Airfield Design Principles and Unmanned Aircraft Systems

November 9, 2023
12pm-1:30pm ET

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

Today's Learning Objectives

(1) Articulate the variations in apron and ramp markings at U.S. airports, including the collaborative practices developed with stakeholders

(2) Explore the fundamentals of large UAS and their airfield infrastructure requirements for airport operations

American Association of Airport Executives (AAAE)

1.0 Continuing Education Units (CEUs) are available to Accredited Airport Executives (A.A.E.)

Report your CEUs:

www.aaae.org/ceu

American Institute of Certified Planners (AICP)

1.5 Certification Maintenance Credits

You must attend the entire webinar to be eligible for credits

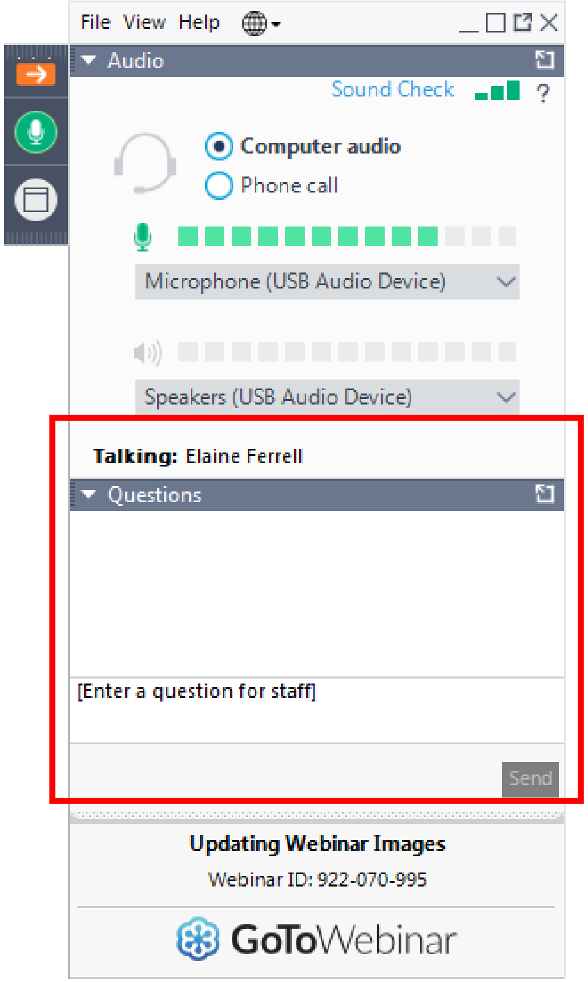
Log into the American Planning Association website to claim your credits

Questions and Answers

Please type your questions into your webinar control panel

We will read your questions out loud, and answer as many as time allows

#TRBwebinar



Matthew Koss
Garver, LLC

Today's Speakers

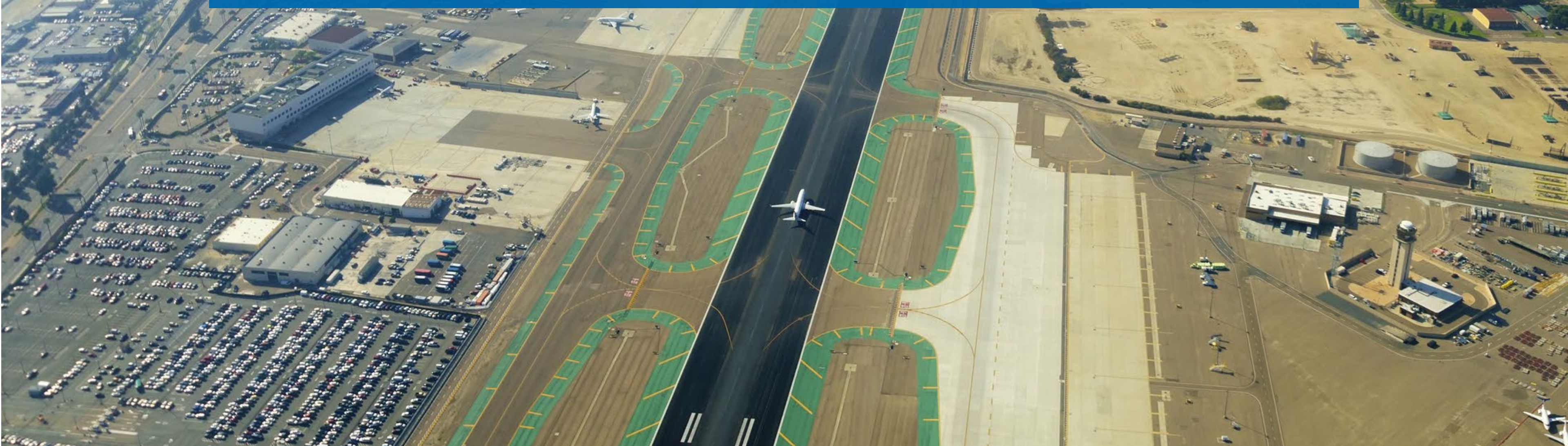
Nathan Polsgrove A.A.E., IAP, ACE
NRPolsgrove@GarverUSA.com
Garver, LLC

Thomas Mackie, PS
Thomas.mackie@woolpert.com
Woolpert

ACRP SYNTHESIS 122

Airfield Apron/Ramp Surface Markings

Nathan Polsgrove A.A.E., IAP, ACE



The National Academies of SCIENCES · ENGINEERING · MEDICINE
TRB TRANSPORTATION RESEARCH BOARD

GARVER

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

INTRODUCTION

Nathan Polsgrove A.A.E., IAP, ACE
Aviation Planning Director

- Prior airport management/leadership experience
- Instrument rated pilot
- Lead role in eight applied research projects
- Airport planning and safety work (e.g. SMS)

TOPIC S07-03 PANEL

Scott M. Ayers,
City of Atlanta Department of Aviation,
Atlanta, GA

David Decoteau,
King County (WA),
Seattle, WA

Raymond A. Herron,
Charlotte Douglas International Airport,
Charlotte, NC

Gaël Le Bris,
WSP,
Pittsboro, NC

Serena Sheetz,
San Francisco International Airport,
San Francisco, CA

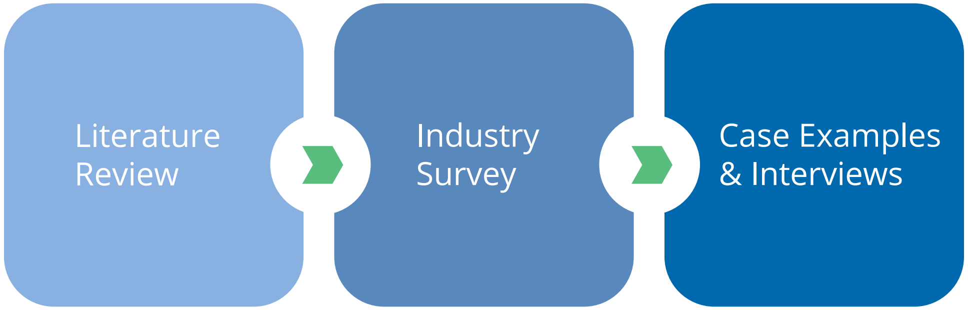
Jordan Stringfellow,
Volkert, Inc.,
Mobile, AL

Mike Rottinghaus,
FAA Liaison

Christopher J. Oswald,
Airports Council International-
North America Liaison

RESEARCH FOCUS AND APPROACH

The objective of this synthesis is to document NPIAS airport ramp and apron marking **variations,** including but not limited to, aircraft parking (hardstand or gate), taxilanes, and airside roadway system areas.



KEY RESEARCH OBSERVATIONS

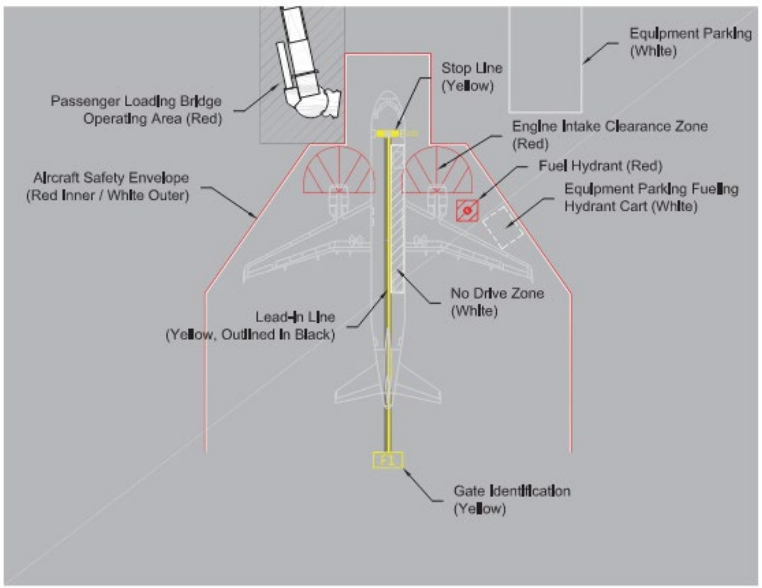
Variable Terminology

A4A SG 908

3-2.3. Aircraft Safety Zone (GSE Lines)

- Aircraft safety zones are two parallel lines painted with a 4" red outer line and a 4" white inner line.
- The minimum distance that the white line should be painted from any point on the aircraft is 10'-0".

ACRP Report 96



ACI Apron Markings and Signs Handbook

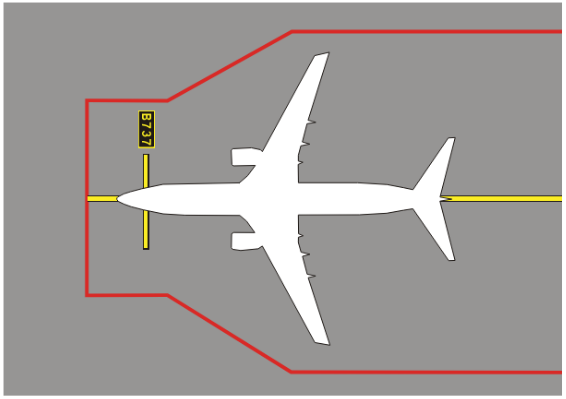
3.2 STAND SAFETY LINE

This line depicts the area that must remain free of staff, vehicles and equipment when an aircraft is taxiing (or being towed) into position or has started engines in preparation for departure. Once all engines have been shut down and the anti-collision lights have been switched off, vehicles may cross the line to service the aircraft.

The size of this area depends on the type of aircraft using the stand position. The area should be dimensioned to allow for a safety zone around jet engine intakes which must be kept free to avoid suction dangers. Aircraft manufacturers give guidance on safety zones required around engines operating on ground idle. A similar safety zone should also be taken into account on stands used by propeller-driven aircraft.

Colour	Line	Border
	Red	White

Dimensions	A	B
	0.2m min.	0.1m



KEY RESEARCH OBSERVATIONS

LITERATURE REVIEW

Current practices go beyond the guidance provided.

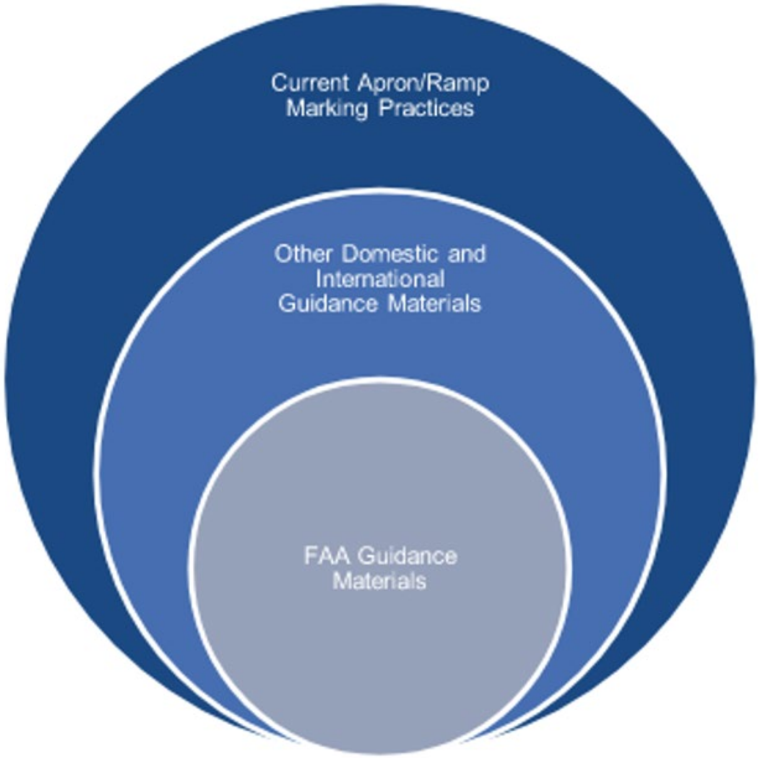
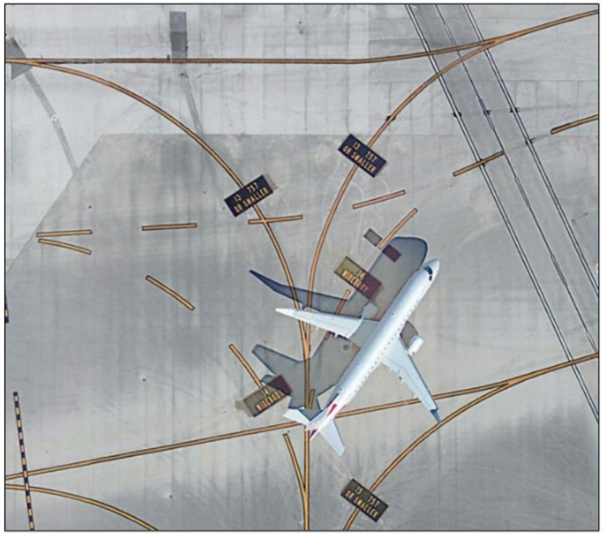


Figure 12: Relationship Between Guidance Materials and Current Practices

KEY RESEARCH OBSERVATIONS

Airports are Solving Similar Challenges Using Different Marking Approaches

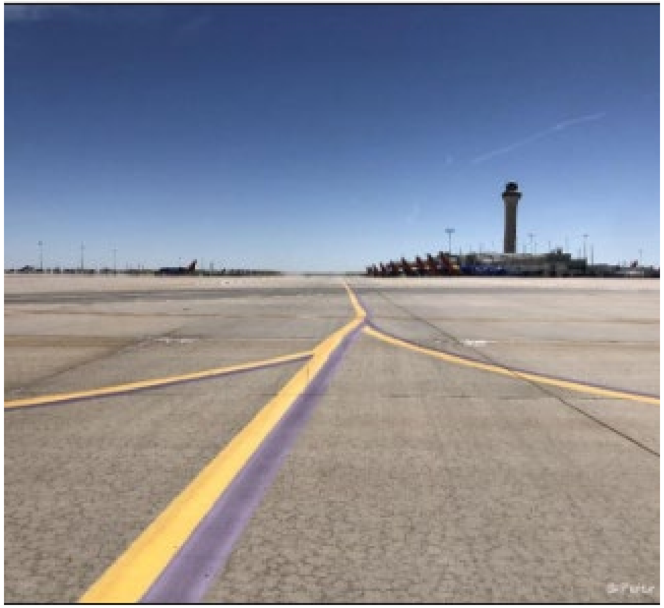

Dashed Taxilane Centerline at MIA

Diamond Taxilane Centerline at SFO

KEY RESEARCH OBSERVATIONS

Airports are Solving Similar Challenges Using Different Marking Approaches

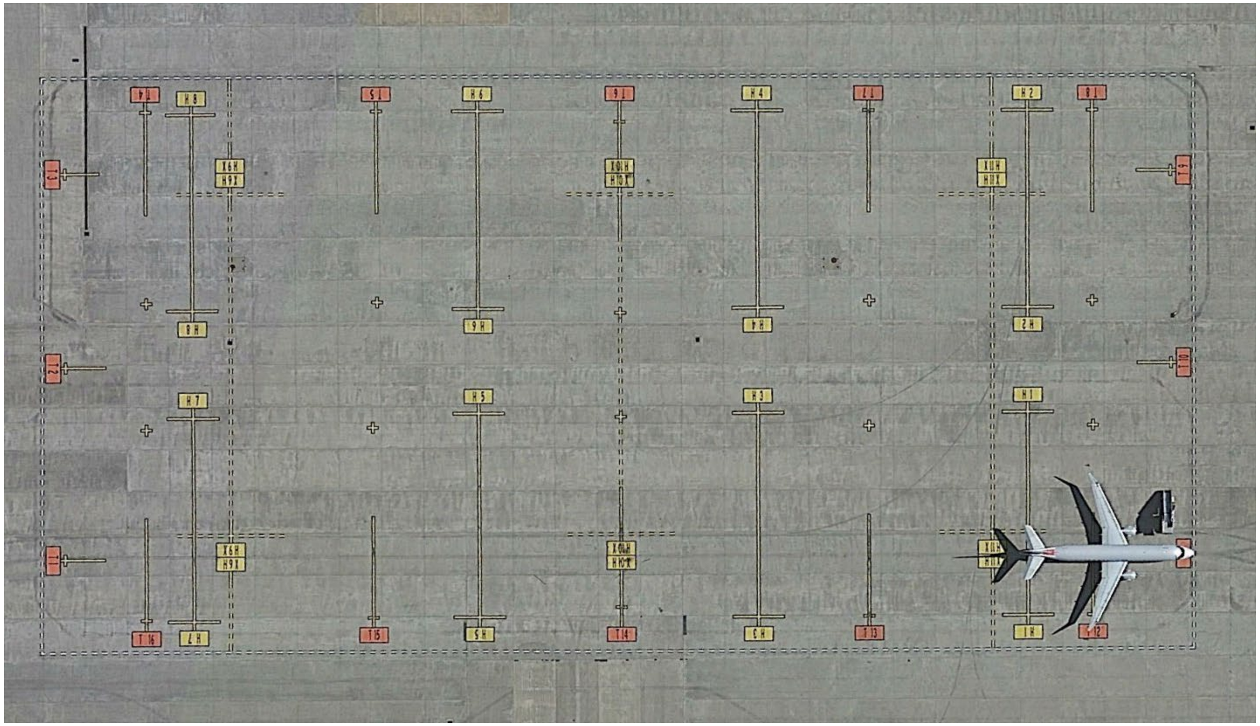
SEA Parallel Taxilane Centerlines



DEN Purple Taxilane Centerline Outline

KEY RESEARCH OBSERVATIONS

Marking Aprons for Aircraft of Different Sizes is a Challenge



KEY RESEARCH OBSERVATIONS

1

Airports generally rated the sufficiency of apron/ramp markings lower for ground personnel compared to pilots in two areas:

Gate Markings
4.2 Pilots vs. 3.72 Ramp Personnel

Hardstand Markings
3.97 Pilots vs. 3.53 Ramp Personnel

2

Communicate wingspan restrictions in ft. instead of Airplane Design Group (ADG)

3

Collaborate with flight data providers to ensure their publications are updated

4

Guard against marking congestion

ACRP Report 238

Airfield Design for Large Unmanned Aircraft Systems

Thomas E. Mackie, PS
Woolpert, Inc.

Thomas E. Mackie, PS
Principal Investigator

- Aviation Program Director, Woolpert, Inc.
- Specializes in Integration of Geospatial and Operations Technology
- Senior UAS and AAM SME for Woolpert
- Licensed Professional Land Surveyor - Ohio

ACRP Report 238 Research Team

KEY (all staff Woolpert unless indicated):
= Full resume in appendix
F = Faith Group | I = Independent Consultant | R = Ricondo

WOOLPERT
ARCHITECTURE | ENGINEERING | GEOSPATIAL

Faith Group

RICONDO®

ACRP Report 238 Oversight Panel

Michael R. Scott, Reno, NV (Chair)

Matthew Dowell, Golden Triangle Regional Airport, Columbus, MS

Jennifer Eckman, Minot International Airport, Minot, ND

Andrew Y. Ndolo, Metropolitan Washington Airports Authority, Washington, DC

Samuel Burk Siewert, Embry Riddle Aeronautical University, Prescott, AZ

Basil Yap, Hovecon, Winston-Salem, NC

James Schroeder, FAA Liaison

Christopher J. Oswald, Airports Council International–North America Liaison

Christine L. Gerencher, TRB Liaison

Project Overview and Goals

Project Objective

- The objective of this research is to develop guidelines for airfield design challenges, issues, and considerations for the unique operational needs of large UAS (currently > than 55 lbs).
  - Integration vs. segregation of operational areas at airfields
  - Considerations for different UAS categories and capabilities
  - Integration of technology
  - Airport master planning, including economic and cost considerations
  - UAS support infrastructure
  - Environmental impacts
  - Approach surfaces and terminal airspace

Approach to Research

Scope of research included entire airfield and all infrastructure

Broke down airfield into buckets of focus

- Lighting, Marking, and Signage
- Hangars and Support Facilities
- Pavement
- Airfield Surface Infrastructure
- Navigational Aids
- Communication and Data Systems
- Fueling and Charging
- Obstacles and Airspace
- Noise and Environmental Impacts
- Airport Passenger Terminals
- Air Traffic Control
- Aircraft Rescue and Firefighting

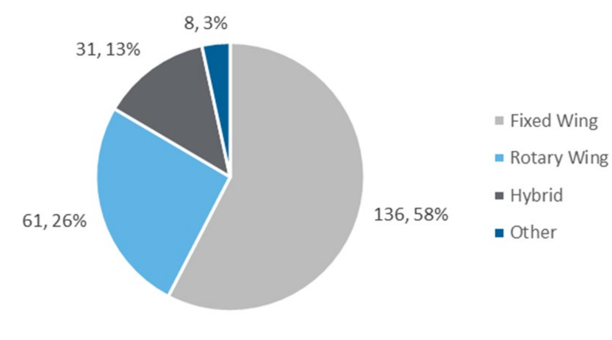
Findings Into Guidance

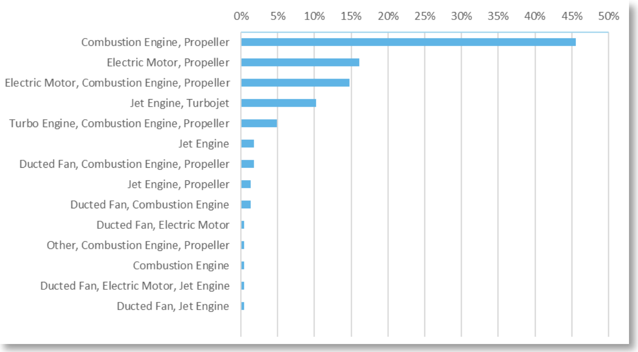
- **Focused on identifying gaps and challenges for L-UAS introduction into airport environment**
- **Provide guidance to sponsors and consultants on ability and challenges of new fleet mix**
  - Unique characteristics of L-UAS and their supporting technology
  - Levels of impacts on applicable airfield infrastructure standards
  - Key indicators for integration versus segregation
  - Important considerations around airfield assets

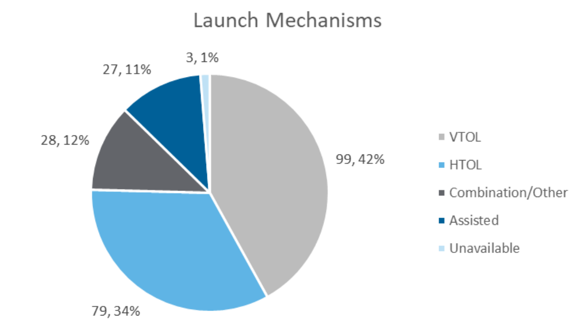
Vehicle Characteristics

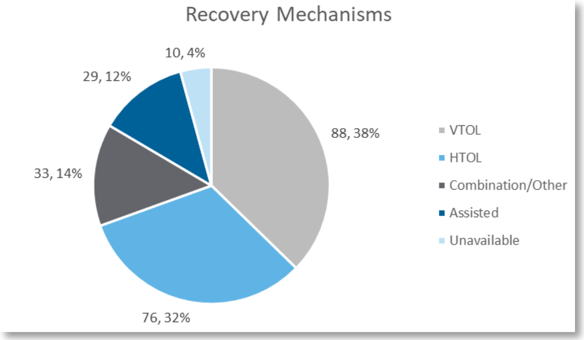
Challenge for "one-size-fits-all" result

- Type – Propulsion – Launch & Recovery
- Table 2-8 summarizes variety of vehicles



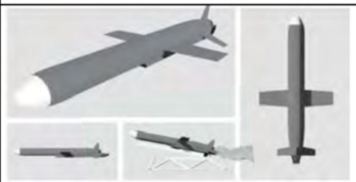


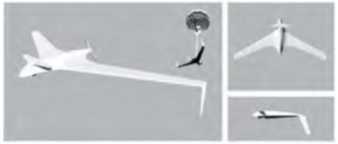




Demonstrating Complexity

Table 2-2. Examples of launch and recovery mechanisms.

	Launch	Recovery
VTOL	 **GL-10 Greased Lightning**, a 10-rotor tiltwing hybrid platform with a 10-ft wingspan and an MTOW of 62 lb developed by NASA as part of research to develop efficient hybrid-electric VTOL aircraft.	 **Dragon Warrior/Vantage**, with a wingspan of 9.08 ft, a length of 9.33 ft, and a MTOW of 380 lb was manufactured as a prototype by U.S. Naval Research Laboratory for research purposes across various applications (e.g., disaster response, imaging, inspection, and precision agriculture).
HTOL	 **Northrop Grumman Firebird** platform. With a wingspan of 65 ft, length of 9.8 ft, and a 5,000 lb MTOW, this platform is primarily used to gather intelligence.	 **Viper M14** by Saxon Remote Systems. This system has a length and width of 14 ft, an MTOW of 55 lb, and is used for mapping, surveying, target acquisition, and other operations.
Combination/Other	 **BQM-74C Chukar III** manufactured by Northrop Grumman. This system has a wingspan of 5.8 ft, a length of 12.9 ft, an MTOW of 1,455 lb, and uses rocket-assisted takeoff (RATO) to launch. This system can be air-launched as well as ground-launched and is used for aerial targeting and training by the U.S. Navy.	 **Aerosonde Mark 4.7** manufactured by Textron Systems. With a 12-ft wingspan and an 8-ft length, this 80 lb system is capable of VTOL flight, catapult assisted flight, or net recovery flight and is used in expeditionary land- or sea-based operations.

Assisted	**Air Launch**  **Airborne Systems North America's DragonFly**. This is a system with a 110 ft wingspan and a maximum MTOW of 10,000 lb. It is used by the U.S. DOD as a Joint Precision Airdrop System.	**Parachute**  **Apex (Airborne Pursuit and Exploitation)**. This system has a wingspan of 14.1 ft, a length of 6.1 ft, and an MTOW of 61.7 lb. The Apex, manufactured by L3Harris Technologies, uses a parachute recovery system. It is used in civil and military applications.
	Catapult/Pneumatic  **Boeing Insitu's ScanEagle2** platform. This platform has a wingspan of 10.2 ft, a length of 5.6 ft, and a total MTOW of 58 lb. It is launched from a pneumatic device for applications in reconnaissance, monitoring, imaging, inspections, and others.	**Skid/Belly**  **MQM-171A BroadSword** manufactured by Griffon Aerospace. This platform has a width of 22.5 ft, a length of 15 ft, and a 551-lb MTOW. Deployed via catapult launch, it performs skid belly recovery and is used for military activities (research, targeting, and training).
	Rocket-Assisted Takeoff (RATO)  **BQM-177A/I** manufactured by Kratos Defense and Security Solutions, Inc. is used by U.S. Navy for aerial target and training. This system has a length of 17 ft and an MTOW of 1,400 lb.	**Net Recovery**  **Northrop Grumman's BAT 12**, an aerial intelligence gathering platform used by the U.S. Armed Forces that relies on a net recovery mechanism. It has a wingspan of 12 ft, a width of 6.3 ft, and a total MTOW of 220 lb.

Summary of Key Findings

Identify gaps between current design standards and impacts "unmanned" vehicles introduce

- AUVSI *Unmanned Systems and Robotics Database (USRD)*
- Existing operations utilizing L-UAS (airport sponsors)
- Available research and literature

Common denominator for comparison – ADG and AAC

- Majority considered ADG I
- Operate at AAC A speeds

ADG	Number of L-UAS	% Breakdown
I	199	88%
II	14	6%
III	6	3%
IV	7	3%
V	0	0%
VI	1	0%

Understand vehicle and operational characteristics

- Type: Fixed-wing, Rotorcraft, Other
- Propulsion: Combustion, Jet, Electric, Ducted Fan
- Launch & Recovery: HTOL, VTOL, Assisted, Combination

	Number of L-UAS	Average MTOW (lbs.)	Average Wingspan (ft)	Average Width (ft)	Average Length (ft)	Average Height (ft)
L-UAS (55-12,499 lbs.)	213	1,168	23	14	5	12
Fixed Wing	123	1,335	27	42	14	4
Hybrid	29	297	15	7	9	3
Rotary	61	1,244	14	6	15	5
Heavy UAS (12,500+ lbs.)	14	32,041	96	44	15	-
Fixed Wing	13	32,236	98	-	44	15
Hybrid	1	29,500	65	-	-	-

Unexpectedly found few drastic impacts

- Majority of design criteria satisfy L-UAS operations

Highly integrable with existing operations

Summary of Impacts & Consideration

Integration vs. Segregation	• Dependent on unique vehicle specs vs. Airfield component • Airfield configuration key driver for integrability of L-UAS
UAS Support Infrastructure	• Comparable infrastructure needs as manned aircraft • Fuel types and L-UAS operating model are key considerations
UAS Categories & Capabilities	• Existing ADG/AAC's sufficient to permit L-UAS operations • Consistent vehicle design between manned vehicles and L-UAS
Integration of Technology	• Specific vehicles & systems require data throughput and access • ATC technology and procedures critical considerations
Environmental Impacts	• Little evidence of notable impacts to levels of manned aircraft • Noise & power/charging have anticipated impacts
Economic & Airport Planning	• Considering specific L-UAS vehicles, or accommodating multiple • Cost impacts driven by support infrastructure needs
Approach and Terminal Airspace	• Current airspace protections and approach capabilities apply • Critical for ATC collaboration and operating agreements

Sample Stakeholder Guidance

Component Impact Analysis

Lighting, Marking and Signage

Impact Overview

The airfield marking, lighting, and signage standards for airports are prescribed in a variety of Advisory Circulars (ACs) published by the FAA. Since these standards vary for airports and heliports, the ... ch ... SI ... re ... or

Key Considerations

The primary concern with accommodating UAS on the airfield and/or heliport is to ensure adequate visibility of the markings, signage, and lighting systems by the aircraft's guidance system. Typically, these guidance systems involve an infrared camera(s) that transmits images of the airfield environment to the operator in real time. The location of the cameras on UAS may not ensure an unobstructed line-of-sight, depth perception to differential objects, or identify markings, lights, and airfield signage. UAS will require case-b ... signag ...

Table 3-2. Airfield Lighting, Marking, and Signage.

AIRFIELD CONSIDERATION	Airfield Lighting, Marking, and Signage
Integration Potential Based on Airfield Consideration	High
Gap Areas	No existing guidance on delineation of movement area boundaries that segregate manned and unmanned operations or rotary/hybrid UAVs from

APPLICABLE STANDARD FOR GUIDANCE	TITLE
Advisory Circular 150/5340-1	*Standards for Airport Markings*
Advisory Circular 150/5340-4	*Installation Details for Runway Centerline Touchdown Zone Lighting Systems*
Advisory Circular 150/5340-5	*Segmented Circle Airport Marker System*
Advisory Circular 150/5340-14	*Economy Approach Lighting Aids*
Advisory Circular 150/5340-18	*Standards for Airport Sign Systems*

Accommodability

Table 4-2. Considerations for segregation versus integration.

L-UAS Characteristic	Scale of Segregation Vs. Integration	Brief Description of Challenges and Impacts
Fixed Wing 100% (HTOL)		L-UAS operating as fixed wing aircraft during both takeoff and landing vary in their ability to integrate. Their integration heavily depends on the vehicle size/weight and its need to use existing runway/taxiway surfaces for movement, with the heavier aircraft integrating more easily than the lighter ones (those similar in weight to an ultralight aircraft). The lighter ones will have more trouble mixing with traditional aircraft depending on their ability to withstand turbulence and crosswinds.
Rotorcraft 100% (VTOL)		Aircraft that operate with rotors during all phases of flight (i.e., they do not have wings or tilting rotors) do not need a runway for takeoff and landing. Their taxi capabilities vary, so integration with the runway and taxiway system may be limited. They may fly a traditional approach or segregate from fixed wing aircraft to a specific "helipad" on the airport. As for fixed wing L-UAS, weight, turbulence tolerance, and crosswind capability are also factors.
Hybrid (HTOL & VTOL)		Hybrid aircraft vary between fixed wing and rotorcraft during either takeoff or landing. Their need for a runway or ability to use a taxiway will impact their integration ability. The uniqueness of each vehicle will require the airport sponsor to understand its specific requirements to determine how existing infrastructure can support its operations.
Assisted Launch and Recovery Mechanism		These aircraft will not likely be able to use the existing runways, taxiways, and ramps because they require a special apparatus for launch and recovery. Segregation is probable with special attention to assure that their approach and departure paths do not cross existing runways and do not encroach on any other protected surfaces.

Recommended Use of Guidebook

Chapter 4: Determining Airport Compatibility

- No unlike other operations at airports (skydiving, helicopters, etc.)
  - How can the L-UAS become part of the crewed ecosystem?
  - Can the L-UAS integrate in existing operations?
  - Do the L-UAS need to be segregated from other operations?
- Integration vs. Segregation
- Do not start by limiting L-UAS, look deeper into each operational component to determine ability to integrate
  - Utilize same approach to traditional planning & design
  - Complicated due to variety of systems & characteristics

Each Airfield & Operation are Unique

What Scenario are you in?

- **Scenario 1:** Support of a specific L-UAS vehicle or type for an individual operator.
- **Scenario 2:** Support a variety of L-UAS—acting like a hub or incubator for emerging aviation technology—potentially with the premise of attracting operators to become tenants.

Table 3-5. Airfield infrastructure.

AIRFIELD COMPONENT	AIRFIELD INFRASTRUCTURE
Integration Potential	Medium.
Gap Areas	Lack of guidance on AAC classification for L-UAS. Lack of guidance on TDG classification for L-UAS. Lack of guidance on maximum allowable crosswind components of L-UAS. Lack of guidance on vertiport/vertipad design standards for VTOL aircraft.
Potential Issues	Airfields equipped with EMAS for aircraft overruns should consider optimizing EMAS design to accommodate L-UAS. Aircraft approach speed and land gear configuration data are not available for the L-UAS researched in the USRD, thus making UAS approach and TDG categorization difficult without OEM input. L-UAS performance and design characteristics need to be thoroughly reviewed to ensure they conform to the existing design standards.
APPLICABLE STANDARD FOR GUIDANCE	**TITLE**
AC 150/5320-6F	*Airport Pavement Design and Evaluation*
AC 150/5220-22B	*Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns*
AC 150/5300-13	*Airport Design*
AC 150/5390-2C	*Heliport Design*
AC 150/5423-4B	*Runway Length Requirements for Airport Design*
AC 150/5320-6F	*Airport Pavement Design and Evaluations*
AC 150/5000-17	*Critical Aircraft and Regular Use Determination*

Table 4-2. Considerations for segregation versus integration.

Airport Feature	Scale of Segregation Vs. Integration	Brief Description of Challenges and Impacts
Airfield Configuration (Movement and Non-Movement Areas)		Each airport is unique in its location, configuration, and assets. Each airfield surface layout and L-UAS vehicle type poses unique issues for determining the level and locations of integration on the airport surface. Airports with multiple movement surfaces will increase integration potential by allowing the best option to be chosen for the mission of each user at the time.
Airfield Capacity		The capacity of an airport is defined by the number of operations it can handle during a specific period. If the airport demand is high and capacity is low, integrating UAS will be more difficult and segregation may be needed.

FOR ADDITIONAL INFORMATION

WOOLPERT

Thomas E. Mackie, PS

[Woolpert, Inc.]

[Thomas.mackie@woolpert.com]

Today's Speakers

Nathan Polsgrove A.A.E., IAP, ACE
NRPolsgrove@GarverUSA.com
Garver, LLC

Thomas Mackie, PS
Thomas.mackie@woolpert.com
Woolpert

Matthew Koss
MAKoss@garverUSA.com
Garver, LLC

Other Events for You:

November 13-15, 2023

TRB's Transportation Resilience 2023

January 7-11, 2024

TRB Annual Meeting

https://www.nationalacademies.org/trb/events

TRB Weekly

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

Subscribe to the newsletter for the most recent TRB news & research:

https://bit.ly/ResubscribeTRBWeekly

Get involved with TRB

Receive emails about upcoming webinars:
https://mailchi.mp/nas.edu/trbwebinars

Find upcoming conferences:
https://www.nationalacademies.org/trb/events

@NASEMTRB

@NASEMTRB

Transportation Research Board

Get Involved with TRB

Be a Friend of a Committee **bit.ly/TRBcommittees**

- Networking opportunities
- May provide a path to Standing Committee membership

Join a Standing Committee **bit.ly/TRBstandingcommittee**

Work with CRP **https://bit.ly/TRB-crp**

Update your information **www.mytrb.org**

Getting involved is free!

TRB 103rd

ANNUAL MEETING

On January 7–11, 2024, join the single largest gathering of transportation practitioners and researchers in the world. *Register today!*

www.trb.org/AnnualMeeting

Get involved with ACRP

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

1. Join the ACRP IdeaHub community
2. Volunteer for a project panel
3. Prepare a research proposal
4. Answer an ACRP survey
5. Apply the research results

Visit us online:

www.trb.org/ACRP

Other Ways to Participate

ACRP AMBASSADOR

Become an Ambassador. Ambassadors represent ACRP at events and conferences across the country!

ACRP CHAMPION

Sponsor or become an ACRP Champion. The champion program is designed to help early- to mid-career, young professionals grow and excel within the airport industry.

ACRP IMPACTS ON PRACTICE

Visit ACRP's Impacts on Practice webpage to submit leads on how ACRP's research is being applied at any airport.

Visit us online:
www.trb.org/ACRP

ACRP Recorded Webinars

ACRP
WEBINAR

Have you missed a past ACRP webinar that you wish you could have attended?

No worries! All ACRP webinars are recorded and posted to TRB's website for viewing at any time.

There are over 100 webinar recordings on a variety of aviation topics available to you at:

https://www.nationalacademies.org/events

Select "Past Events" tab and search for "TRB Webinars".