Drone Safety Team

Safety Enhancement No. 1
Airspace Awareness and Geofencing

Final Report

Out-of-the-Box Protection of High-Risk Airport Locations

Prepared by DST SE-1 Team to address the SE-1 objective to recommend enabling technology safety features that can help prevent flight into unauthorized airspace.

May 1, 2020

Contents

1. Background

The Drone Safety Team (DST) is an industry-government partnership committed to ensuring the safe operations of unmanned aircraft systems (UAS) in the national airspace system (NAS). The DST supports the safe integration of UAS by developing data-driven and consensus-based safety enhancements through collaboration amongst members of the UAS industry. The DST identified Airspace Awareness and Geofencing as one its first three safety enhancements (SE-1), with several underlying intervention strategies. A working group of DST subject matter experts and stakeholders was formed to develop this first white paper emphasizing the benefits of geofencing protections as an out-of-the-box solution to mitigate risk at high-risk airport locations.

This document provides an example of how the DST is able to leverage industry partnerships and collaboration to develop solutions focused on improving awareness and enhancing safety in the NAS.

2. Scope

The objective of SE-1 Airspace Awareness and Geofencing is to reduce the risk of collision with other aircraft or structures by improving airspace awareness (of operators) and geofencing capabilities (of systems).

The DST identified two areas that should be addressed:

a) Education, outreach (and possibly credentialing) centered around airspace authorization.
b) Enabling technology safety features to help prevent flight into unauthorized airspace.

The DST supports concurrent UAS safety enhancement efforts focusing on individual operators, product manufacturers, and service providers alike. While other industry and government efforts are ongoing that will address the education, outreach, and credentialing aspects of SE-1, this white paper focuses one specific technology – geofencing, for industry consideration and system integration. Further, this white paper is limited to one specific recommendation regarding geofencing. Other recommendations may follow in the future.

The DST acknowledges that subsequent refinement of concepts proposed in this document or related standards and specifications must be jointly developed by qualified government and industry stakeholders (e.g., FAA, ASTM, RTCA, etc.).

3. Recommendation

The DST recommends that geofencing be implemented on small UAS platforms for high risk locations, namely the FAA-designated primary airports within Class B and Class C airspaces. Geofencing protection should be provided 'out-of-the-box' and can only be overridden by a defined process. Coverage area should be determined based on the performance and geofencing capability of the UAS. This recommendation is intended to help prevent inadvertent, careless, or reckless flight in proximity to frequent flights of manned aircraft.

4. Definition of Terms

Term	Definition
Out-of-the-box	Refers to the state of the UAS on delivery from the manufacturer (i.e., the functional state of the system at power up or reset).
High Risk Location	A location (or area) where the inadvertent, careless, or reckless flight of a UA could pose a serious aviation safety risk, largely because of the risk of collision with manned aircraft or disruption to routine air transportation services.
Geofencing-capable UAS	A UAS that has sufficient technological capability so as to have access to real-time location data, and can include flight-control programming to limit or impede its flight based on its location relative to high-risk areas stored on the UAS. There are three levels of capability defined here. • Minimum capability: Protected high-risk areas can be represented by one or more circles defined by a center point and radius. • Intermediate capability: Protected high-risk areas can be represented by one or more generic or simple polygons that cover the airport surface area and may include regions under approach and departure paths. • Advanced capability: Protected high-risk areas can be represented by one or more complex polygons that may cover each airport's unique surface and/or airspace geometry (e.g. regions under approach and departure paths). This capability level may also allow for vertical constraints on geofenced areas.
Hard-lockout	The automatic geofencing function cannot be disabled or over-ridden; except by a defined process requiring interaction between the UAS owner/operator and another party (such as the manufacturer, a service, or a traffic management system).
Soft-lockout	The automatic geofencing function can be disabled or over-ridden; under certain conditions by the UAS owner/operator entirely on its own, pursuant to a defined process not requiring interaction with other parties or systems.
Protection Enable and Authorization Categories	The type of geofencing protection implemented in a UAS and how/when it is authorized or enabled. • Hard-lockout, out-of-the-box • Soft-lockout, out-of-the-box • Hard-lockout, updates via connection or upload procedure • Soft-lockout, updates via connection or upload procedure Note: Only the first Category is addressed by this recommendation.

5.

5. High Risk Locations to Protect

The primary airports within Class B and C airspace. See Appendix A.

6. Method of Geofencing: Technical Considerations

Different UAS will have differing technical capabilities. Geofencing at a minimum requires a positioning system (e.g. a GPS receiver), so that the UA flight controller has data on its current location, and also requires a flight controller that can respond to override pilot flight commands and "keep out" of geofenced areas.

One method of implementation of a geofence is with a circular shape, where the outer circumference of the circle a specified distance from its center point. Thus, programming a UAS flight controller to pause flight operations and hover when it approaches a certain distance from a fixed geographical point creates a "geofence" in the shape of a circle around that point. This form of geofencing is two-dimensional, and does not take into account the altitude of the UA. Therefore, the geofencing will keep the drone out of the preprogrammed area whether it is flying at 3 feet AGL or 3,000 feet AGL. We refer to circular geofencing without regard to altitude as Minimum Capability geofencing.

Flight controllers with more complex technology may be capable of three-dimensional geofencing, which could for example add an altitude ceiling to keep the UA at a lower altitude as/if it approaches an airport. This technology may also allow for defining multi-sided shapes of geofences. This Advanced Capability geofencing has the benefit of more precisely defining high-risk areas. For example, they could represent boundaries of controlled/uncontrolled airspace and/or LAANC cells. Somewhere in between is an Intermediate Capability where polygonal coverage areas of limited complexity can be defined.

Aircraft responses or maneuvering in response to encountering geofences are not within the scope of this document. Several options have been implemented by manufacturers and operators; including, for example, slow down and hover in position, auto-land, and return-to-launch point.

7. Method of Geofencing: Recommended Areas and Shapes

Based on recent events and legislation, geofencing should encompass runways and approach/departure paths at a minimum. It is the airborne traffic in and out of runways that represents the highest risk factor at the major airports as aircraft are in configurations with reduced thrust and maneuverability, and reaction time to address an issue is less due to proximity to the ground.

The United States Congress passed legislation in 2018 that defined a Runway Exclusion Zone as one in which unauthorized drone operations is a federal crime. This Runway Exclusion Zone extends one statute mile from the end of each active runway at certain airports, and appears designed to reflect the increased risk in those locations. Note that the active runways can change at any time for a given airport.

Therefore, for UAS that have minimum capability geofencing, the DST recommends the geofencing be implemented as one or more circle(s) extending around the runways, and large enough to extend at least one statute mile beyond each runway threshold. For reference, aircraft that are 1.5 miles from the runway on a precision approach will be approximately 450 feet above the runway threshold elevation. This is above the 400 feet AGL general limit for Part 107 operations. For UAS that have Intermediate or Advanced capability geofencing, the DST recommends the geofencing be implemented in a way that covers at least the Runway Exclusion Zones at Class B/C airports, specifically "the length of which extends parallel to the runway's centerline to points that are one statute mile from each end of the runway and the width of which is 1⁄2 statute mile." UA that have the ability to perform geofencing of complex polygonal and/or three-dimensional (3D) shapes could also add an “approach path” region and/or “departure path” region to these zones, potentially creating lower altitudes in which the UA may operate while still protecting the approach/departure paths at higher altitudes. Complex polygonal or 3D capability could allow for additional areas near airports to safely operate UAS.

Appendix B provides example illustrations of areas and shapes such as described above.

For airport and runway location information, see https://www.faa.gov/air_traffic/flight_info/aeronav/aero_data/Airport_Data/.

8. OEM Considerations for Geofencing Implementation

The decision to implement geofencing has downstream effects that should be considered by any UAS manufacturer. UAS are becoming tools in use by, and at airports, for applications that include fuselage inspection, wildlife hazard mitigation, runway foreign object debris (FOD) inspection, building construction, and perimeter security. Therefore, disabling their operation based simply on proximity to airport runways creates a need for an exception process to override or “unlock” the geofencing functions for authorized operators. Given that geofencing is intended to protect against inadvertent, careless, or reckless operation of UAS in high-risk areas, authorized operators who make a deliberative decision to fly should likely be released from geofencing limitations.

Although the DST recommends that OEMs implement a process for unlocking or overriding out-of-the-box geofencing, the methods for determining which operators and which scenarios will compel an “unlock” to the geofencing, and over what area or period of time, is beyond the scope of this document. These decisions may depend on the intended customer market for the product (consumers versus professionals), and OEMs’ perspective on facilitating flights versus being more conservative on safety. For some manufacturers, operators could unlock the geofence themselves, or a request from a customer may constitute a sufficiently thoughtful step to proceed with unlocking, placing the flight decision back into the hands of the remote pilot-in-command. Other manufacturers may desire documentation of some kind, such as a Part 107 certificate, registration number, certificate of authorization, or waiver. In the future, and if connected, authorized UTM/LAANC systems may also be able to automatically unlock ‘out-of-the-box’ geofences based on their real time assessment of the airspace risk associated with the defined high risk location.

For unlocking implementation, OEM’s may need to consider how to deal with specific time and location based constraints within an approval while not unlocking the system everywhere at all times. Other considerations include customer support resources, explanations in product instruction manuals, maps of the geofencing zones online, and notification of flight limitation functions in UAS ground control software.

Given that these decisions can be complex, and depend on the structure, sophistication, risk-aversion and resources of each manufacturer, the DST does not have specific recommendations for how to “unlock” geofencing. It is conceivable that a manufacturer would choose a conservative approach to safety, and simply implement geofencing without an ability to unlock the drone in the high-risk locations, knowing that its products will then be unusable for authorized operations at or near certain airports.

Appendix A. High Risk Locations to Protect through Geofencing

High risk locations that merit consideration for geofencing protections referenced in this document include among other areas of national interest, FAA-designated primary airports within Class B and Class C airspace. This appendix provides some, but not necessarily all airports for geofencing protection considerations.

Class B Airports

Table 1: Class B Airspace with VFR Enhancement Graphics

Ref	Class B Enhancement	Date Added (**)	Notes
1	Atlanta (PDF)	07 March 2013	
2	Boston (PDF)	14 May 2014	
3	Charlotte (PDF)	28 March 2012	
4	Chicago (PDF)	25 April 2019 **	
5	Cincinnati (PDF)	28 April 2014	
6	Cleveland (PDF)	28 March 2012	
7	Dallas - Ft. Worth (PDF)	06 March 2014	
8	Denver (PDF)	05 June 2013	
9	Detroit (PDF)	16 August 2018	
10	Honolulu (PDF)	28 March 2012	
11	Houston (PDF)	28 April 2014	Hobby and George Bush
12	Kansas City (PDF)	13 December 2012	
13	Las Vegas (PDF)	21 August 2013	
14	Los Angeles (PDF)	07 December 2017	
15	Memphis (PDF)	21 August 2013	
16	Miami (PDF)	28 April 2014	
17	Minneapolis (PDF)	09 January 2014	
18	New Orleans (PDF)	17 August 2018	
18	New York (PDF)	24 March 2015	JFK, LaGuardia, & Newark
19	Orlando (PDF)	28 May 2014	

20	Philadelphia (PDF)	30 January 2019	
21	Phoenix (PDF)	21 December 2011	
22	Pittsburgh (PDF)	06 February 2014	
23	St. Louis (PDF)	7 May 2019 **	
24	Salt Lake City (PDF)	14 October 2014	
25	San Diego (PDF)	21 December 2011	
26	San Francisco (PDF)	16 August 2018	
27	Seattle (PDF)	07 December 2011	
28	Tampa (PDF)	28 January 2016	
29	Washington Tri-Area (PDF)	30 January 2019	Baltimore, Reagan National, & Dulles

Chart data downloaded on April 10, 2020 from www.faa.gov.

Special Operating Restrictions Airports

Table 2: Appendix D to Part 91—Airports/Locations: Special Operating Restrictions

Ref	Airport	Below 10K w/in 3nm	No FW SVFR	Min Private Pilot Rating
1	Atlanta, GA (Hartsfield-Jackson Atlanta International)	X	X	X
2	Baltimore, MD (BWI Thurgood Marshall)	X	X	
3	Boston, MA (General Edward Lawrence Logan Intl)	X	X	X
4	Buffalo, NY (Greater Buffalo International)		X	
5	Camp Springs, MD (Joint Base Andrews)	X	X	X
6	Chantilly, VA (Washington Dulles International)	X		
7	Charlotte, NC (Charlotte/Douglas International)	X		
8	Chicago, IL (Chicago-O'Hare International)	X	X	X
9	Cleveland, OH (Cleveland-Hopkins International)	X	X	
10	Columbus, OH (Port Columbus International Airport)		X	
11	Covington, KY (Cincinnati/Northern Kentucky Intl)	X	X	
12	Dallas, TX (Dallas/Fort Worth International)	X	X	X
13	Dallas, TX (Dallas Love Field)		X	
14	Denver, CO (Denver International)	X	X	
15	Detroit, MI (Detroit Metropolitan Wayne County)	X	X	
16	Honolulu, HI (Honolulu International Airport)	X	X	
17	Houston, TX (George Bush Intl /Houston)	X	X	
18	Houston, TX (William P. Hobby)	X		
18	Indianapolis, IN (Indianapolis International)		X	
19	Kansas City, MO (Kansas City International)	X		
20	Las Vegas, NV (McCarran International)	X		
21	Los Angeles, CA (Los Angeles International)	X	X	X
22	Louisville, KY (Louisville Intl Airport-Standiford Field)		X	
23	Memphis, TN (Memphis International)	X	X	
24	Miami, FL (Miami International)	X	X	X
25	Minneapolis, MN (Minneapolis-St. Paul Intl / World-Chamberlain)	X	X	
26	Newark, NJ (Newark Liberty International)	X	X	X

Ref	Airport	Below 10K w/in 3nm	No FW SVFR	Min Private Pilot Rating
27	New Orleans, LA (Louis Armstrong New Orleans Intl)	X	X	
28	New York, NY (John F. Kennedy International)	X	X	X
29	New York, NY (LaGuardia)	X	X	X
30	Orlando, FL (Orlando International)	X		
31	Philadelphia, PA (Philadelphia International)	X	X	
32	Portland, OR (Portland International Airport)			
33	Phoenix, AZ (Phoenix Sky Harbor International)	X		
34	Pittsburgh, PA (Pittsburgh International)	X	X	
35	Portland, OR (Portland International)		X	
36	Salt Lake City, UT (Salt Lake City International Airport)			
37	San Diego, CA (Miramar Marine Corps Air Station)			
38	San Diego, CA (San Diego International Airport)			
39	San Francisco, CA (San Francisco International)		X	X
40	Seattle, WA (Seattle-Tacoma International)		X	
41	St. Louis, MO (Lambert-St. Louis International)	X	X	
42	Tampa, FL (Tampa International)		X	
43	Washington, DC (Ronald Reagan Washington National)			X

Chart data downloaded on April 10, 2020 from www.ecfr.gov.

Class C Airports

Table 3: Class C Airports

	State/City	Notes
	ALABAMA	
1	Birmingham	Birmingham-Shuttlesworth International
2	Huntsville	International-Carl T Jones Fld

	State/City	Notes
3	Mobile	Regional
	ALASKA	
4	Anchorage	Ted Stevens International
	ARIZONA	
5	Davis-Monthan	AFB
	Tucson	International
	ARKANSAS	
6	Fayetteville (Springdale)	Northwest Arkansas Regional
7	Little Rock	Adams Field
	CALIFORNIA	
8	Beale	AFB
9	Burbank	Bob Hope
10	Fresno	Yosemite International
11	Monterey	Peninsula
12	Oakland	Metropolitan Oakland International
13	Ontario	International
14	Riverside	March AFB
15	Sacramento	International
16	San Jose	Norman Y. Mineta International
17	Santa Ana	John Wayne/Orange County
18	Santa Barbara	Municipal
	COLORADO	
19	Colorado Springs	Municipal
	CONNECTICUT	
20	Windsor Locks	Bradley International
	FLORIDA	
21	Daytona Beach	International
22	Fort Lauderdale	Hollywood International

	State/City	Notes
23	Fort Myers	SW Florida Regional
24	Jacksonville	International
25	Orlando	Sanford International
26	Palm Beach	International
27	Pensacola	NAS
28	Pensacola	Regional
29	Sarasota	Bradenton International
30	Tallahassee	Regional
31	Whiting	NAS
	GEORGIA	
32	Savannah	Hilton Head International
	HAWAII	
33	Kahului	Kahului
	IDAHO	
34	Boise	Air Terminal
	ILLINOIS	
35	Champaign	Urbana U of Illinois-Willard
36	Chicago	Midway International
37	Moline	Quad City International
38	Peoria	Greater Peoria Regional
39	Springfield	Abraham Lincoln Capital
	INDIANA	
40	Evansville	Regional
41	Fort Wayne	International
42	Indianapolis	International
43	South Bend	Regional
	IOWA	
44	Cedar Rapids	The Eastern Iowa

	State/City	Notes
45	Des Moines	International
	KANSAS	
46	Wichita	Mid-Continent
	KENTUCKY	
47	Lexington	Blue Grass
48	Louisville	International-Standiford Field
	LOUISIANA	
49	Baton Rouge	Metropolitan, Ryan Field
50	Lafayette	Regional
51	Shreveport	Barksdale AFB
52	Shreveport	Regional
	MAINE	
53	Bangor	International
54	Portland	International Jetport
	MICHIGAN	
55	Flint	Bishop International
56	Grand Rapids	Gerald R. Ford International
57	Lansing	Capital City
	MISSISSIPPI	
58	Columbus	AFB
59	Jackson	Jackson-Evers International
	MISSOURI	
60	Springfield	Springfield-Branson National
	MONTANA	
61	Billings	Logan International
	NEBRASKA	
62	Lincoln	Lincoln
63	Omaha	Eppley Airfield

	State/City	Notes
64	Offutt	AFB
	NEVADA	
65	Reno	Reno/Tahoe International
	NEW HAMPSHIRE	
66	Manchester	Manchester
	NEW JERSEY	
67	Atlantic City	International
	NEW MEXICO	
68	Albuquerque	International Sunport
	NEW YORK	
69	Albany	International
70	Buffalo	Niagara International
71	Islip	Long Island MacArthur
72	Rochester	Greater Rochester International
73	Syracuse	Hancock International
	NORTH CAROLINA	
74	Asheville	Regional
75	Fayetteville	Regional/Grannis Field
76	Greensboro	Piedmont Triad International
77	Pope	AFB
78	Raleigh	Raleigh-Durham International
	OHIO	
79	Akron	Akron-Canton Regional
80	Columbus	Port Columbus International
81	Dayton	James M. Cox International
82	Toledo	Express
	OKLAHOMA	
83	Oklahoma City	Will Rogers World

	State/City	Notes
84	Tinker	AFB
85	Tulsa	International
	OREGON	
86	Portland	International
	PENNSYLVANIA	
87	Allentown	Lehigh Valley International
	PUERTO RICO	
88	San Juan	Luis Munoz Marin International
	RHODE ISLAND	
89	Providence	Theodore Francis Green State
	SOUTH CAROLINA	
90	Charleston	AFB/International
91	Columbia	Metropolitan
92	Greer	Greenville-Spartanburg International
93	Myrtle Beach	Myrtle Beach International
94	Shaw	AFB
	TENNESSEE	
95	Chattanooga	Lovell Field
96	Knoxville	McGhee Tyson
97	Nashville	International
	TEXAS	
98	Abilene	Regional
100	Amarillo	Rick Husband International
101	Austin	Austin-Bergstrom International
102	Corpus Christi	International
103	Dyess	AFB
104	El Paso	International
105	Harlingen	Valley International

	State/City	Notes
106	Laughlin	AFB
107	Lubbock	Preston Smith International
108	Midland	International
109	San Antonio	International
	VERMONT	
110	Burlington	International
	VIRGIN ISLANDS	
111	St. Thomas	Charlotte Amalie Cyril E. King
	VIRGINIA	
112	Richmond	International
113	Norfolk	International
114	Roanoke	Regional/Woodrum Field
	WASHINGTON	
115	Point Roberts	Vancouver International
116	Spokane	Fairchild AFB
117	Spokane	International
118	Whidbey Island	NAS, Ault Field
	WEST VIRGINIA	
119	Charleston	Yeager
	WISCONSIN	
120	Green Bay	Austin Straubel International
121	Madison	Dane County Regional-Traux Field
122	Milwaukee	General Mitchell International

Chart data downloaded on April 13, 2020 from [Airman's Information Manual (AIM)]

Appendix B. Examples of Geofencing Areas and Shapes

Circular Geofences

Protected high-risk areas can be represented by one or more circles defined by a center point and radius.

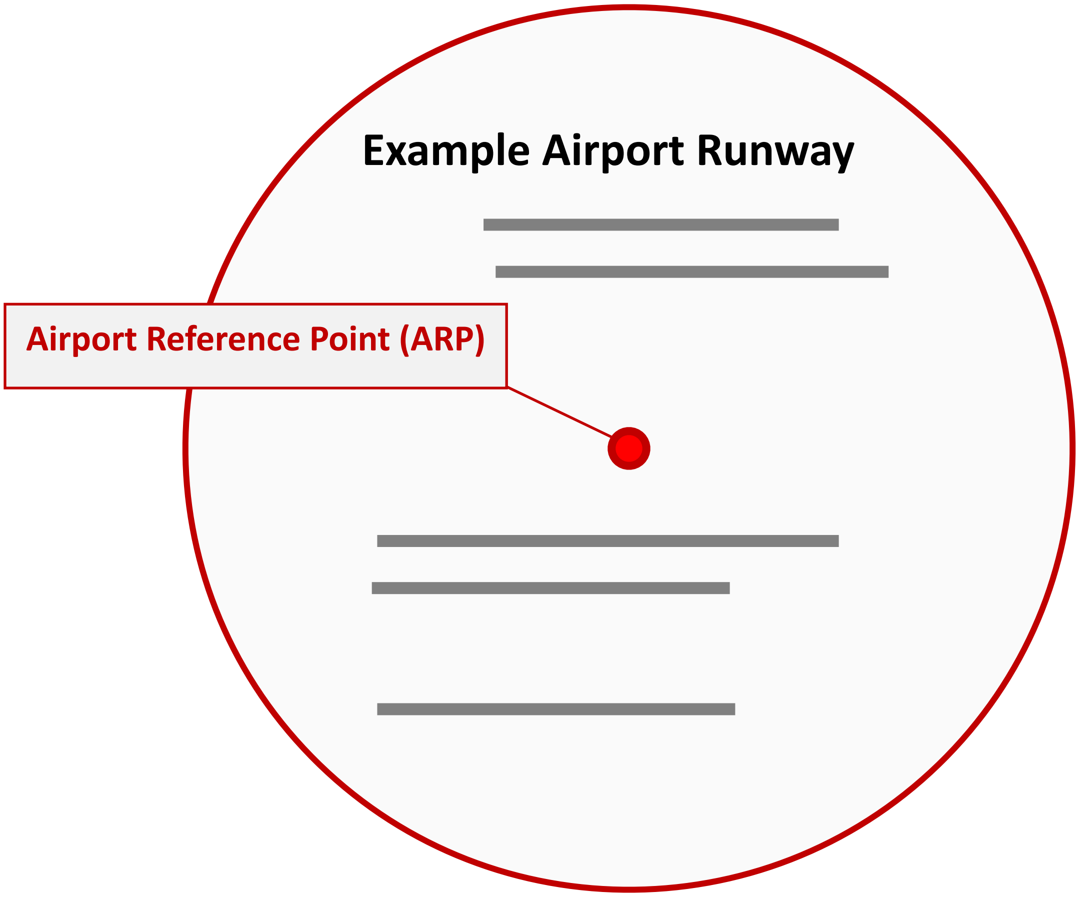

Figure 1: Example of Minimal Geofencing Capability

Polygonal Geofences

Protected high-risk areas can be represented by one or more generic or simple polygons that cover the airport surface area and may include regions under approach and departure paths.

Figure 2: Example of Minimal Geofencing Capability

Complex Geofences

Protected high-risk areas can be represented by one or more complex polygons that may cover each airport's unique surface and/or airspace geometry (e.g., regions under approach and departure paths, etc.). This capability level may also allow for vertical constraints on georeferenced areas.

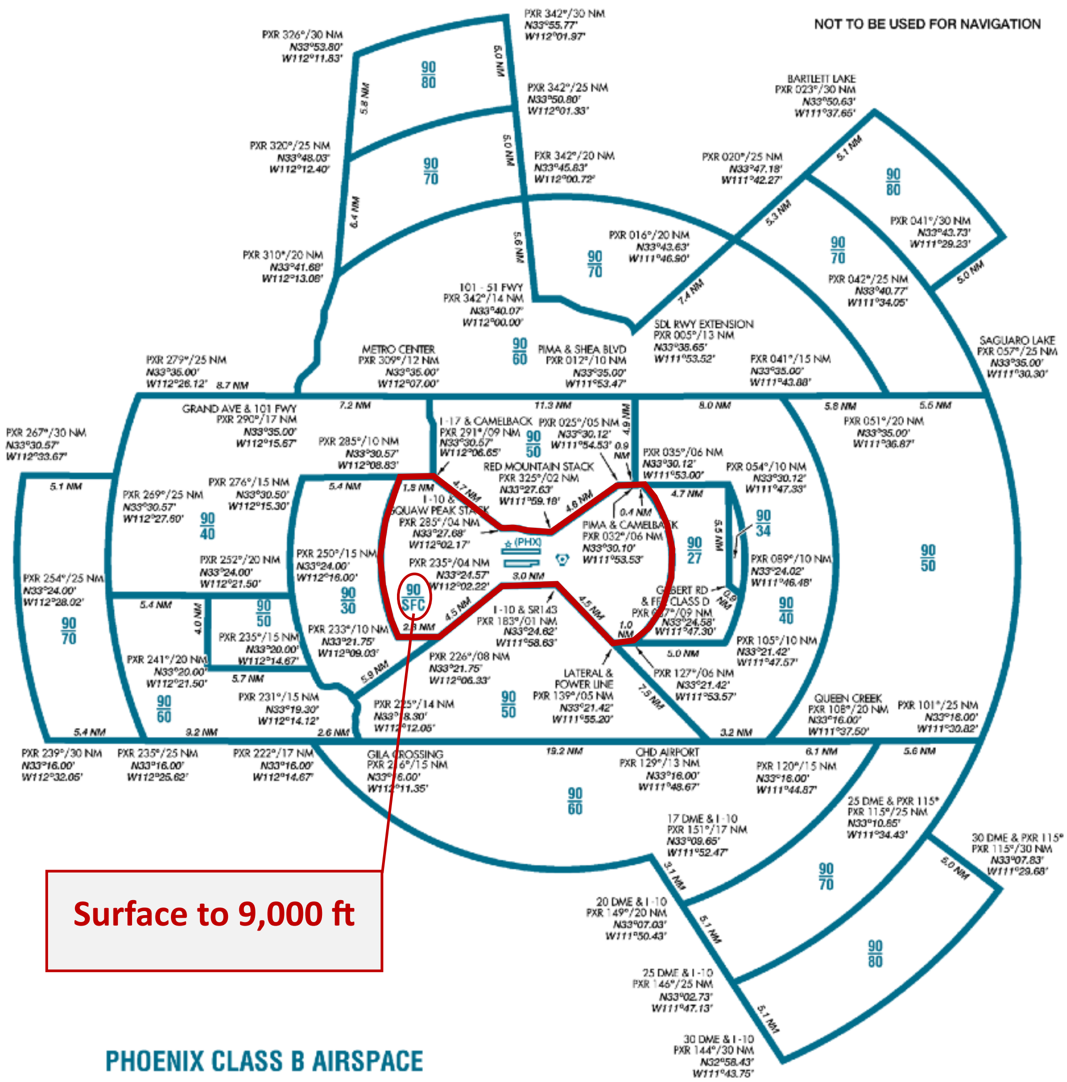

Figure 3: Example of Complex Geofencing Capability

Appendix C. Drone Safety Team

To learn more about the Drone Safety Team visit http://dronesafetyteam.org. Site visitors can review and download an electronic copy of this report as well as other DST products. Readers are also encouraged to revisit the site periodically to learn of new safety enhancement products and projects as they are developed by the team and its working groups.

DST SE-1 Team

The DST would like to acknowledge the contributions of members who helped to develop this white paper into a consensus-based recommendation. The DST thanks the following SE-1 team members for volunteering their time and expertise to this project.

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- Anuja Verma (MITRE)
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