Hampton Roads
AAM Service Enablement Assessment

Minimum Viable Infrastructure System Assessment Document

Prepared by ATA, LLC

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Overview and Executive Summary

This document summarizes interactions over the past year with stakeholders in the Hampton Roads region as part of the Old Dominion University GoVirginia grant “UNMANNED SYSTEMS (UxS) ROUTE/ CORRIDOR NETWORK STUDY.” This document is intended to summarize key findings and to provide a preliminary assessment of Advanced Aerial Mobility (AAM) Service Enablement options, approaches, and potential costs using cost-effective solutions enabling near-term services and return on investment through the “Flight Information Exchange” (FIX) and “Minimum Viable Infrastructure” (MVI) concepts developed together with the Virginia Department of Aviation (DOAV), the Virginia Innovation Partnership Corporation (VIPC), and the Virginia AAM Activity (VAAMA).

FIX-MVI is focused on the creation of Public Digital Services that support industry needs today and into the future. FIX is focused on cost-effective, secure mechanisms for data sharing to support Federal Aviation Administration (FAA) requirements for safe AAM integration as Public Digital Services. MVI is a risk-based approach to infrastructure resulting in cost-effective deployment of infrastructure enabling immediate next steps in AAM. The result is a return on investment and a path to financial sustainability within two-three years.

This document describes specific opportunities, ideas, concerns, and potential requirements to start enabling a Hampton Roads (HR) regional service area and the associated MVI design for AAM Service Enablement (ASE), referred to as the HR ASE. It characterizes the types of operations that have been discussed, the risks associated with those operations, and the scale of MVI that may be needed to mitigate these risks and safely execute those operations in the HR ASE.

Successful implementation of MVI will support the growth of the aviation industry, provide new goods and services for residents, and set the stage for advanced air mobility (AAM) by focusing on AAM capabilities that are ready now. HR ASE MVI could deliver functional Public Digital Services that support these and future capabilities—the concept is to realize benefits that are available now while paving the way for the future.

If implemented, a HR ASE would be “multi-use” infrastructure supporting Public Safety missions, commercial AAM services, and airspace integration and safety research. As such, the HR ASE would be long-term, potentially even permanent, infrastructure that could support the following research goals:

1. Characterize airspace in a real-world environment over a longer period of time;
2. Characterize performance of Data Services within a multi-modal sensor approach in a real-world environment;
3. Assess the performance and use of a multi-model approach supporting Beyond Visual Line of Sight (BVLOS) flight;
4. Assess the performance and benefit of the multi-modal approach to support Public Safety missions, both Drone as a First Responder (DFR) and Counter-UAS (cUAS);
5. Assess the cost profile (both deployment and O&M) along with potential services and benefits to residents to develop real world costing and ROI models; and

6. Engage in user fee discussions and design through USS integration to begin identifying and developing a model for supportable infrastructure.

Summary of Discussions and Findings

Over the course of monthly meetings and interactions, along with in-person site visits and discussions with Hampton Roads area stakeholders such as York County Fire, DroneUp, ODU VISA, Commonwealth level stakeholders such as VIPC and DOAV, and stakeholder briefings organized both by the local Transportation Planning Organization and groups of military stakeholders, ATA identified the following opportunities, concepts, and concerns for consideration in developing a HR ASE:

- Opportunities for the Hampton Roads region:
    - The HR region has both urban and rural areas for development, allowing for test and demonstration of multiple types of conceptual operation
    - The HR region has complex airspace which presents a unique opportunity for development and adjacent Class G uncontrolled airspace that would support demonstration of operations transitioning between airspace classes
    - The HR region also has underserved rural areas that could be serviced by the region's commercial and general aviation airports
    - The HR region has multiple waterways separating components of the region, making transit much more complex in a distributed metropolitan area and substantially increasing the value of aerial operations to the region
    - The HR region has unique assets, such as NASA Langley and military aviation facilities that are willing to partner in developing the region's capabilities
    - The HR region has substantial expertise in aerospace and aviation manufacturing and operations
    - The HR region is close to Richmond and only three hours from Washington, DC
    - The HR region has the opportunity to leverage all of these assets as a perfect development area for complex operations that transition multiple partners and airspaces
- Concerns of Local Stakeholders:
    - General Safety: Community stakeholders want to ensure that the overall system is safe, both for participants and the residents that the system will by flying over
    - Counter-UAS: Public Safety participants had substantial concerns related to use of UAS for terrorist and illicit activities, such as attacking or disrupting critical infrastructure, surveilling or attacking public safety and military facilities, and just general risks to public safety
    - Publication of NAVAIDS: Public Safety wanted to ensure that published NAVAIDS and hazards, such as information on obstructions and critical infrastructure, could not be used for nefarious purposes

  - Integration with the military: Community stakeholders wanted to ensure that any operations and systems developed and deployed integrated with the HR military presence in a manner that is complimentary
  - Community equity: Community stakeholders wanted to ensure that sufficient public input be provided into system design and development so that the concerns and interests of the community were accounted for (e.g., noise, risk, location of take-off and landing facilities, overflight and sensitive areas, use rules for public facilities)
  - System Cost: Community stakeholders wanted to ensure that the model for development and sustainment did not place additional burden on public finances
  - Roadmap: Community stakeholders want to understand how to develop a planning activity to support the measured development of regional capabilities
- Concepts for Operations Identified in the HR region:
  - Last Mile Retail: As home to one of the leading sUAS last-mile delivery operators (DroneUp) the HR region is a logical host for more aggressive development of last-mile delivery operations under Part 107, Part 135, or a potential FAA “Part 108” rule – the distributed nature of the HR region, including water that is not easily transited with surface options, makes last-mile delivery appealing for the region
  - Commercial Medical: Similar to Last Mile Retail, Commercial Medical delivery involves the delivery of small items in time sensitive, last mile scenarios – however, Commercial Medical has certain aspects that differentiate it from Last Mile Retail: the time criticality of medical goods also results in life criticality, combined with custody requirements for medical goods this results in both a high service level requirement, but also the potential for greater fees and sustainment revenues than Last Mile Retail
  - Drone as a First Responder: This Concept refers specifically to the use of sUAS for Public Safety applications, such as assessment and overwatch or Police and Fire response, Search and Rescue, or delivery of time critical small goods (such as emergency medical supplies) in an emergency
  - Middle Mile Logistics: This involves specific, point-to-point operations using large (Group 3+) UAS for carrying either smaller, time sensitive cargo (<200 Lbs) using UAS or using next generation, including pilot-optional or reduced crew aircraft for larger (>200 Lbs) cargo loads
  - UAM/RAM: These operations involve, in the medium term, next generation platforms that use new powerplants such as electric, hybrid-electric, or hydrogen in either retrofitted existing airframes or next generation airframes; in the long-term, they involve some of the regional mobility concepts being developed by the electric vertical takeoff and landing (eVTOL) and electric short takeoff and landing (eSTOL) aircraft manufacturers, and will involve new procedures and takeoff and landing areas

The overall tone of the Stakeholder meetings showed that the Hampton Roads regional stakeholders recognize the potential promise of AAM for their region as well as the challenges of enabling it, given the complexities of the Hampton Roads region. The stakeholders recognize the unique opportunities and benefits to the Hampton Roads region given the distributed nature of the region in conjunction with waterways, and the region's military and manufacturing bases. The stakeholders also recognize that the same complex transit realities and military presence that make Hampton Roads a promising region for AAM development also present clear challenges, as the dev elopement of new services and infrastructure must account for the complex nature of the Hampton Roads airspace and groundspace and provide high levels of risk mitigation to support integration into existing air and surface transit operations.

All of the concepts discussed above are relevant and economically viable given the size, diversity, needs, and economic base of the Hampton Roads region. However, two ideas in particular stood out because of strong need, collaborative partners, and specific locations that are well suited to specific operational concepts laid out above:

- A middle-mile logistics / UAM / RAM test corridor between Hampton Roads Executive Airport and NASA Langley;
- Commercial Medical Delivery between Riverside Shore Memorial Hospital and Tangier Island

The corridor between Hampton Roads Executive (KPVG) and Langley Airfield represents a strong opportunity because KPVG has expressed a desire for these types of operations and a willingness to invest in infrastructure to support these aircraft and operations, while Langley already has surveillance and traffic management capabilities for next generation aircraft in place. The route represents interesting challenges, including integration over medium-density communities, integration with a General Aviation (KPVG) and a military (Langley) airfield, integration over a high density area (Newport News) and with surface controlled airspace (around Langley).

The Commercial Medical Delivery concept represents a response to strong need and value for enhanced, especially emergency, delivery services to Tangier Island. The service area includes one General Aviation airport (Johnson Field), the heliport at Riverside Shore Memorial Hospital, and Tangier Island Airport (with a short, 2,426-foot runway) and overflight over rural (3-4 miles) and water (approximately 10 miles) surface.

These areas are further described below in the context of operational risk and required mitigations.

Introduction and Approach to Advanced Aerial Mobility Infrastructure

AAM is the combination of Uncrewed Aerial Systems (UAS) Traffic Management (UTM - sUAS, <55Lbs), Urban Air Mobility (UAM - large vehicles for transporting people and freight), Regional Air Mobility (RAM – electrification and autonomy), and traditional Air Traffic Management (ATM). The premise isn't just about drones – it's about enabling the next generation of aviation: remote, autonomous, accessible, and inexpensive. Doing this effectively requires a substantial expansion of capabilities – communications, planning, charting, airspace awareness and coordination, airspace management, and local zoning and planning.

An AAM Service Enablement (ASE) needs to account for the development of infrastructure (physical, digital, policy, and configuration) while also charting a path that allows for the elements of infrastructure to be developed and deployed in a manner that is incremental and risk based. By charting a path for incremental roll-out of AAM infrastructure, we can manage the technical and performance risk of new infrastructure investments while also reducing total system cost by leveraging existing infrastructure and focusing new investment specifically where needed to address risk and demand. The result is a "MVI" approach to the roll-out of AAM.

The MVI approach to AAM recognizes that there is no "one shot" out of the box solution – it will require multiple parties and multiple technologies working together to get this done – public and private services for communications and surveillance, sharing of flight planning and intent data, groundspace configuration data from local governments, and helping communities prepare for integration. Consider three models that have been identified for the development of AAM systems, two of which have been tried in two states and a third that has emerged out of the Commonwealth of Virginia's work on VA-FIX:

- A mini-FAA "high investment" model that cues off of typical federal investments (think the Air Traffic Organization) where government commits to fund all of the infrastructure through a large systems integrator– based on what is being developed under this model, this is going to likely require hundreds of millions, if not billions, of dollars of funding;
- An "industry only" model where government lets industry sort it out and build all of this as private infrastructure – while this will require little public investment, but will result in a "toll only" system where even government agencies will have to pay private providers to access airspace and services (or, worse, government will build parallel public infrastructure); or
- A "Public Option – Private Option Hybrid" model (the Virginia model) focused on identifying the core assets and information that are needed, and using existing infrastructure and available, best-of-breed providers and technologies to provide a low cost "public option" that allows current sUAS operators to operate more safely and start to demonstrate some of the basic capabilities necessary to move toward BVLOS and autonomy, laying the groundwork for UAM, RAM, and full AAM.

In the "Public Option – Private Option Hybrid" model, the focus should be on supporting the discovery of existing infrastructure that can be repurposed for AAM; the hosting of basic public information services by State and Local agencies; and supporting basic, reusable integrations that scale across vehicles and across the different components of the AAM spectrum. The infrastructure for AAM (excluding vehicles) will likely fall into four key categories:

- **Physical infrastructure**, consisting of both public and private infrastructure, on- and off-airport, such as: take-off and landing areas; Vertiports; Delivery Hubs; transfer facilities; and maintenance and operations facilities.
- **Digital infrastructure** consisting of ground-based sensors for vehicle position and navigation, environmental and weather sensors, navigation and charting services, and vehicle communications.
- **Policy infrastructure** clarifying basic operating rules on the ground, schedules, allowable supplemental rules, and common standards of use.

- **Configuration infrastructure** that supports localities describing how physical infrastructure can be used in a manner consistent with policy infrastructure and provided through digital infrastructure.

Critically, *much of the infrastructure listed above already exists in some form today*. The key is to identify, organize, and publish it to the AAM industry. Based on our experience in the Commonwealth of Virginia, we can approach the development of an ASE plan through the following steps:

- **Establish Asset Governance**: Establish a basic, minimum-necessary governance activity that supports state and local agencies in consistently discovering, describing, configuring, and publishing physical and digital assets into the AAM system;
- **Asset Discovery and Publication:** Through the Governance activity, work with state and local agencies to discovery AAM assets (e.g., take-off and landing areas, existing sensors) that can be properly and consistently described and published into the AAM system;
- **Asset Integration:** Conduct basic data integration and asset publication through digital infrastructure for use by AAM operators and vehicles; and
- **Plan and Pilot Investment:** Identify targeted opportunities to invest in specific physical, digital, policy, and configuration infrastructure through asset integration to demonstrate functionality and performance of the ASE.

One key aspect of FIX-MVI AAM infrastructure is a commitment to infrastructure sustainability as a key driver of an economically viable AAM industry. Current models costs are in the range of $250,000 - $1,500,000 per square mile. Experience in Virginia and in ongoing work in Alaska, California, and Pennsylvania with enablement using the hybrid model suggests initial enablement costs in the range of $25,000 - $50,000 per square mile with long-term costs in the range of $1,500 - $2,000 per square mile by leveraging existing infrastructure and using hybrid public-private services. Not only is a lower cost model valuable in that it supports the ability to enable services over wider areas (especially for lower income and underserved communities), but it also results in lower long-term operations and maintenance costs, reducing the risk of under-maintained or abandoned infrastructure.

This initial assessment for the HR ASE is intended to provide an initial assessment, design, and plan for what is necessary to achieve “UTM 1.0” given the desired operations.

Summary Description of Proposed Concept of Operations

This section provides details needed to assess the risk levels that determine the level of fidelity of surveillance and groundspace description necessary to address the operational-specific risk mitigations. Operational types are based upon specific UAV mission objectives. They include:

- Public Safety Drone as a First Responder (DFR);
- Medical Delivery, emergency and non-emergency;
- Retail Delivery, small package;
- Survey / Videography;

- Middle Mile Logistics using larger (Group 3-5) UAS and Pilot Optional aircraft;
- Regional Air Mobility using next-generation platforms; and
- Urban Air Mobility platforms such as electric vertical takeoff and landing (eVTOL) aircraft.

Operational Description

The following table describes the Operational Types, including equipment specifications, control modes, approximate ranges, examples of Takeoff and Landing areas (ToLa), and examples of payloads. Note the operation type identification number in the left column:

#	Operation Type	Equipment	Control Mode	Range	ToLa Types	Payload
1	Public safety response / overwatch	sUAS <25Lbs	VLOS, EVLOS, BVLOS	3-5 Mi	Public	Imaging sensors
2	Emergency Medical delivery (NARCAN, AED, Epi)	sUAS <55Lbs	VLOS, EVLOS, BVLOS	3-5 Mi	Public, and private	NARCAN, AED, EPI
3	Non-Emergency Medical Delivery	sUAS <55Lbs	VLOS, EVLOS, BVLOS	3-5 Mi	Private	Packages < 5Lbs (HAZMAT, Controlled?)
4	Retail delivery	sUAS <55Lbs	VLOS, EVLOS	1-3 Mi	Private	Packages < 5Lbs
5	Survey / Videography	sUAS <55Lbs	VLOS	<1 Mi	Private and Public	Imaging sensors
6	Middle Mile Logistics	Group 3-5 UAS (55-1,320 Lbs)	BVLOS	50-200 miles	Private and Public	Cargo
7	Regional Air Mobility	Group 5 UAS (>1,320 Lbs)	BVLOS	50-200 miles	Private and Public	Cargo, Passengers
8	Urban Air Mobility	Group 5 UAS: (>1,320 Lbs)	BVLOS	10-50 miles	Private and Public	Passengers

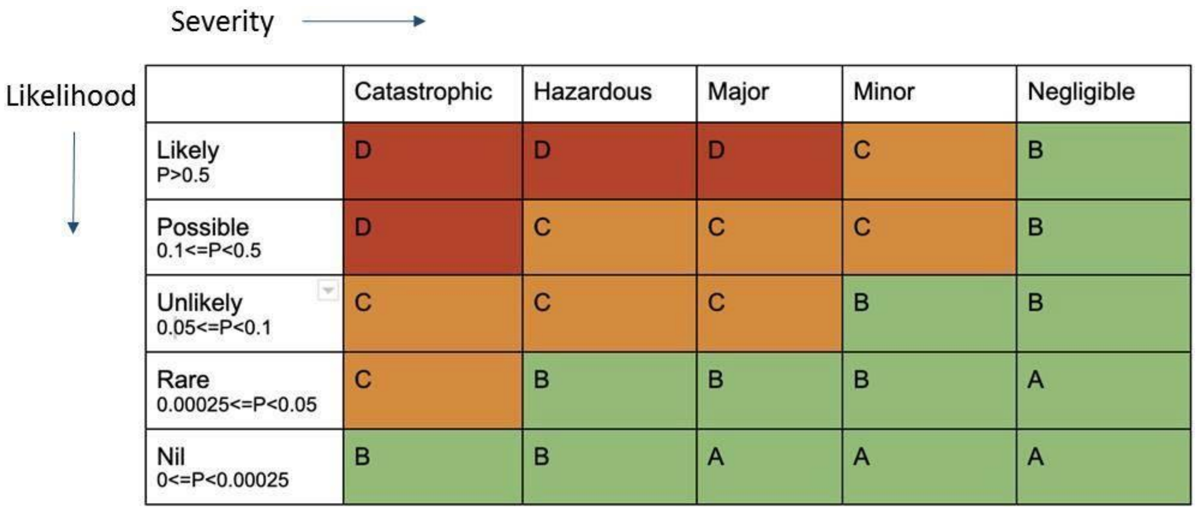
Table 1: Operational Descriptions

Risk Assessment of Proposed Operations

The summary operational description above is the basis used to develop an operation-specific risk level model. Operations are categorized into four levels of risk, with increasing levels of failure modes, effects, and criticality analysis, referred to as FMECA Risk Tiers:

- Class D: This risk category is never acceptable and must either be engineered out of the system or the operational category must be prohibited.
- Class C: This risk category constitutes outcomes where specific, demonstrable mitigations and redundancies must be engineered into the solution to effectively lower the Class.
- Class B: This risk category consists of those risks for which likelihood or severity are low enough to not warrant specific mitigation but do warrant alerting to the operator.
- Class A: This risk category consists of those risks that do not warrant further action.

The operation specific risk breaks into categories of likelihood and severity per the FMECA matrix below. Based on the assessment of individual operations, the potential severity of the different risk categories can be assessed. This provides the ability to correlate across the proposed operations and the ground assessment to identify the level of service fidelity required for a given operation. The FMECA matrix defines the statistical likelihood of an event cross referenced to the level of risk, and results in the FMECA risk level of the operation:



	Catastrophic	Hazardous	Major	Minor	Negligible
Likely P>0.5	D	D	D	C	B
Possible 0.1<=P<0.5	D	C	C	C	B
Unlikely 0.05<=P<0.1	C	C	C	B	B
Rare 0.00025<=P<0.05	C	B	B	B	A
Nil 0<=P<0.00025	B	B	A	A	A

Table 2: FMECA Characterization

Based on the operational descriptions and the FMECA matrix above, the table below allows for a thoughtful assessment of operational risk that allows us to describe specific risks and mitigations and place each expected operation type into a FMECA category that can then be used to plan the depth and fidelity of enablement coverage.

#	Complexity Elements	Specific Risks	Specific Mitigations	Risk Category
1	Potential for intersecting flight paths; other public safety activity	Loss of separation between UAVs or Manned Aircraft; Vehicle Failure; Exhausted Power Supply	Route/Groundspace design; DAA	Category B
2	Potential for intersecting flight paths; other public safety activity; lowering / delivering goods	Loss of separation between UAVs or Manned Aircraft; Vehicle Failure; Exhausted Power Supply; ensnaring delivery apparatus	Route/Groundspace design; DAA	Category B

#	Complexity Elements	Specific Risks	Specific Mitigations	Risk Category
3 / 4	Potential for intersecting flight paths; lowering / delivering goods	Same as 2	Route/Groundspace design; DAA	Category B
5	Potential for intersecting flight paths	Same as 1	Route/Groundspace design	Category A
6	Will need to be integrated with approach departure traffic at GA and controlled airfields	Larger (Group 3) vehicles will cause non-negligible damage in collision with another aircraft	Route/Groundspace design Procedural deconfliction Flight Planning / Scheduling deconfliction High surveillance performance Ditch plans	Category B-C
7	Will need to be integrated with approach departure traffic at GA and controlled airfields	Larger (Group 3) vehicles will cause non-negligible damage in collision with another aircraft	Route/Groundspace design Procedural deconfliction Flight Planning / Scheduling deconfliction High surveillance performance Ditch plans	Category C-D (note: category D is never acceptable and must be engineered out of either the ConOps and system or the airframe)
8	Will need to be integrated with approach departure traffic at GA and controlled airfields	Larger (Group 3) vehicles will cause non-negligible damage in collision with another aircraft Very novel, untested airframes	Route/Groundspace design Procedural deconfliction Flight Planning / Scheduling deconfliction High surveillance performance Ditch plans	Category C-D (note: category D is never acceptable and must be engineered out of either the ConOps and system or the airframe)

Table 3: Operational Risk Characterization

Service Volume Description

Ground Risk Tiers

The analysis of ground risk differs from overall operational risk in that we essentially only consider three factors and their interaction with the likelihood and severity of a ground impact: i) population density and exposure on the ground; ii) structures that either contribute to the likelihood of ground impact or mid-air collision or the severity of incident; and iii) topographical features that contribute to the likelihood of ground impact or mid-air collision. Further discussion about how to assess each of these factors follows:

- Population Density and Exposure: This risk considers ground population, population density, population activity, and the nature of structural cover to assess their contribution to the risk of mortality and morbidity in the event of a ground impact incident;
- Air Traffic Density: This risk considers the air traffic density of the specific service volume;
- Structure Risk: This risk considers degree to which ground based structures either contribute to the risk of a mid-air collision (in the case of cranes, towers, or RF interference) or the severity of a ground impact (as in the case of hazardous materials or flimsy cover;
- Climate Risk: This risk considers the region-specific weather patterns and microclimate risks associated with operational type, such as unpredictable winds and visibility due to topographical and structural features; and
- Topographical Risk: This risk considers specific topographical features that may contribute to challenging flight conditions (such as unpredictable winds), loss of communications (such as ridges), or navigational ambiguities (such as inability to assess terrain).

Within these factors, we can assess Low, Medium or High risk. Because these risks are difficult to quantify, the Low/Medium/High determination for a given factor within a service volume and the overall determination of ground risk for that volume should be narratively derived. That risk can then be matrixed against the operational risk analysis to derive an overall risk pairing, which will then provide a level of requirement enablement fidelity and currency.

In exploring how we segment a particular operational area into enabled volumes, the segmentation can be along topographical lines (because of natural communications barriers that will be required to treat the volumes separately), operational lines (because of the intended operating areas), or natural “risk” lines that divide a volume based on overall risk.

The risk analysis in the System Design document supports two key aspects of the enablement plan: Procedural Deconfliction and Systems and Sensor Integration Activities. The Systems and Sensor Integration components support real time event, environmental, and weather data advisories that support safe and compliant operations.

The premise in the Systems and Sensor integration activities is to focus on existing, functional systems and sensors that are currently available in the marketplace as the building blocks of FIX-MVI for the HR ASE. The key to FIX-MVI is to overlay “Tiers” of sensors to provide the right level of fidelity and currency relative to the combined operational / ground profile. The System Design Document will provide specific geospatial volumes for service enablement that represent the synthesis of operational goals, ground topography and assessment, and risk mitigations and tolerances.

The model assumes three Tiers of Performance Based Information provided by the sensor network:

- Tier 1 provides position, awareness and environmental services at the lowest Performance level, for a combination of lower risk, lower density service volumes and operations
- Tier 2 provides position, awareness and environmental services at a mid-Tier Performance level, for medium level risk, medium density service volumes and operations or for areas where a medium or high-risk operation occurs in a low risk service volume
- Tier 3 provides position, awareness, and environmental services at a high performance level, commensurate with current General Aviation services, intended to support medium or low risk operations in a high risk volume, such as adjacent to a General Aviation airport or over an urban core where the risk of injury is greater

Table 4 below provides examples of sensors, costs, and potential coverage areas by Tier. The intent is for Tier 1 to be implemented in Phase I, Tier 2 and Phase II, and Tier 3 in Phase III.

Tier	Example Sensors	Cost Profile	Example Coverage Area Type(s)
Tier 1	Procedural deconfliction + • RemoteID • ADS-B • Weather • GNSS RTK beacons	Inexpensive <$5,000 / sq mi	Low Density Rural sUAS operations at low weight / altitudes / Part 107 Procedurally deconflicted AAM at higher altitudes
Tier 2	Tier 1+ • Audio • Optical • RF / RDF	Mid-Cost $10,000 - $25,000 / sq mi	Low Density Rural Cargo Suburban Metro sUAS package delivery Group 2 long distance / Group 3 UAS conducting survey activities
Tier 3	Tier 2+ • Radar/LIDAR	Higher Cost > $50,000 / sq mi	Major Urban Area, Airports UAM Vehicle Vertiport Areas sUAS package delivery at high weight

Table 4: Examples of Tiered Sensor Infrastructure

Ground Description

The HR ASE is focused on enabling detailed airspace characterization and supporting navigation and surveillance services for the two concepts described above:

- Initially for Last Mile Retail and Commercial Medical Delivery using Group 1 / Group 2 sUAS for a service area including Riverside Health Shore Memorial Hospital in Onancock and Tangier Island;
- Initially testing Group 3 UAS for middle mile logistics, with the potential to develop Group 4-5 UAM/RAM operations in an area encompassing Hampton Roads Executive Airport (KPVG) to Langley Airfield.

The two HR ASE proposed service areas are described below, including Service Area 1 from KPVG to Langley Airfield, comprising a largely rural area south of the river, a river transit, and a largely urban, surface-controlled airspace north of the river. The overall service area is approximately 30 linear miles and 30 square miles (assuming 0.5 mile service coverage each side of the center line). Service Area 2 is from Riverside Shore Memorial Hospital to Tangier Island, approximately 20 linear miles and 20 square miles (assuming 0.5 mile service coverage each side of the center line).

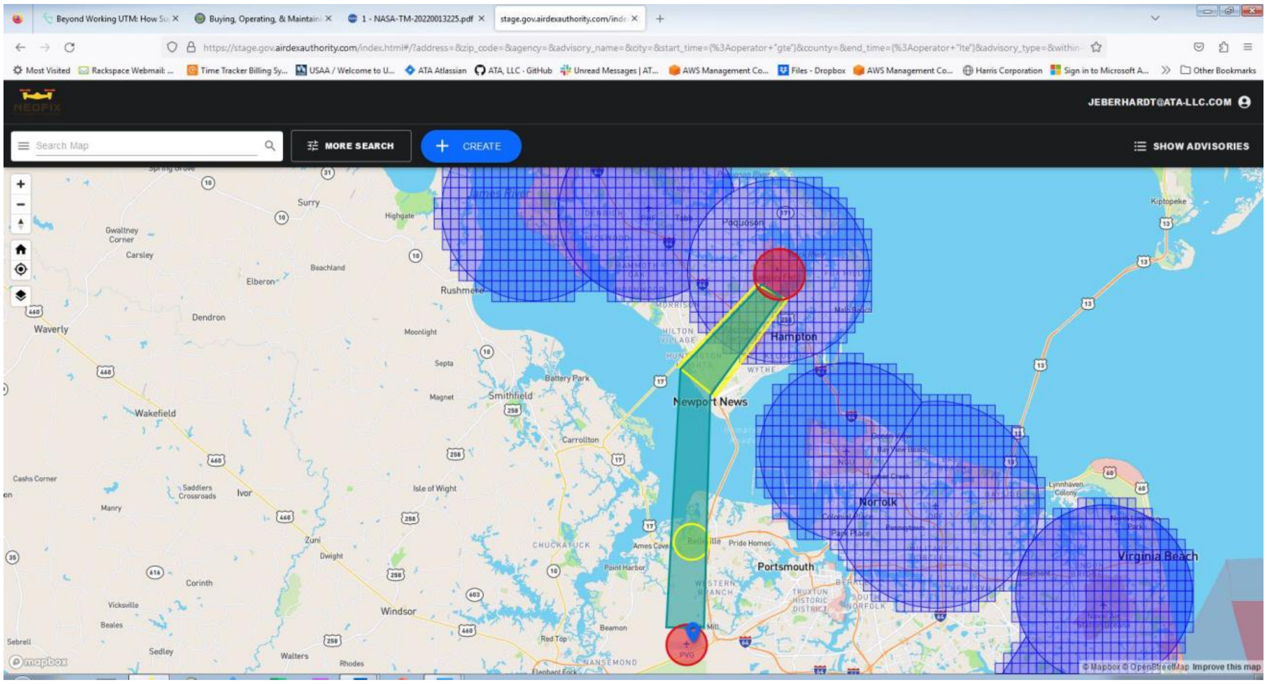


Figure 1: Proposed ASE Service Area 1 – Hampton Roads Executive to Langley

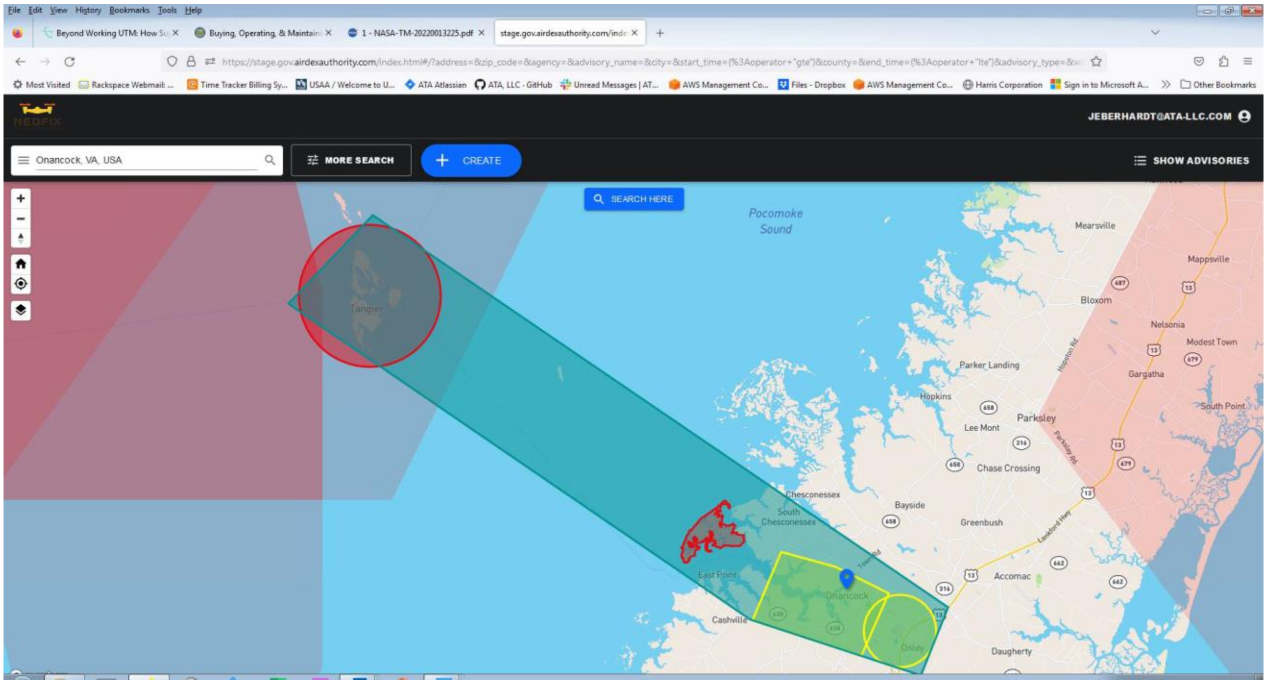


Figure 2: Proposed ASE Service Area 2 – Onancock to Tangier Island

Area of Enablement – Physical Volumes

To enable an area for service, we need to identify specific physical volumes for service enablement. Each volume may be bounded by i) topographical features, iii) desired area of service, iii) risk boundaries, or iv) a combination of the above. Figures 1 and 2 above define the two segments of the proposed service area. Service Are 1 is an angled approach that diverts around much of the surface-controlled airspace and US Interstate 664. It passes over the Belleharbour heliport. Service Area 2 represents a direct route from the Riverside Shore Memorial Hospital heliport to Tangier Island..

Given the 2 Service Areas, the HR ASE contains **nine** distinct service volumes:

- Service Area 1: 30 linear miles, 30 square miles
    - Service Volume 1: The overall Tier 1 service volume consisting of 30 linear miles / 30 square miles, including all over-water flight and encompassing other Tier 2 and Tier 3 Service Volumes – note that the risk and cost assessment of Service Volume 1 excludes Service Volumes 2-5
    - Service Volume 2: A Tier 2 service volume encompassing the Belleville-Belleharbour area including medium density development, comprising approximately 1.5 square miles.
    - Service Volume 3: A Tier 3 service volume from the James River to Langley Airfield comprising high and medium density urban development and Langley surface-controlled airspace comprising approximately 8 square miles.
    - Service Volume 4: A Tier 3 service volume encompassing the immediate vicinity of Hampton Roads Executive Airport comprising approximately 1.5 square miles.
    - Service Volume 5: A Tier 3 service volume encompassing the immediate vicinity of Langley Airfield Executive Airport comprising approximately 4 square miles.
- Service Area 2: 20 linear miles, 20 square miles
    - Service Volume 6: The overall Tier 1 service volume consisting of 20 linear miles / 20 square miles KPVG to Tangier Island, including all over-water flight and encompassing other Tier 2 and Tier 3 Service Volumes – note that the risk and cost assessment of Service Volume 6 excludes Service Volumes 7-9.
    - Service Volume 7: A Tier 2 service volume in the vicinity of Riverside Shore Memorial Hospital, Onley, and Johnson Field, comprising approximately 1.5 square miles.
    - Service Volume 8: A Tier 2 service volume comprising Onancock and the surrounding environs, comprising approximately 2 square miles.
    - Service Volume 9: A Tier 3 service volume comprising Tangier Island, including Tangier Island Airport and the surrounding environs, comprising approximately 2 square miles.

Each service volume presents specific risk characteristics that assign it to Tier 1, 2, or 3. Further, given the contemplated operations, additional mitigations may be required for each service volume.

- Service Volume 1consists of a complex transit airspace moving from low-population density rural areas across the James River into high density dev development terminating with the Langley Airfield controlled airspace. Excluding Service Volumes 2-5, which comprise the medium-high density areas, airfields, and controlled airspace, the remainder of Service Volume

1 consists of low density rural areas with minimum structural obstructions. Given adjoining controlled airspace, Service Volume 1 is likely to have medium-high density airspace. While the service volume deliberately skirts the more developed areas and I-664 to lower overall risk, the overall likely risk level for Service Volume 1 is a Medium Risk service volume;

- Service Volume 2 incorporates the Belleville-Belleharbour area, consisting of largely medium density commercial/residential with lower structural height adjacent to two major highways, , including a low-traffic volume heliport and medium density air traffic. The overall likely risk level for Service Volume 2 is a Medium Risk service volume.
- Service Volume 3 consists of the high density developed area from the James River to Langley Airfield. This includes potential tall structures, high density ground development, medium-high density interactions with conventional air traffic, and interactions with surface-controlled airspace. The overall likely risk for Service Volume 2 is a Medium-High risk service volume, given operations and mitigations.
- Service Volume 4 consists of the area surrounding Hampton Roads Executive Airport, a Class G private General Aviation Airport approximately 30 miles southwest of Langley Airfield. As an airport, it is by definition a Medium-High risk Service Volume, and KPVG has sufficient traffic to denote Service Volume 4 a High Risk volume.
- Service Volume 5 consists of the area surrounding Langley Airfield, a surface-controlled military airfield approximately 30 miles northeast of KPVG. As a surface-controlled airport with high traffic, Service Volume 4 is by definition a High Risk Service Volume.
- Service Volume 6 consists of an approximately 20-linear mile Service Volume from Riverside Shore Memorial Hospital to Tangier Island, approximately 14 miles of which are over water. The remainder of Service Volume 6 is almost entirely rural and low density, except for the town of Onancock, VA. The airfields contained within Service Volume 6 all have extremely low operational volumes. Therefore Service Volume 6 is a Low Risk Service Volume.;
- Service Volume 7 consists of the medium density town of Onancock, which has medium level development and limited tall structures. Because of development, Service Volume 7 is a Medium Risk Service Volume.
- Service Volume 8 consists of Johnson Field and the heliport facility at Riverside Shore Memorial Hospital as well as the town of Onley. These are relatively low volume facilities, however the complexity of medevac operations in a rural area and the low-altitude structure of Riverside Shore Memorial Hospital yield potentially higher risk. Service Volume 8 is a Medium-High Risk Service Volume.
- Service Volume 9consists on Tangier Island, a medium density rural community with Tangier Island Airport, a small General Aviation airport conducting 80-90 operations per month. Service Volume 9 is a Medium-High Risk Service Volume.

The service volumes and their characteristics are risk assessed and Tiered in the table below.

Volume	Likely Risk	Operations Risk	Tier	Other Mitigations
1	Medium	A-C	3 (2 excluding C operations)	Use of procedural deconfliction to publish specific operational routes and times; identification of safe ditch and hold sites; implementation of detect and avoid; focus initially on Category A-B operations
2	Medium	A-C	3 (2 excluding C operations)	Use of procedural deconfliction to publish specific operational routes and times; identification of safe ditch and hold sites; implementation of detect and avoid; focus initially on Category A-B operations
3	Medium	A-C	3	Use of procedural deconfliction to publish specific operational routes and times; identification of safe ditch and hold sites; implementation of detect and avoid; focus initially on Category A-B operations
4	High	A-C	3	Use of procedural deconfliction to publish specific operational routes and times; identification of safe ditch and hold sites; focus on air traffic deconfliction procedures; implementation of detect and avoid; focus initially on Category A-B operations
5	High	A-C	3	Use of procedural deconfliction to publish specific operational routes and times; identification of safe ditch and hold sites; focus on air traffic deconfliction procedures; implementation of detect and avoid; focus initially on Category A-B operations
6	Low	A-B	1	Use of UTM and procedural deconfliction to publish expected flight routes; identification of safe ditch and hold sites; operational risk management
7	Medium	A-B	2	Use of UTM and procedural deconfliction to publish expected flight routes; identification of safe ditch and hold sites; operational risk management
8	Medium-High	A-B	2	Use of UTM and procedural deconfliction to publish expected flight routes; identification of safe ditch and hold sites; operational risk management; specific procedural deconfliction through Riverside Heliport dispatch
9	Medium-High	A-B	3	Use of UTM and procedural deconfliction to publish expected flight routes; identification of safe ditch and hold sites to restrain UAS operations in the event of manned conflict; operational risk management; enhanced surveillance and alerting at Tangier Island Airport

Table 5: Service Volume Risk Characterization and Assignment

General Enablement Model

Overview of Conceptual Standard Deconfliction and xTM Model

Conceptually we can leverage operating lessons learned from traditional Air Traffic Management, the FAA's UTM concept, ASTM UTM, and U-Space standards development work to develop a general model for integration of UAS operations, risk management, and most importantly, risk mitigation through the design and emplacement of infrastructure at the local level. Our conceptual model for deconfliction Is a layered approach consisting of four principal layers:

- Procedural Deconfliction – Configuration of the groundspace and airspace constraints, potential fixed hazards, and operational design to procedurally reduce the potential for conflict and loss of separation;
- Surveillance / Situational Awareness / Conformance – Provide digital services that allow pilots to be aware of transient hazards (weather, ground incidents and condition) and surveillance of and awareness of position of craft in the airspace;
- Operational Deconfliction – Common situational awareness of planned operations and operational intent for vehicles operating in proximate airspace; and
- Onboard Systems – Vehicle designs, piloting procedures, sensors, and detect and avoid systems to act as a definitive failsafe if the other three layers fail.

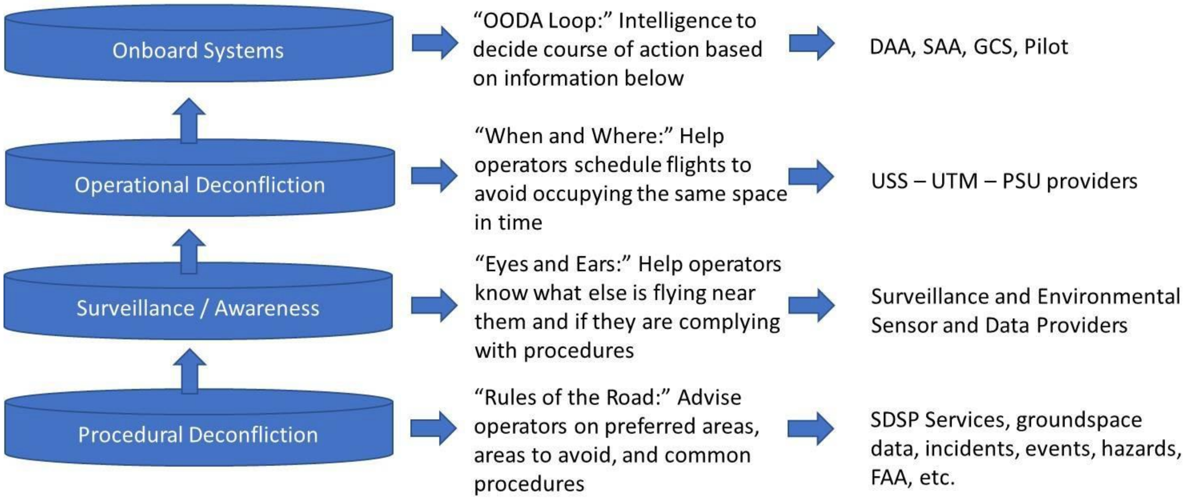


Figure 3: Layered Risk Mitigation Model – Conceptual Diagram

Discussion of Modalities and Components

This section discusses the potential components and modalities for Procedural Deconfliction, Operational Deconfliction, and Surveillance / Awareness. Table 7 below details different potential mitigations that can be applied within each layer of the four-layer model described in Figure 7. These can be used as specific proposed, planned mitigations in the overall ASE Plan.

Safety Layer	Specific Examples
Procedural Deconfliction	State or Local Government Information Advisory State or Local Government Supplemental Rule Advisory Ground Operations Prohibited Hazard / Obstruction Take Off and Landing Area (Hobbyist, Public Safety, Commercial)
Operational Deconfliction	Public Safety First Responder Emergency Incident Activity State or Local Agency Site Data Collection Public Safety Large Audience Event Public Safety Hazardous Materials Incident Public Safety Disaster Management Flight Operations / Operating Area (Hobbyist, Public Safety, Commercial)
Surveillance / Awareness	Weather, Visibility, Environmental Conditions Ground Environmental Conditions Detection and Position of Crewed Aircraft (ADS-B, Passive Detection, Active Detection) Detection and Position of Uncrewed Aircraft (RemoteID, Passive Detection, Active Detection)

Table 6: Examples of Layered Mitigations

Table 8 below details some of the specific modalities for Surveillance and Awareness that are available, including some of the characteristics of each mode, for consideration in the ASE Plan.

Modality	Pros	Cons	Range*
Passive – RemoteID (UAS only, participatory)	Very inexpensive and FAA mandated, decent range; strong position accuracy; no RF interference; no privacy issues	Not implemented yet, requires participation, not clear what / when compliance will look like	1 – 5 miles, depending on topography, RF conditions, and unit
Passive - ADS-B (Manned only, participatory)	Manned aircraft, already universally available; FAA mandated; strong position accuracy; inexpensive; no RF interference; no privacy issues	Compliance is not universal, doesn't work for UAS; requires participation which is not universal	20-200 miles, depending on aircraft altitude and receiver
Passive – Decoding (UAS only)	Leverages existing comms on the vehicle; many provide information on operator as well; strong accuracy; can be inexpensive; no RF interference; does not require participation; strong position accuracy	Totally vehicle dependent, may not provide operator information, mixed performance, malicious actors can easily engineer around; cost profiles vary; privacy issues	1-5 miles, depending on quality of receiving unit, topography, and RF conditions

Modality	Pros	Cons	Range*
Passive – Audio (UAS and manned)	Audio signature detection; no RF interference, no privacy issues; relatively inexpensive; doesn't require participation	Lower detection rate and positional accuracy than participatory, decoding, or radar methods; need more than one sensor to really calculate location, bearing and heading; cost profiles mixed	2-5 miles, depending on quality of receiving unit, topography, unit positioning, and vehicle altitude and trajectory
Passive – Optical (UAS and manned)	Optical signature detection; no RF interference, no privacy issues; relatively inexpensive; doesn't't' require participation	Lower detection rate and positional accuracy than participatory, decoding, or radar methods; need more than one sensor to accurately calculate location, bearing and heading; cost profiles mixed	2-5 miles, depending on quality of receiving unit, topography, unit positioning, and vehicle altitude and trajectory
Passive – RF (UAS only)	Triangulate RF signals; no RF interference, no privacy issues; relatively inexpensive; doesn't require participation	Lower detection rate and positional accuracy than participatory, decoding, or radar methods; need more than one sensor to accurately calculate location, bearing and heading; no current COTS solutions	1-10 miles, depending on quality of receiving unit, topography and RF conditions
Active – Small Radar (UAS and manned)	Detects all vehicles, participating or not; unlikely that a malicious actor can engineer around; no privacy issues; doesn't require participation; can achieve high rates of accuracy	Expensive; limited coverage area; dependent on line of sight; achieving accuracy requires siting and tuning; training	1-3 miles dependent on topography, conditions, siting and tuning
Active – Large Radar (UAS and manned)	Detects all vehicles, participating or not; unlikely that a malicious actor can engineer around; no privacy issues; doesn't require participation; can achieve high rates of accuracy	Very Expensive; dependent on line of sight; achieving accuracy requires siting and tuning; training	5-15 miles dependent on topography, conditions, siting and tuning

Table 7: Discussion of Potential Sensor Modalities in the Surveillance / Awareness Layer

General Enablement Performance Based Information Template by Risk

A key concept of the FIX-MVI model is to used shared services and data to create a “multi-modal” overlay that will provide a public MVI data stream through the FIX that can then be used by experts and various actors to conduct “track fusion” modeling. This modeling can then be used to create an overall performance baseline for the Service Volume that, together with the characterization of the Operational and Service Volume risk (see Table 6), can provide an overall mitigation strategy to pursue approvals from the FAA for operations. The multi-model aspect of the overlay is critical, as the different surveillance modalities complement each other, and voting network and filtering techniques can be used to create an overall Service Volume detection performance that exceeds the performance of any one sensor modality. Finally, the use of physically and logically distributed, multi-modal sensors reduces the risk of catastrophic failure where all surveillance is down – instead this allows for graceful service degradation that can then be addressed procedurally through operational mitigations.

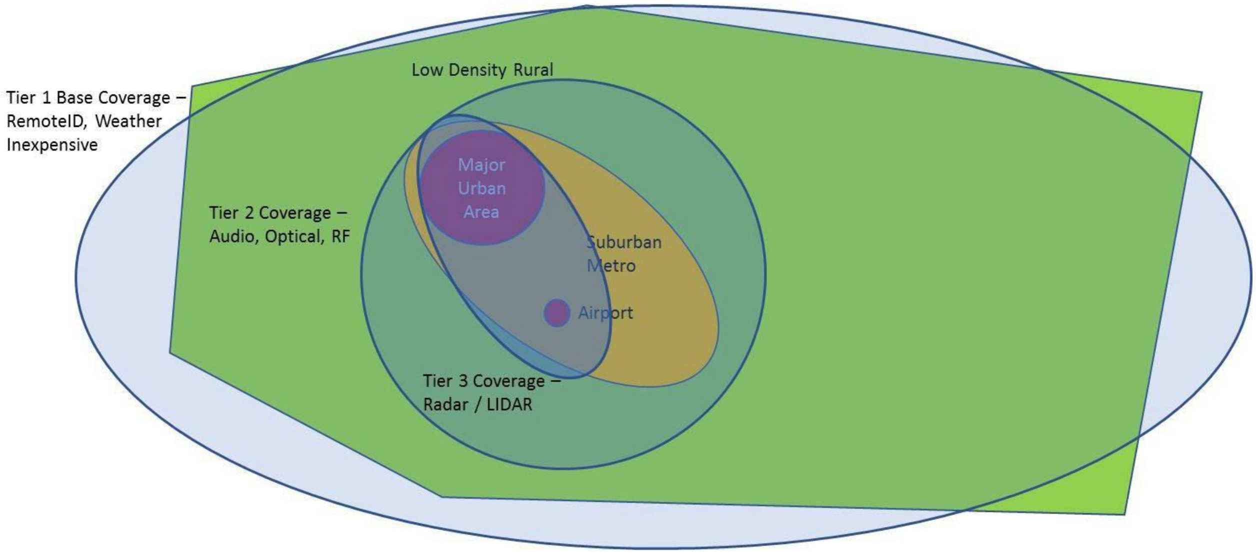


Figure 4: Tiered Performance Overlay Model – Conceptual Diagram

A key aspect of achieving the targeted level of risk mitigation is to establish a measurable performance baseline. Along with the expected performance baseline for the enablement services, we also need to develop a performance baseline for the data services themselves. Table 9 below discusses data service performance characterization metrics that can be built in and collected to characterize compliance to the proposed Service Performance Baseline.

Metric	Surveillance / Telemetry	Procedural / Configuration
Message Technical Latency	Metric: Milliseconds Evaluation: Elapsed milliseconds between relevant time stamps -- Are deviations within tolerance for the service?	
Message Completeness	Metric: Potential data elements Evaluation: Proportion of messages with fully reported elements	

Metric	Surveillance / Telemetry	Procedural / Configuration
Message Integrity	Metric: Expected message format Evaluation: messages validated for format -- What proportion of messages are malformed?	
Frequency / Refresh	Metric: Milliseconds frequency for the source service Evaluation: deviation in frequency delta between transmission timestamps and comparison to expected service level	NA
Message Precision / Confidence	Metric: Meters Evaluation: Underlying error of the source data -- Does the source data service report (decimal) at the expected level of precision? Are errors within tolerance?	
Geographic Availability	Metric: Geographic coverage Evaluation: Is the data service available for the geography -- Are messages generated within the geography for known characterized services?	

Table 8: Data Service Performance Characteristics

The matrix below leverages these concepts and describes potential surveillance / awareness performance benchmarks based on the overall Volume – Operational risk level (see matrix in Table 6 above). Procedural and Operational deconfliction are not listed generally, as these are general foundational capabilities that cover the enabled area regardless of surveillance modality; however, specific requirements are discussed in the sections below. It is important to note that the initial proposed service performance baseline is notional and will need to be refined together with industry and the FAA.

Risk: Volume x Operation	D	C	B	A
L	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Detailed microweather	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Basic surveillance / awareness with minimum frequency (<1m) and accuracy (<50m)	- Basic surveillance / awareness with minimum frequency (<1s) and accuracy (<50m) - Basic weather conditions	- Basic surveillance / awareness with minimum frequency (<1s) and accuracy (<50m)

Risk: Volume x Operation	D	C	B	A
		- Detailed microweather		
M	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Environmental surveillance with high frequency (<1s) and accuracy (<3m) - Detailed microweather	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Environmental surveillance with high frequency (<1s) and accuracy (<3m) - Detailed microweather	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with medium frequency (<30s) and accuracy (<10m) - Environmental surveillance with medium frequency (<30s) and accuracy (<10m) - Detailed microweather	- Basic surveillance / awareness with minimum frequency (<1s) and accuracy (<50m) - Basic weather conditions
H	N/A –must be engineered out of operation	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Environmental surveillance with high frequency (<1s) and accuracy (<3m) - Detailed microweather	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with high frequency (<1s) and accuracy (<3m) - Environmental surveillance with high frequency (<1s) and accuracy (<3m) - Detailed microweather	- Special procedural considerations such as no-go and ditch areas - Vehicle On-Board PNT with medium frequency (<30s) and accuracy (<10m) - Environmental surveillance with medium frequency (<30s) and accuracy (<10m) - Detailed microweather

Table 9: Notional Performance Baseline – Overall Service Volume Performance

Note that the table above is intended to be a starting point, and that specific mitigation strategies in each of the layers should be refined based upon knowledge of the terrain and specific operational risk.

This should involve specific considerations of frequency and accuracy based upon assessment of risk and knowledge of vehicle types and operators.

Enablement of Deconfliction and Awareness Services

This section details our understanding of the current state of readiness in the proposed service volumes and identifies applicable integration requirements and regulatory requirements that may apply to the contemplated operations as understood at this time.

Assessment of Current Enablement Readiness

This section applies the risk assessments and system design discussed above to the individual service volumes, and provides a starting baseline of service coverage by Service Volume, assessed at one of five statuses, as described in Table 11 below:

- Sufficient: There is sufficient service coverage within the Service Volume to meet the Performance Baseline;
- Incomplete: Some level of service coverage exists; additional existing local assets may be able to bring service coverage up to the Performance Baseline;
- Not Available: No existing service coverage or local assets, need to build from scratch;
- Unknown: Not known to exist, local assets may exist, further investigation needed; and
- Not Applicable: This particular service is not applicable to the Service Volume given the risk assessment.

The HR region, and the contemplated operations and Service Volumes, will likely require two types of Procedural Deconfliction: the publication of NAVAIDS through the Virginia Flight Information Exchange (VA-FIX) and the integration of flight planning and intent with services that share information such as UAS Traffic Management (UTM), NOTAMs and supplements for affected airfields, and potential radio broadcast services to advise adjacent manned traffic. The HR region already has VA-FIX coverage and certain parts of the region have well-characterized groundspace and NAVAIDS, while others will require a modest amount of incremental community engagement to complete the groundspace characterization. VA-FIX also supports various modes of UTM integration, however, identification and incorporation of USS tools and potential publication of information back into the National Air Space will also be required for full procedural deconfliction.

Additional services will also be required for integration of microweather and GNSS/RTK GPS correction to improve overall risk management and positional accuracy. Microweather services can likely be addressed by integrating existing locally owned sensors, however we should assume some modest investment will be required. We should also assume the need to acquire GNSS RTK beacons.

Surveillance currently exists at Langley Airfield through both the existence of a Raytheon Skyler system at Hampton University and existing surveillance equipment at NASA Langley Research Center (LARC). There is also existing FAA and Military surveillance at Langley Airfield as well. It is likely that NASA LARC will share surveillance feeds, and we may be able to receive shared FAA/Military feeds, but we should not assume this and plan as if we cannot access FAA/Military data.

Manned Integration Requirements

Service Area 2, given the proximity of UAS operations to Tangier Island Airport, will need to provide some level of procedural integration/accommodation, even if manual. The use of UTM, NOTAMS, and radio broadcasts on the CTAF (even if conducted manually at the airport) would provide a substantial increase in situational awareness and safety.

In Service Area 1, given the contemplated Middle Mile, UAM, and RAM operations between KPVG and Langley Airfield, Manned Integration will be essential. This will involve not only the types of integration contemplated in Service Area 2 (UTM, NOTAMS, radio) but also potentially using FAA LAANC for filing flight plans in the Langley surface-controlled airspace. It is important to note that this use is not currently permitted for LAANC, however the FAA has in other cases (such as Las Vegas and LVPD) allowed for LAANC to be used in an exceptional manner under waiver. Finally, accommodations will need to be made directly with the Langley military control tower for conetmplated Group 3-4-5 operations.

Applicable FAA and Industry Requirements

Based on the contemplated operations and initial risk characterization, the Performance Baseline and final design of the HR ASE should reflect requirements and performance parameters identified in the following rules and standards:

- FAA Part 107, regulating commercial small UAS operations;
- FAA Part 135, regulating charter operations, under which certain commercial package delivery operations will take place;
- FAA Part “108”, a notional regulation pertaining to extended commercial deliveries under a modified small UAS rule;
- FAA guidance and approvals to date of EVLOS / BVLOS under waiver and COA;
- ASTM F3178-16;
- ASTM F3442/F3442M-20; and
- Current FAA indications given by the current BVLOS NPRM.

Potential Enablement Plan and Costs

The risk analysis and preliminary design approach described in this document have identified three risk categories of initially contemplated operations (A, B, and c) and three levels Service Volume risk (Low, Medium, and High). Based on this analysis, the matrixed risk levels (A/L, B/L, A/M, B/M, A/H, B/H) translate into three logical infrastructure rollout tiers (Tier 1, Tier 2, and Tier 3). Table 10 below provides a high level overview of what digital infrastructure is needed by service volume based on known performance, and the following paragraphs provide a brief discussion of likely UTM and integration costs for the two Service Areas.

Service Volume	Tier	Equipment Need	Notes	Units	Unit Cost	Total Cost
Service Area 1						
Volume 1	2	Weather	Assume largely provided, need a few units	2	$1,500	$3,000
		GNSS RTK	Need triangulation coverage	3	$2,500	$7,500
		ADS-B	Assume largely available, need to add 1 unit	1	$1,500	$1,500
		RemoteID	Assume linear coverage with 2 miles radius	8	$7,500	$60,000
		Optical	Assume linear coverage with 2 miles radius	8	$15,000	$120,000
		Audio	One system with three sites	3	$35,000	$105,000
		RF Triangulation	One system with three sites (note approach is experimental)	3	$10,000	$30,000
		Radar	Assume only in Tier 3 service areas	NA		
Volume 2	2	Weather	Leverages Volume 1 capabilities	NA		
		GNSS RTK	Leverages Volume 1 capabilities	NA		
		ADS-B	Leverages Volume 1 capabilities	NA		
		RemoteID	Leverages Volume 1 capabilities	NA		
		Optical	Leverages Volume 1 capabilities	NA		
		Audio	Leverages Volume 1 capabilities	NA		
		RF Triangulation	Leverages Volume 1 capabilities	NA		
		Radar	Assume only in Tier 3 service areas	NA		
Volume 3	3	Weather	Leverages Volume 1 capabilities	NA		
		GNSS RTK	Leverages Volume 1 capabilities	NA		
		ADS-B	Leverages Volume 1 capabilities	NA		
		RemoteID	Leverages Volume 1 capabilities	NA		
		Optical	Leverages Volume 1 capabilities	NA		
		Audio	Leverages Volume 1 capabilities	NA		
		RF Triangulation	Leverages Volume 1 capabilities	NA		
		Radar	Assume 3 units in linear configuration to fill in coverage between the James River and Langley	3	$40,000	$120,000

Service Volume	Tier	Equipment Need	Notes	Units	Unit Cost	Total Cost
Volume 4	3	Weather	Leverages Volume 1 capabilities	NA		
		GNSS RTK	Leverages Volume 1 capabilities	NA		
		ADS-B	Leverages Volume 1 capabilities	NA		
		RemoteID	Leverages Volume 1 capabilities	NA		
		Optical	Leverages Volume 1 capabilities	NA		
		Audio	Leverages Volume 1 capabilities	NA		
		RF Triangulation	Leverages Volume 1 capabilities	NA		
		Radar	Assume 4 units in 360-degree configuration	4	$40,000	$160,000
Volume 5	3	Weather	Leverages Volume 1 capabilities	NA		
		GNSS RTK	Leverages Volume 1 capabilities	NA		
		ADS-B	Leverages Volume 1 capabilities	NA		
		RemoteID	Leverages Volume 1 capabilities	NA		
		Optical	Leverages Volume 1 capabilities	NA		
		Audio	Leverages Volume 1 capabilities	NA		
		RF Triangulation	Leverages Volume 1 capabilities	NA		
		Radar	Assume provided by NASA through sharing	NA		
Total Service Area 1						**$607,000**
Service Area 2						
Volume 6	1	Weather	Assume largely provided, need a few units	2	$1,500	$3,000
		GNSS RTK	Need triangulation coverage	3	$2,500	$7,500
		ADS-B	Assume need to add 2 units	2	$1,500	$3,000
		RemoteID	Assume linear coverage with 2 miles radius, cannot cover water	3	$7,500	$22,500
		Optical	Not applicable	NA		
		Audio	Not applicable	NA		
		RF Triangulation	One system with three sites (note approach is experimental)	3	$10,000	$30,000
		Radar	Not applicable	NA		

Service Volume	Tier	Equipment Need	Notes	Units	Unit Cost	Total Cost
Volume 7	2	Weather	Leverages Volume 6 capabilities	NA		
		GNSS RTK	Leverages Volume 6 capabilities	NA		
		ADS-B	Leverages Volume 6 capabilities	NA		
		RemoteID	Leverages Volume 6 capabilities	NA		
		Optical	Assume linear coverage with 2 miles radius	1	$15,000	$15,000
		Audio	Leverages Volume 8 capabilities	NA		
		RF Triangulation	Leverages Volume 6 capabilities	NA		
		Radar	Not applicable	NA		
Volume 8	2	Weather	Leverages Volume 6 capabilities	NA		
		GNSS RTK	Leverages Volume 6 capabilities	NA		
		ADS-B	Leverages Volume 6 capabilities	NA		
		RemoteID	Leverages Volume 6 capabilities	NA		
		Optical	Assume linear coverage with 2 miles radius	1	$15,000	$15,000
		Audio	One system with two sites	2	$35,000	$70,000
		RF Triangulation	Leverages Volume 6 capabilities	NA		
		Radar	Not applicable	NA		
Volume 9	3	Weather	Leverages Volume 6 capabilities	NA		
		GNSS RTK	Leverages Volume 6 capabilities	NA		
		ADS-B	Leverages Volume 6 capabilities	NA		
		RemoteID	Leverages Volume 6 capabilities	NA		
		Optical	Assume linear coverage with 2 miles radius	1	$15,000	$15,000
		Audio	Not applicable	NA		
		RF Triangulation	Leverages Volume 6 capabilities	NA		
		Radar	Assume 2 units in 180-degree configuration facing Onancock	2	$40,000	$80,000
Total Service Area 2						**$261,000**

Table 10: Expected Equipment Needs by Service Volume – Excludes UTM and Integration Costs

In addition to the hardware / sensor costs described, there are also two other categories of costs to be considered:

- Integration costs: these costs consist of siting and installing the sensors, integrating the sensors to VA-FIX for dissemination to UTM and system participants; validating and calibrating those sensor feeds, and supporting downstream integration with UTM participants. As much of the work will be common between the Service Areas, we should assume this will cost approximately $150,000 for one Service Area or $200,000 for both Service Areas; and
- The cost of acquisition and support for a USS-UTM provider/tool varies widely, but based on prior experience we should assume this would cost $100,000 for one or both service volumes.

Summary

In developing the rollout plans for each of the Service Volumes, contemplated Operations and related high level risk was considered, each Service Volume's risk was assessed and a notional Performance Baseline was considered, as was the current baseline for each Volume. As each Service Volume was planned, overlapped coverage areas were deconflicted in order to develop a set of specific roll-outs that account for overlapping coverage that may be provided by other already enabled, or to be enabled, Service Volumes. The result is a basic plan for an HR ASE with initial Rough Order of Magnitude budget numbers. Since some of the integration costs overlap, we should assume service enablement costs as follows:

- Service Area 2 Only:
    - Sensors / Hardware: $261,000
    - Integration: $150,000
    - UTM: $100,000
    - Total for Service Area 1 Only: $511,000
- Service Area 1 Only:
    - Sensors / Hardware: $607,000
    - Integration: $150,000
    - UTM: $100,000
    - Total for Service Area 2 Only: $857,000
- Service Area 2 following Service Area 1
    - Sensors/Hardware: $868,000
    - Integration: $200,000
    - UTM: $100,000
    - Total for both Service Areas: $1,168,000

It is important to not that the nature of integration and UTM services would likely result in being able to amortize these costs over both Service Areas, therefore the incremental costs of adding a particular service are for these costs categories is minimal. The HR Region may also be able to leverage existing partnerships and systems to defer some of these costs. What is clear from this analysis, however, is that in terms of complexity, feasibility, and minimum cost, Service Area 2 (Onancock-Tangier) should lead Service Area 2 (KPVG-Langley) which will maximize the potential to leverage savings.