus Manager evaluates the request against Campus "operational regulations" to approve the request (with modifications if necessary.
4. Campus Manager registers the drone/asset in the LAIDAVAMS system.

Day of Operations

1. Drone operator prepares a drone for operation including "operational plan" and inspects vehicle/asset. Operational Plan includes times of operation, location, type of operation, safety range plans/procedures, … Note: operational plan can be filed up to 7 days in advance, not no less than 30 minutes from the time of operation.
2. Drone operator registers vehicle and "Operation Plan" with LAIDAVAMS.
3. LAIDAVAMS processes "Operational Plan." This includes deconflicting with other Campus Tenant operations, as well as filing for FAA Low Altitude Authorization and Notification Capability (LAANC) approval.
4. LAIDAVAMS approves Operational Plan
5. Drone Operator initializes drone and LAIDAVAMS acknowledges tracking (i.e. receiving drone broadcast signal).
6. Drone operator performs mission.
7. LAIDAVAMS provides the Campus Manager and Drone Operator the means to track operations and provide an alert if necessary. An example of an alert may be a change in weather forecast (e.g. wind magnitude and/or direction)

End of Month/Quarter/Annual Reporting

1. LAIDAVAMS provides Campus Manager (and Drone Operators) monthly/quarterly/annual operational statistics. Also identifies pre-cursors, cautions, and warnings related to safety margins as appropriate.

2. Campus Manager/Drone Operators adjust procedures as appropriate to improve safety margins.

LAIDAVAMS Requirements

Requirements for the LAIDAVAMS are defined below. The requirements refer to Campus Tenants operating drones. The requirements for drones apply to tenants using other mobile assets including fuel trucks, security vehicles, construction equipment, etc...

1. The LAIDAVAMS shall register all Campus Tenants and their vehicles and assets with a process that takes less than 5 minutes and can be completed with a Probability of Failure to Complete (PFtC) of < 1%.
2. The LAIDAVAMS shall register all proposed operations (i.e. Operational Plans) a process that takes less than 1 minute and can be completed with a PFtC < 1%.
3. The LAIDAVAMS shall deconflict all proposed operations (i.e. Operational Plans) within 3 minutes with an accuracy of 99%.
4. The LAIDAVAMS shall support a process that initializes the drone and acknowledges broadcast of drone position in less than 1 minute with a PFtC < 1%.
5. The LAIDVAMS shall track drone position with an accuracy of +/-5 meters with a latency of less than 5 seconds.
6. The LAIDAVAMS shall be secure from spoofing and jamming of the transmission/reception of drone position broadcasts.
7. The LAIDAVAMS shall store up to X Gigabytes of track data
8. The LAIDAVAMS shall secure all stored data from malware and cyber-attack
9. The LAIDAVAMS shall identify non-compliance with geo-fencing within 3 seconds and notify the Drone Operator/Campus Manager within another 3 seconds. The non-compliance shall have an accuracy of 99.9% and a Type II error of less than 5%.
10. The LAIDAVAMS shall generate operational reports with statistics for operations count, operations duration, operations distance traveled, operations max altitudes, operations average altitudes, operations geographic hot-spots, operations geo-fencing non-compliance.
11. The LAIDAVAMS shall exhibit an availability of 99%.

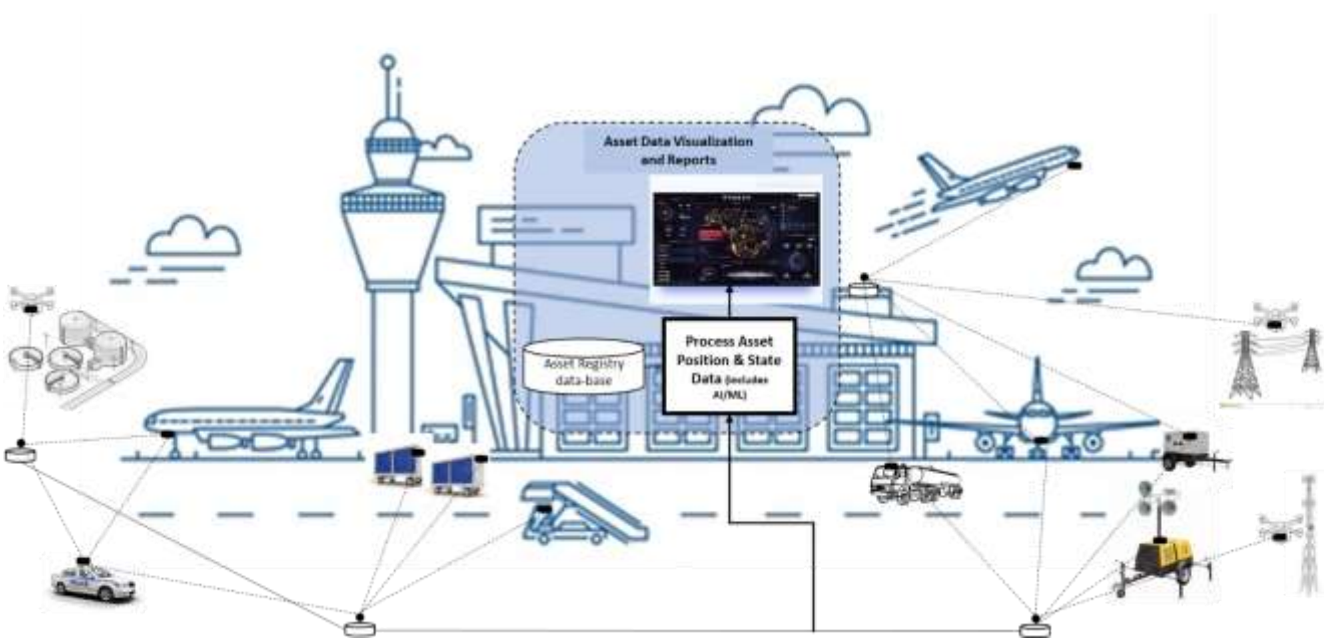

FIGURE 1: LAIDAVAMS component diagram

12. The LAIDVAMS shall exhibit MTBF of 1000 hours.

LAIDAVAMS Functional Architecture

The LAIDVAMS includes the following components:

1. Transmitters for mounting on drones, ground vehicles, (portable and fixed) assets. Transmitters include built-in GPS to transmit position data. Transmitters can also transmit additional data provided by the host drone/vehicle/asset
2. Ground receivers/Gateway located to provide complete coverage for the campus.
3. Transmitted data data-base
4. Data analysis
    a. Hot-spot analysis
    b. Anomalous behavior analysis
    c. Operational analysis reporting
5. Visualization (real-time), Visualization (historic), Report generation
6. Registration of Transmitters
7. Schedule and Operations Planning
    a. Visualization of Schedule
    b. Operations Deconfliction
    c. LAANC Coordination
    d. Geofencing and Geo-caging
8. API for external users such as Law Enforcement and ATC
9. Public-facing portal for voluntary, anonymous complaints, sightings/questions

LAIDAVAMS Component diagram (see Figure 1)

LAIDAVAMS Design and Analysis Simulation

Further definition of the requirements and the design architecture and the functional design requirements are in-process. These activities are supported by a simulation of the activities at an airport and the associated operations of the LAIDAVAMS. The simulation can be used to layout the ground receiver network (Figure 2), establish performance criteria and design thresholds, and the design of LAIDAVAMS user-interfaces (Figure 3).

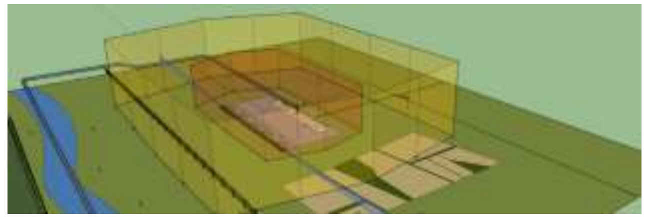

Figure 2: LAIDAVAMS Simulation of ground network receivers

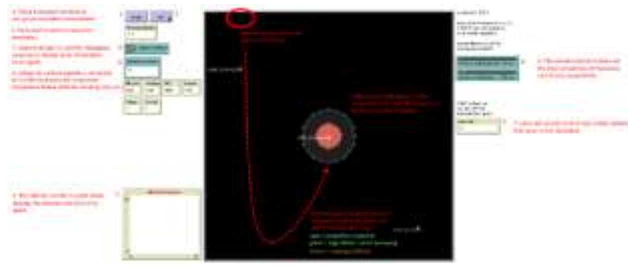

Figure 3: Simulation control panel for defining operations and setting parameters

LAIDAVAMS Business Case for Campus Managers

The business case for the purchase of the LAIDAVAMS varies for each unique application. The main argument is that the Campus Manager can generate additional revenue from new leases and extend existing leases by offering the LAIDAVAMS capabilities. The exact magnitude of the additional revenue is heavily dependent on the various local factors including the type of infrastructure and facilities and their benefits from drone operations and local industrial land leases prices.

Drone package delivery may be operated from the airport introducing a new tenant. Once the actuarial tables catch up, there could be benefits to the airport from reduced insurance liability costs.

There are also several intangible benefits to public relations and perceptions of being a forward-thinking enterprise. A spreadsheet tool has been developed to help make the business case of airport managers.

LAIDAVAMS Business Plan

This business plan covers only airports. The plan could be expanded for other campuses including military bases, business parks, critical infrastructure, and recreational and protected wildlife parks.

The product is the LAIDAVAMS that includes the ground receiver network, and the data storage and analysis. It is assumed that the drones, vehicles and assets will have the appropriate required transmitter.

The product, purchased by Campus Managers to coordinate and facilitate drone, vehicles, and assets to operate safely in close proximity.

There are 3,310 airports that are part of the National Plan of Integrated Airport Systems (NPIAS). A study of 66 Virginia mid and small-size airports identified 19 airports (i.e. 28%) with more than 20 facilities and infrastructure within 5 nautical miles that would benefit from drone operations. If that percentage holds across the NPIAS airports, the tenants of an estimated 927 airports in the U.S. would benefit from significant drone operations.

With a Total Addressable Market (TAM) of 927 and a 5% percent annual market penetration rate, with unit revenues of $500K over 5 years (i.e. $250K installation, $50K annual subscription), the 5-year revenue projection of $23M (conservative).

Startup costs are estimated $750K with annual operational costs of $500K, yielding a 6X return on investment (conservative) in 5 years, and a break-even in less than 3 years.

References

[1] Sherry, L. C. Wang, J. Bashata (in review) Method for Analysis of Drone Operations and Incursion Risk at Airports. Journal of Unmanned Aerial Systems. Volume tbd, Issue tbd. Page tbd.

[2] Khaloo, A.; Lattanzi, D.; Cunningham, K.; Dell'Andrea, R.; Riley, M. Unmanned aerial vehicle inspection of the Placer River Trail Bridge through image-based 3D modeling. *Struct. Infrastruct. Eng.* **2018**, *14*, 124–136

[3] Rakha, T.; Gorodetsky, A. Review of Unmanned Aerial System (UAS) applications in the built environment: Towards automated building inspection procedures using drones. *Autom. Constr.* **2018**, *93*, 252–264.

[4] Nooralishahi P, Ibarra-Castanedo C, Deane S, López F, Pant S, Genest M, Avdelidis NP, Maldague XPV. Drone-Based Non-Destructive Inspection of Industrial Sites: A Review and Case Studies. *Drones*. 2021; 5(4):106. https://doi.org/10.3390/drones5040106

Acknowledgements

The authors acknowledge the excellent review comments and suggestion from Jomana Bashata, Sara Nikdel, Jon West, George Donohue, John Shortle, Michael Hieb, Ali Raz..

Email Addresses

lsherry@gmu.edu

Conference Identification

2022 Integrated Communications Navigation and Surveillance (ICNS) Conference

April 5-7, 20