Urban Airspace and eVTOL Design Concepts - Challenges

Session:
Safe and Equitable Airspace and Flight Operations

Jasenka Rakas
University of California, Berkeley

Future of Aviation Conference
UC Berkeley Institute of Transportation Studies
August 4, 2022

Urban Airspace and eVTOL Design Concepts - Challenges

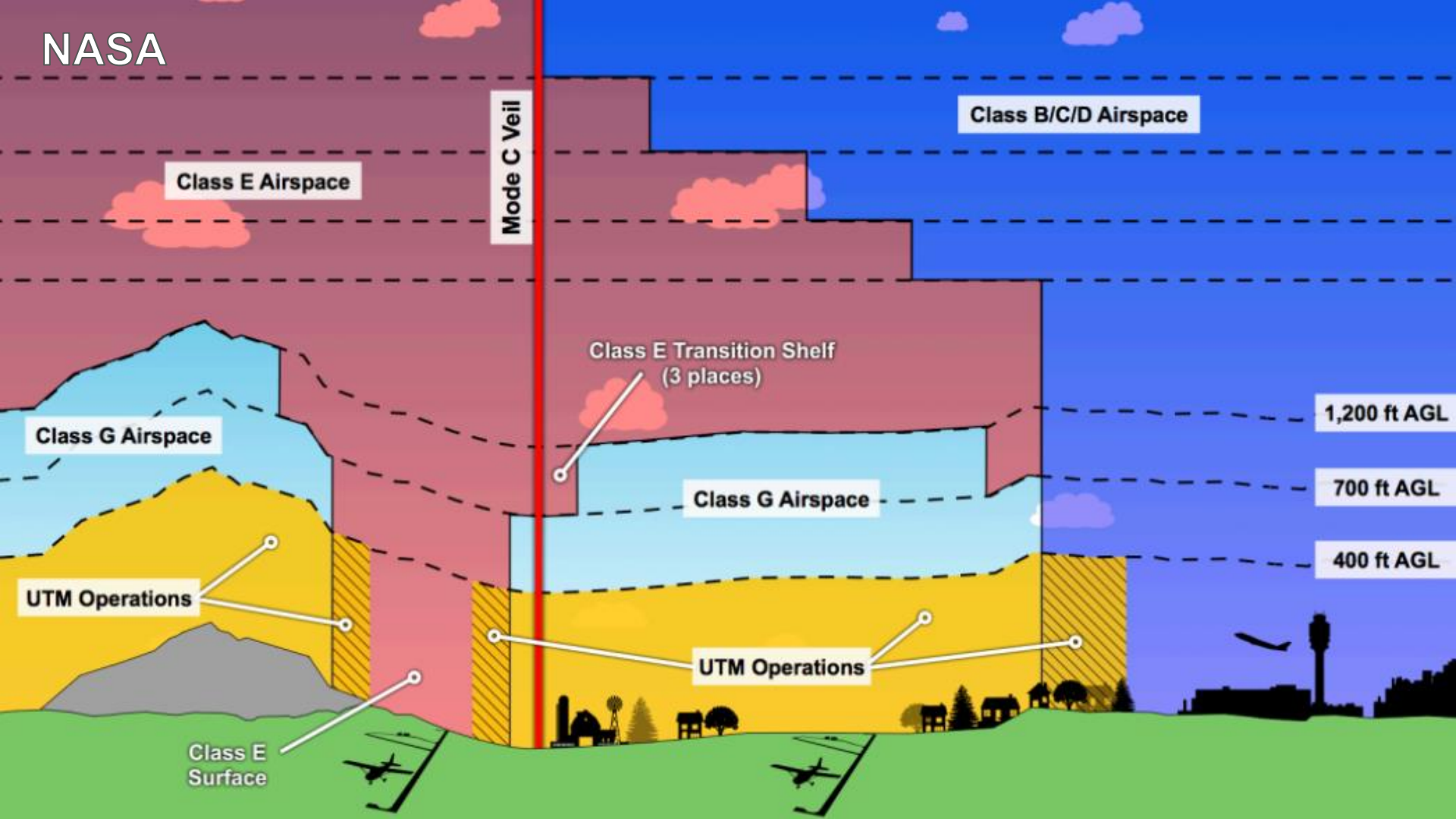
Urban airspace design concepts:

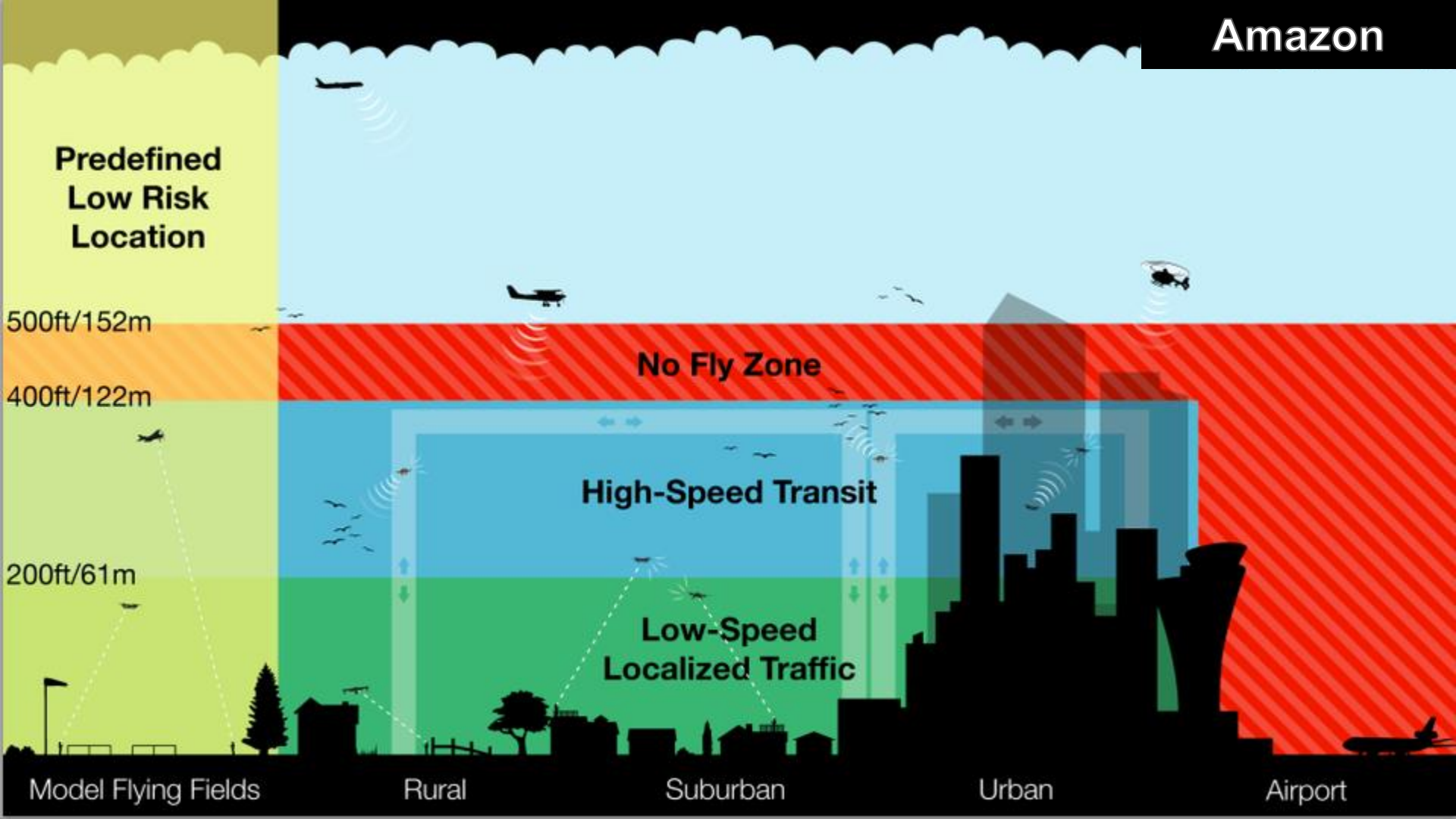
- *Government-led initiatives: NASA, FAA, MITRE, SESAR U-SPACE, DLR U-SPACE,* METROPOLIS, *ONERA, Singapore, China's Civil UAS Aviation Operation Management System (UOMS),* Japan Aerospace Exploration Agency (JAXA)-the UAS traffic management (UTM)
- *Industry-led initiatives: Amazon, Airbus, Boeing, Embraer-X, former Uber Elevate*

eVTOL design concepts

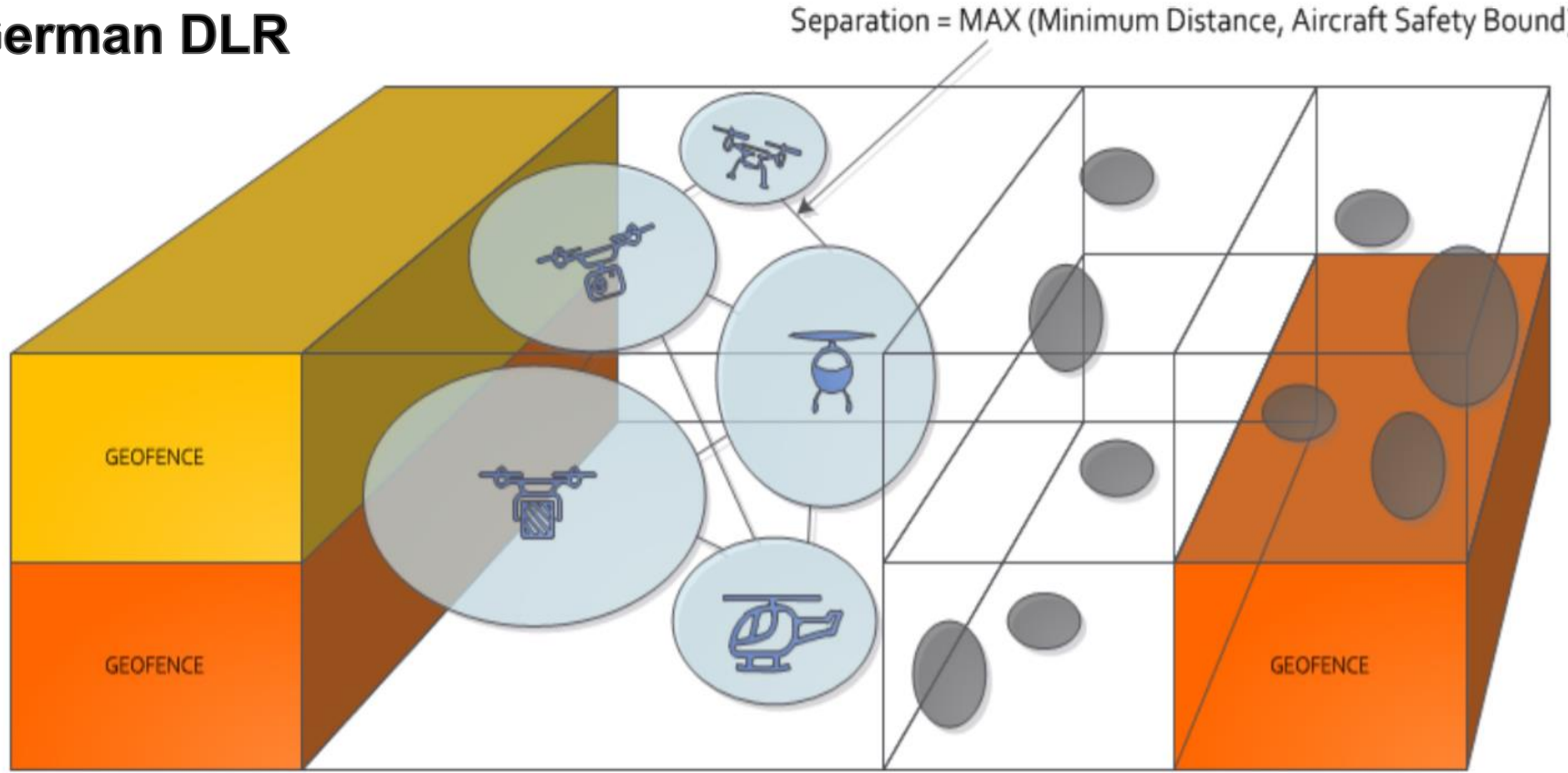
- Over 500 types, across the globe

FAA Airspace Classification

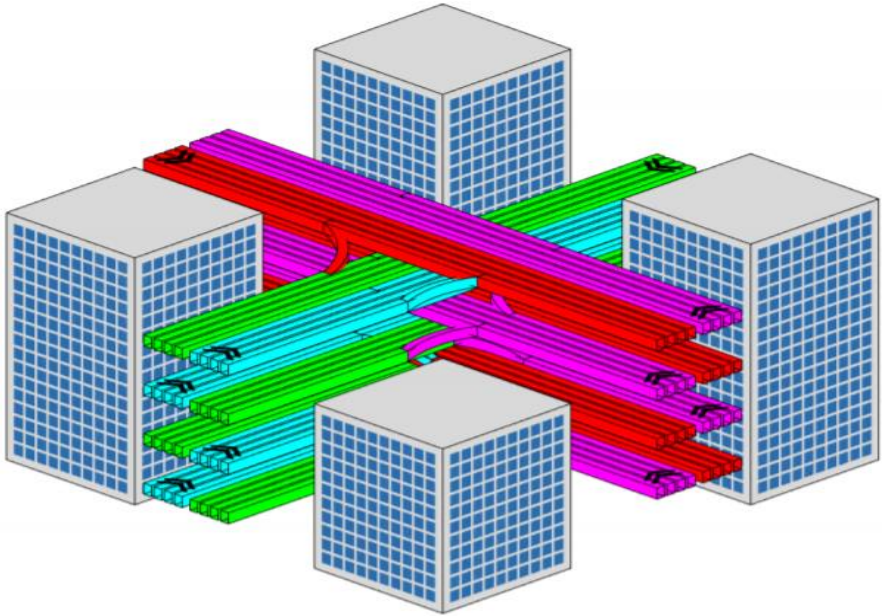

NASA
Mode C Veil
Class B/C/D Airspace
Class E Airspace
Class E Transition Shelf
(3 places)
Class G Airspace
1,200 ft AGL
Class G Airspace
700 ft AGL
400 ft AGL
UTM Operations
UTM Operations
Class E
Surface

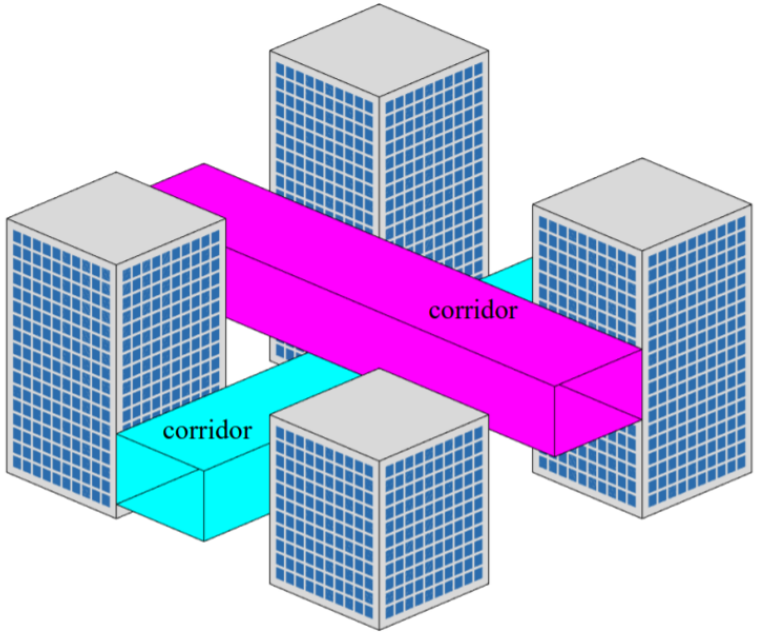

Amazon
Predefined
Low Risk
Location
500ft/152m
No Fly Zone
400ft/122m
High-Speed Transit
200ft/61m
Low-Speed
Localized Traffic
Model Flying Fields
Rural
Suburban
Urban
Airport

German DLR

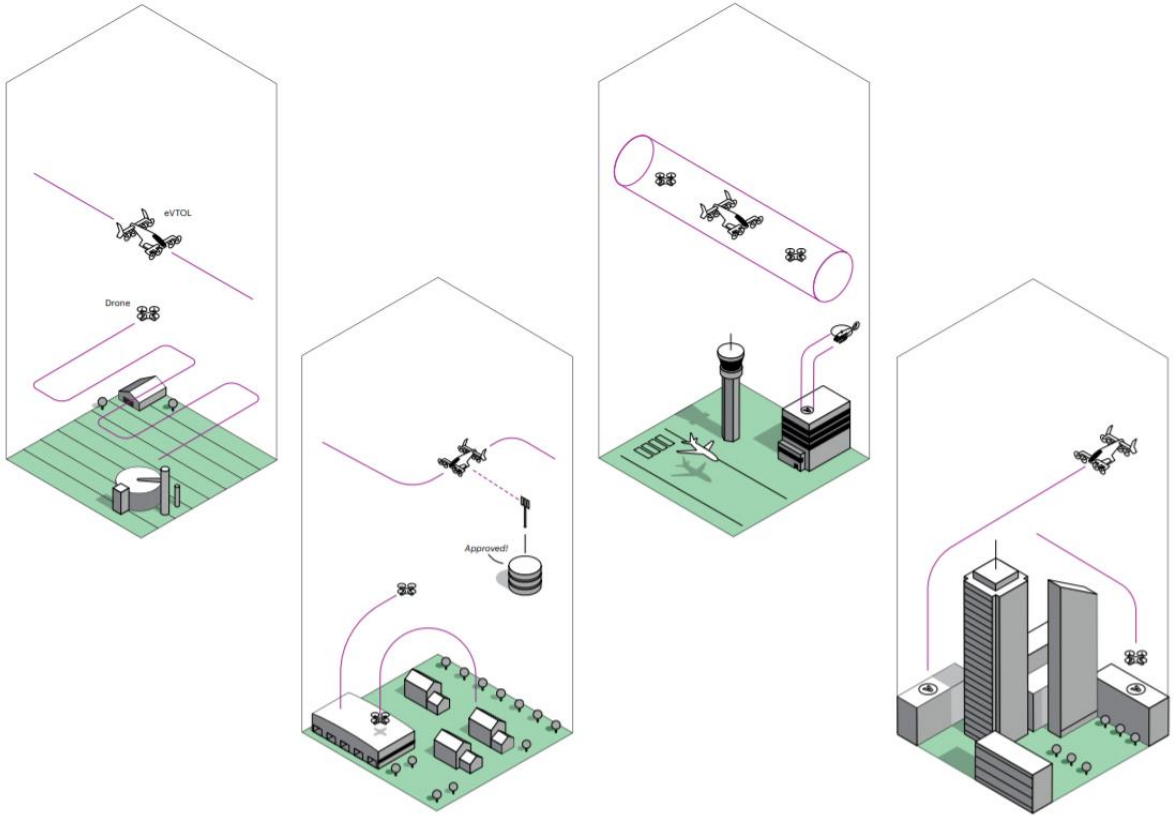

Separation = MAX (Minimum Distance, Aircraft Safety Bound)
GEOFENCE
GEOFENCE
GEOFENCE

NASA - experimental





Airbus

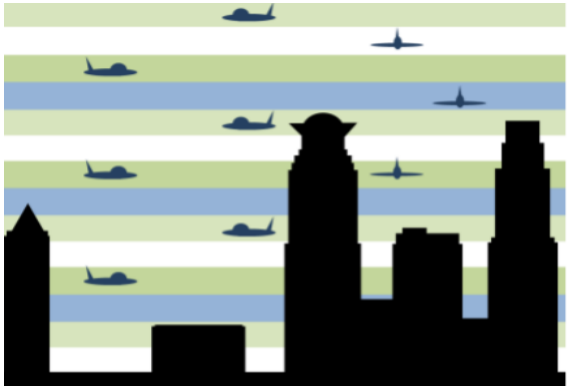


Airspace structures by Airbus: Basic Flight, Free Route, Corridors, and Fixed Route

DUTCH METROPOLIS

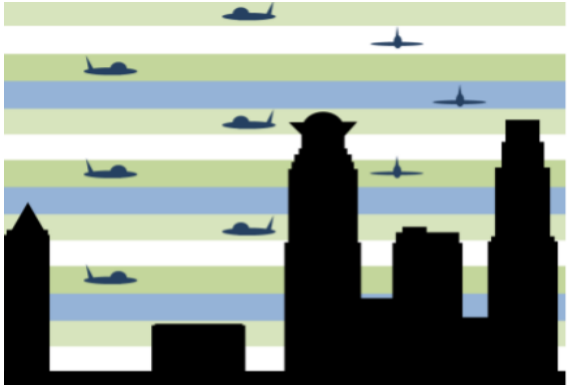
FREE FLIGHT

LAYERS



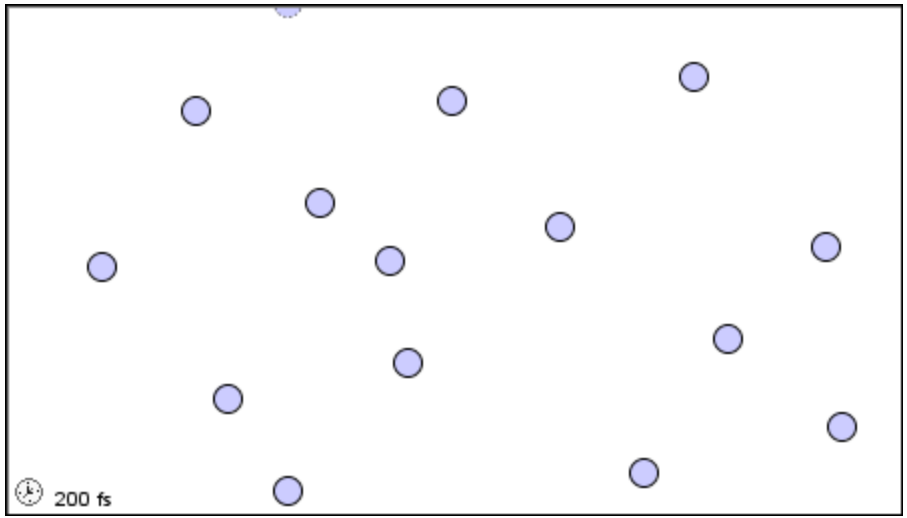
ZONES

TUBES



HOW TO EVALUATE??

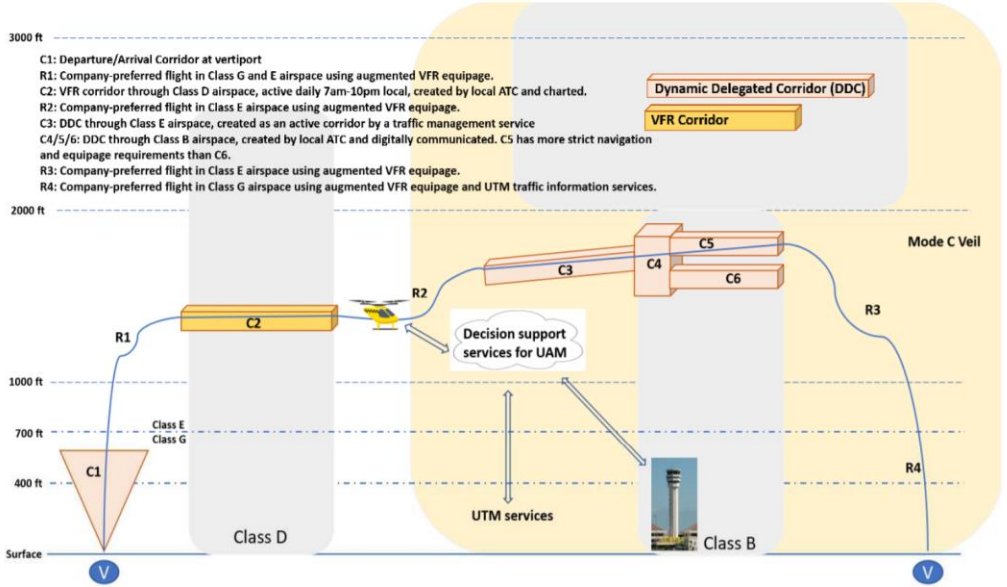
Structure of airspace is important!



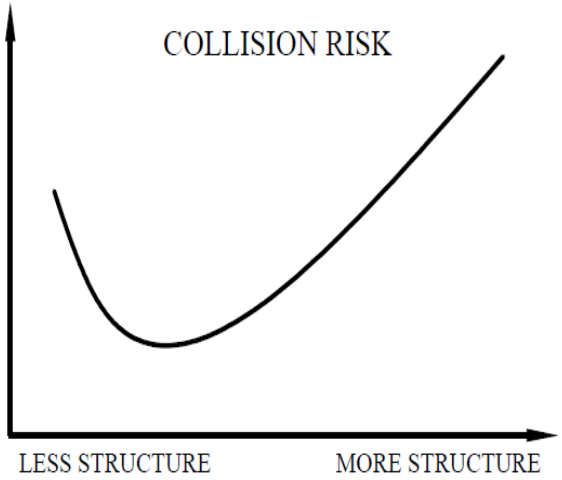
Free flight

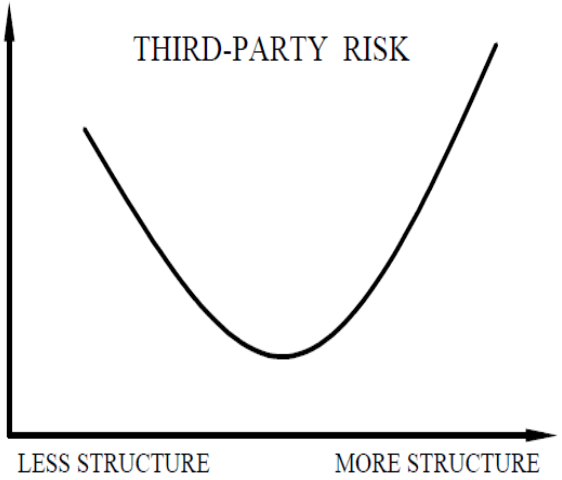
Structure of airspace is important!

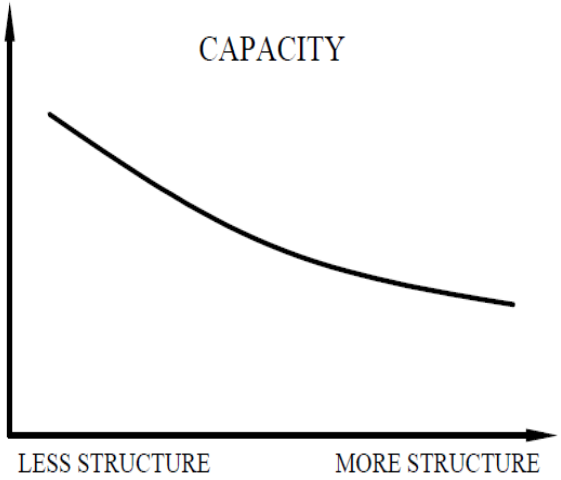
Layers

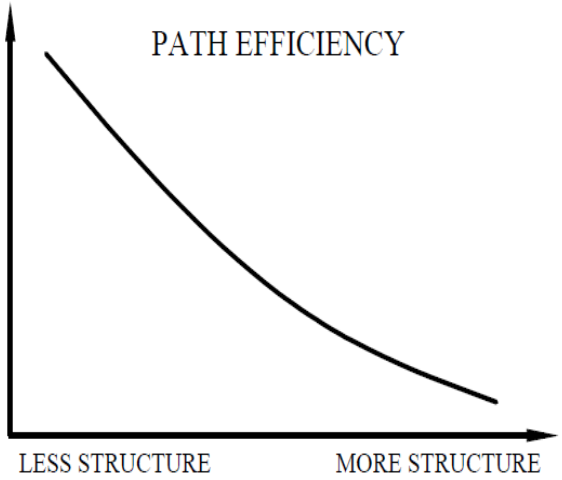


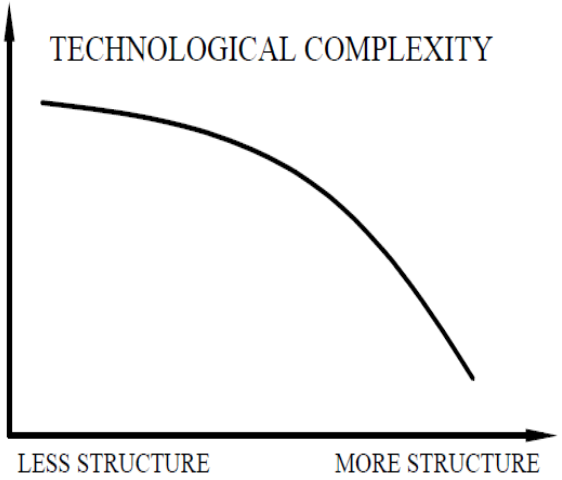
Strict trajectories

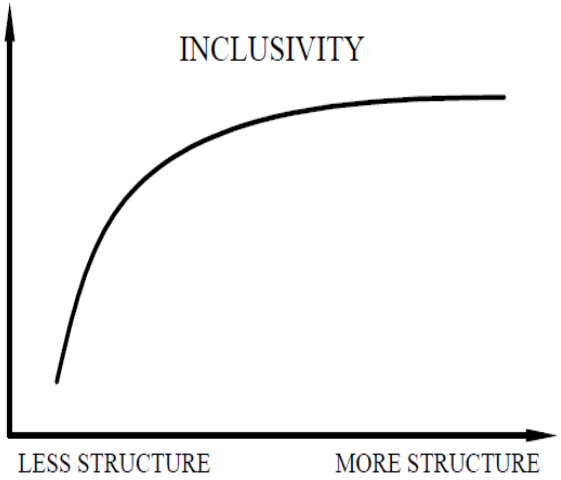

COLLISION RISK
LESS STRUCTURE
MORE STRUCTURE

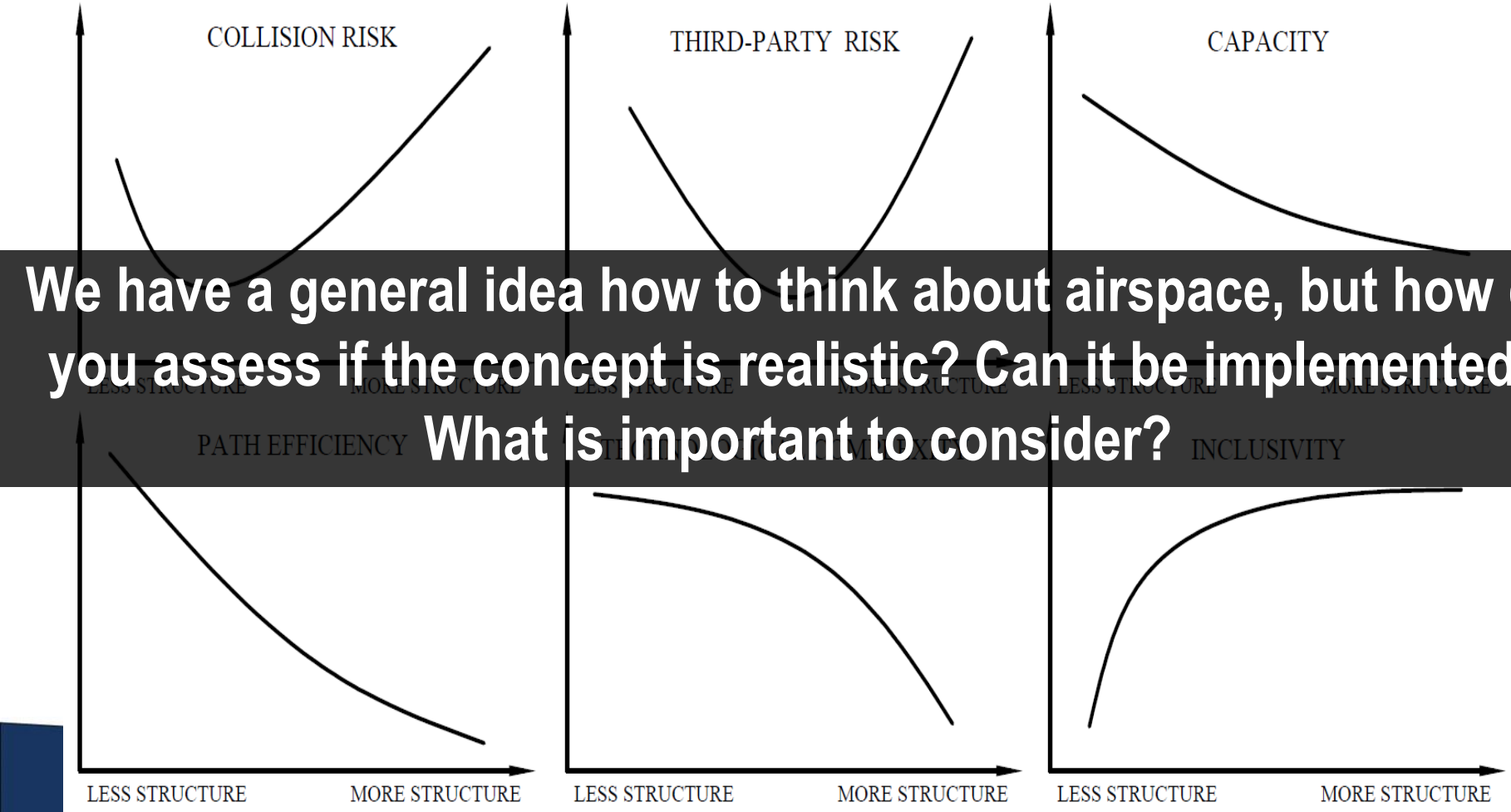

THIRD-PARTY RISK
LESS STRUCTURE
MORE STRUCTURE


CAPACITY
LESS STRUCTURE
MORE STRUCTURE

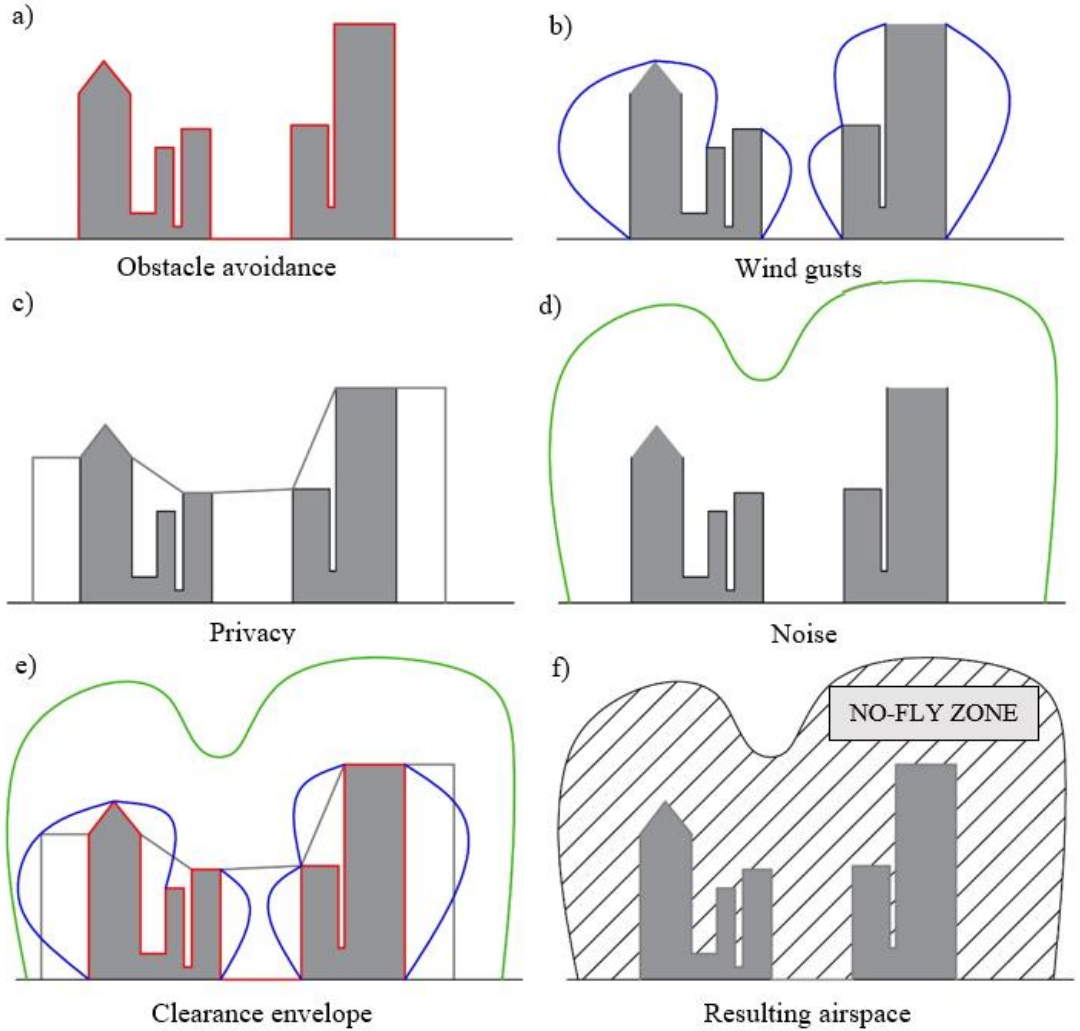

PATH EFFICIENCY
LESS STRUCTURE
MORE STRUCTURE


TECHNOLOGICAL COMPLEXITY
LESS STRUCTURE
MORE STRUCTURE


INCLUSIVITY
LESS STRUCTURE
MORE STRUCTURE



We have a general idea how to think about airspace, but how do you assess if the concept is realistic? Can it be implemented? What is important to consider?



Clearance depends on these selected variables:

(a) obstacle avoidance;
(b) wind gusts;
(c) privacy;
(d) noise;
(e) clearance envelope;
(f) resulting airspace.

Factors that impact airspace design

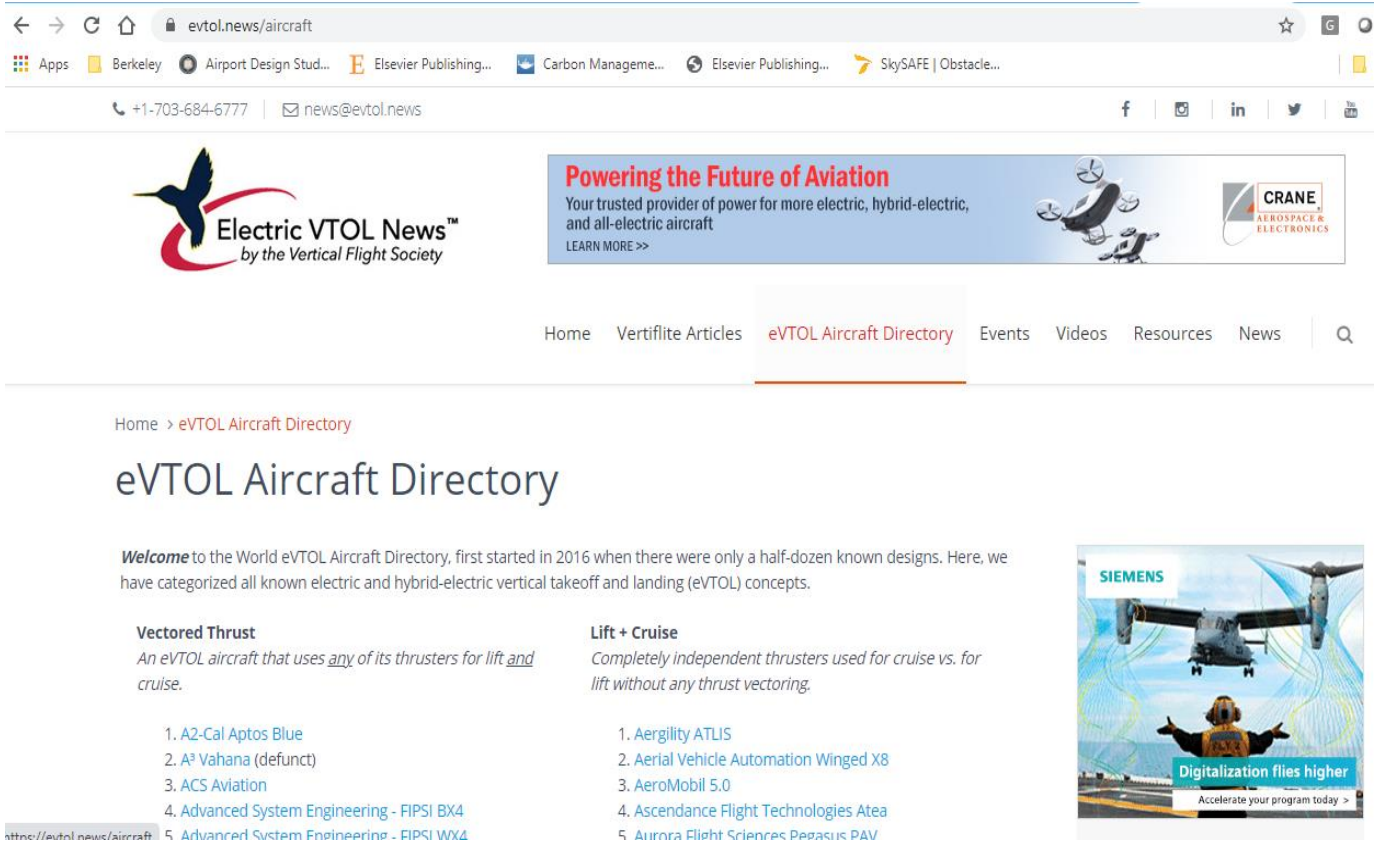
Group	Factor	
Safety	Object avoidance	Separation
		Sense-and-avoid
		Aircraft avoidance
		Static Geofence
		Dynamic Geofence
	Wind gusts	
	Weather	
Social	Noise	
	Privacy	
	Visual pollution	
System	Air Traffic Management	
	Communication, Navigation, and Surveillance	
	Capacity	
Vehicle	Critical aircraft	
	Autonomy	
	Energy efficiency	

Review of airspace concepts

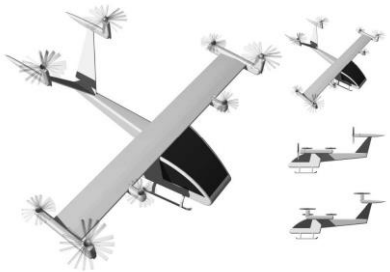
			NASA UTM	NASA UTFC	MITRE	SESAR U-Space	DLR U-Space	Metropolis-a [24]	Metropolis-b	Metropolis-c	Metropolis-d
Country/Region			USA	USA	USA	EU	Germany	Netherlands	Netherlands	Netherlands	Netherlands
Structure			Preapproved Trajectories	Skylanes	Preapproved Trajectories	Preapproved Trajectories	Cells	Full mix	Layers	Zones	Tubes
Safety	Object avoidance	Static Geofence	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Dynamic Geofence	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Sense and avoid	Not required	Required	Required	Not required	Not required	Required	Not required	Not required	Not required
		Separation	Static	Static	Static	Static	Dynamic	Static	Static	Static	Static
	Wind gusts		×	×	×	×	✓	×	×	×	×
	Weather		✓	×	✓	✓	✓	✓	✓	✓	✓
Social	Noise		×	×	×	×	×	×	×	×	×
	Privacy		×	×	×	×	×	×	×	×	×
	Visual pollution		×	×	×	×	×	×	×	×	×
System	Airspace Management		Centralized	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized	Centralized
	CNS		GPS, ADS-B	Not specified	Not specified	LTE, FLARM, ADS-B	LTE, FLARM, ADS-B	LTE, FLARM, ADS-B	LTE, FLARM, ADS-B	LTE, FLARM, ADS-B	LTE, FLARM, ADS-B
	Capacity		High	Low	High	High	High	High	High	Medium	Low
Vehicle	Automation	Manned	×	×	✓	✓	✓	✓	✓	✓	✓
		Unmanned	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Critical aircraft		sUAS	sUAS	Various	Various	Various	Various	Various	Various	Various
	Energy efficient paths		✓	×	✓	✓	×	✓	×	×	×

Vehicle

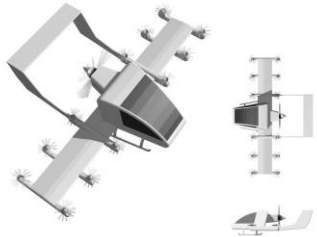
Currently, there are over 500 new air vehicle designs.



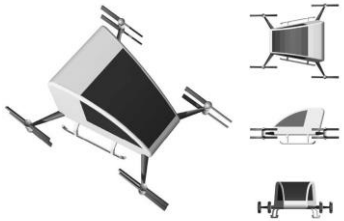
Types of eVTOL



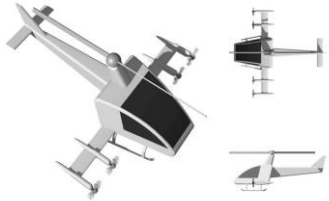
Vectored Thrust
An eVTOL aircraft that uses any of its thrusters for lift and cruise. It has a wing for an efficient cruise and uses the same propulsion system for both hover and cruise.



Lift + Cruise
Also aircraft with wings. Completely independent thrusters used for cruise vs. for lift without any thrust vectoring.

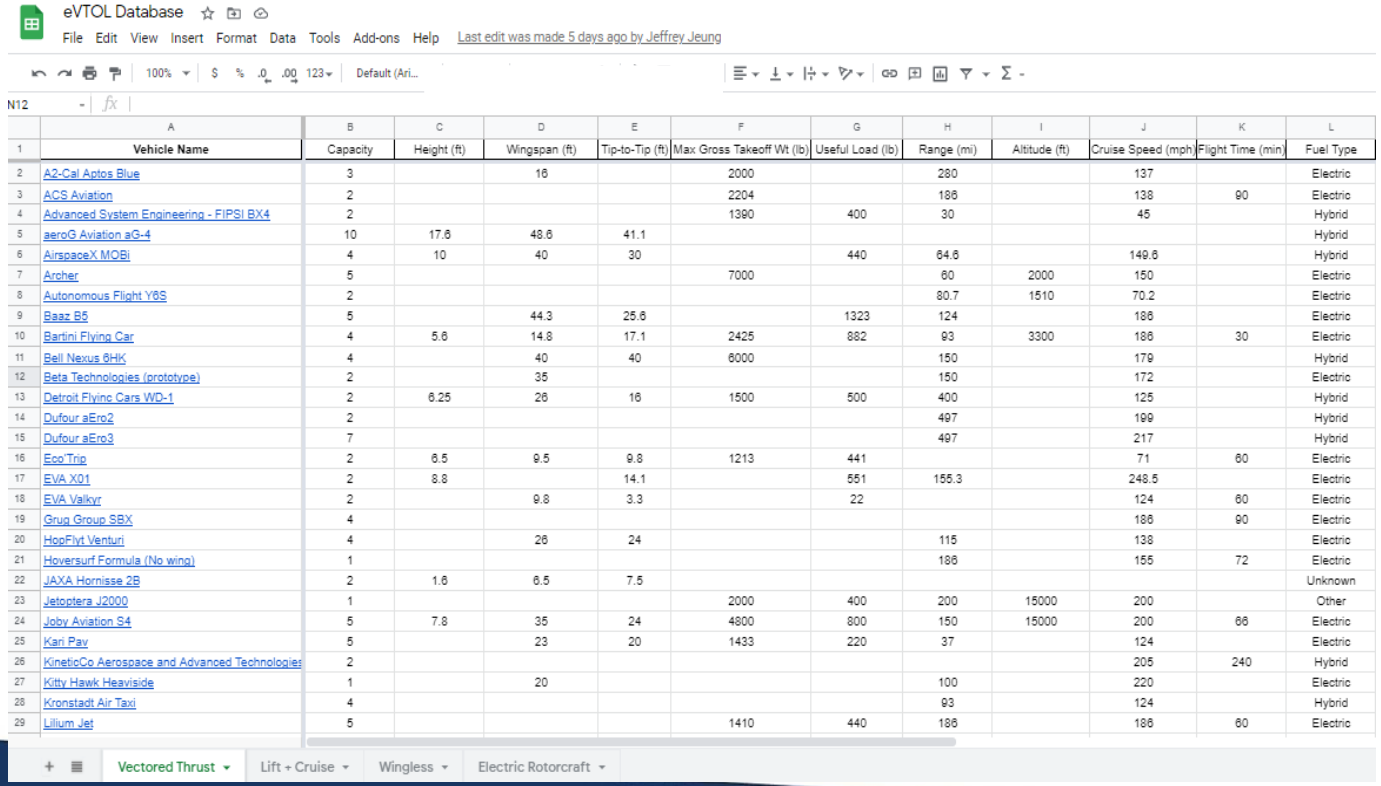


Wingless (Multicopter)
No thruster for cruise – only for lift. They are multirotors. They have large disk actuator surface which makes them efficient in hover, but they do not have a wing for an efficient cruise. Suited for short-range operations in cities where they can fly over traffic jams.



Electric Rotorcraft
An eVTOL aircraft that utilizes a helicopter frame plus a carrying wing.

UC Berkeley eVTOL Database



eVTOL Database

File Edit View Insert Format Data Tools Add-ons Help Last edit was made 5 days ago by Jeffrey Jeung

N12

	A	B	C	D	E	F	G	H	I	J	K	L
1	Vehicle Name	Capacity	Height (ft)	Wingspan (ft)	Tip-to-Tip (ft)	Max Gross Takeoff Wt (lb)	Useful Load (lb)	Range (mi)	Altitude (ft)	Cruise Speed (mph)	Flight Time (min)	Fuel Type
2	A2-Cal Aptos Blue	3		16		2000		280		137		Electric
3	ACS Aviation	2				2204		186		138	90	Electric
4	Advanced System Engineering - FIPSI BX4	2				1390	400	30		45		Hybrid
5	aeroG Aviation aG-4	10	17.6	48.6	41.1							Hybrid
6	AirspaceX MOBi	4	10	40	30		440	64.6		149.6		Hybrid
7	Archer	5				7000		60	2000	150		Electric
8	Autonomous Flight Y6S	2						80.7	1510	70.2		Electric
9	Baaz B5	5		44.3	25.6		1323	124		186		Electric
10	Bartini Flying Car	4	5.6	14.8	17.1	2425	882	93	3300	186	30	Electric
11	Bell Nexus 6HK	4		40	40	6000		150		179		Hybrid
12	Beta Technologies (prototype)	2		35				150		172		Electric
13	Detroit Flying Cars WD-1	2	6.25	26	16	1500	500	400		125		Hybrid
14	Dufour aEro2	2						497		199		Hybrid
15	Dufour aEro3	7						497		217		Hybrid
16	Eco'Trip	2	6.5	9.5	9.8	1213	441			71	60	Electric
17	EVA X01	2	8.8		14.1		551	155.3		248.5		Electric
18	EVA Valkyr	2		9.8	3.3		22			124	60	Electric
19	Grug Group SBX	4								186	90	Electric
20	HopFlyt Venturi	4		26	24			115		138		Electric
21	Hoversurf Formula (No wing)	1						186		155	72	Electric
22	JAXA Hornisse 2B	2	1.6	6.5	7.5							Unknown
23	Jetoptera J2000	1				2000	400	200	15000	200		Other
24	Joby Aviation S4	5	7.8	35	24	4800	800	150	15000	200	66	Electric
25	Kari Pav	5		23	20	1433	220	37		124		Electric
26	KineticCo Aerospace and Advanced Technologies	2								205	240	Hybrid
27	Kitty Hawk Heaviside	1		20				100		220		Electric
28	Kronstadt Air Taxi	4						93		124		Hybrid
29	Lilium Jet	5				1410	440	186		186	60	Electric

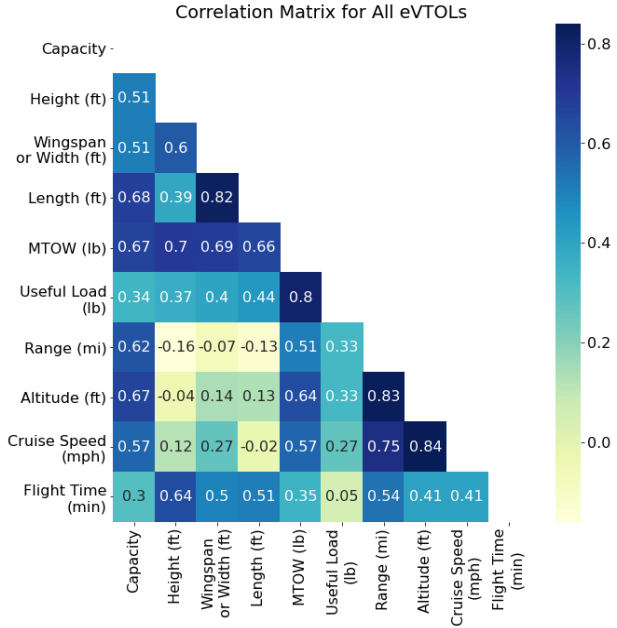
Vectored Thrust | Lift + Cruise | Wingless | Electric Rotorcraft

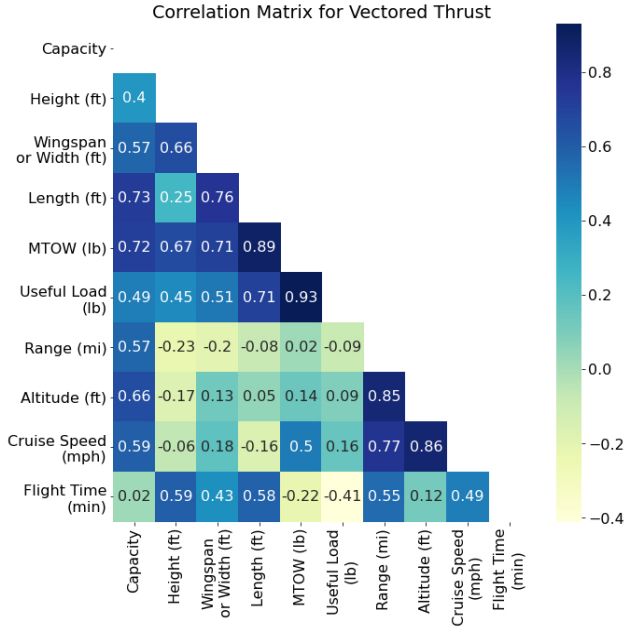
Berkeley
UNIVERSITY OF CALIFORNIA

Performance Metrics (for infrastructure sizing)

- Range (miles)
- Altitude (feet)
- Cruise Speed (miles per hour)
- Flight Time (minutes)
- Seating Capacity (# of passengers)
- Maximum Takeoff Weight (MTOW) (pounds)
- Useful Load (pounds)
- Size: height, wingspan or width, length (feet)

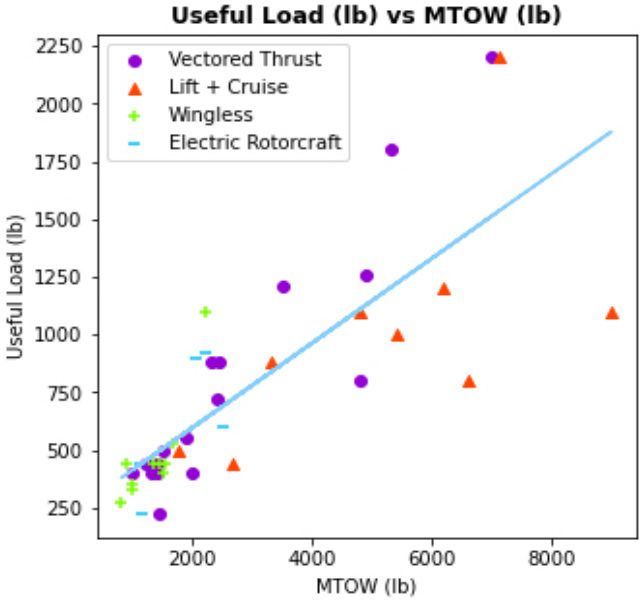
Performance Metric Correlations

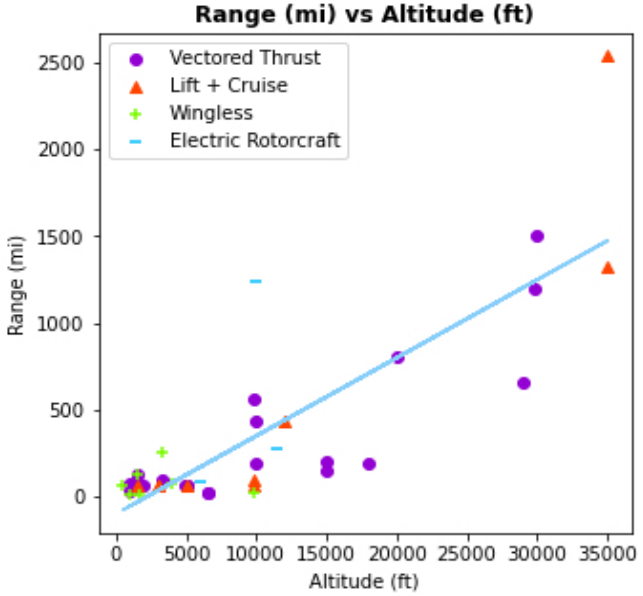




Berkeley
UNIVERSITY OF CALIFORNIA

Performance Metric Correlations





Summary

- Diverse airspace concepts
- Diverse air vehicle design concepts

How many AAM airspace concepts will be used in the future?

How will you determine a design (i.e. critical) eVTOL air vehicle?