Vertidrome Design:
State of the Art and Current Research

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Agenda

1. Vision of Urban Air Mobility
then vs. now

2. Why do we need UAM tailored Ground Infrastructure?

3. Regulatory Framework

4. Challenges of Terminologies

5. *„Vertidrome-in-the-lab“*
Performance Assessment of a Vertidrome‘s Airside Operation

6. Summary and Outlook

1. Vision of Urban Air Mobility

1. Vision of Urban Air Mobility
then vs. now

Central London Helidrome proposed by Norman Dodds (1951)

Gannett Fleming‘s proposal for the Uber Elevate Skyport Challenge (2018)

[1]I. Mansfield, ‘Unbuilt London: How Charing Cross nearly became a giant helipad’, ianVisits, Jun. 20, 2015. https://www.ianvisits.co.uk/blog/2015/06/20/how-charing-cross-nearly-became-a-giant-helipad/ (accessed Sep. 17, 2021).

2. Why do we need UAM tailored Ground Infrastructure?

Airport

- High performance and affordable fixed-wing operations
- ICAO Standard: ICAO AN 14-1

Heliport

- Low frequency and less affordable rotorcraft operations
- ICAO Standard: ICAO AN 14-2

UAM Ground Infrastructure

On-demand but affordable	Ground taxi
High dispatch frequencies	Simultaneous, automatic operations
Complex obstacle scenery	Steep approaches/ departures

2. Why do we need UAM tailored Ground Infrastructure?

Demand

Variation of demand densities

(On-demand) Request

Minutes to hours before actual flight

Complex (Obstacle) Scenery

Urban environment, often in controlled airspace

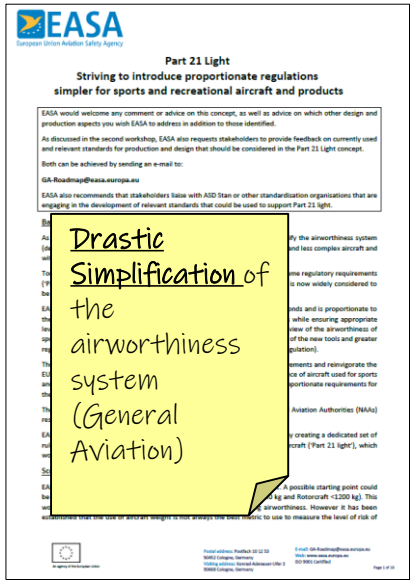
New Aircraft Technologies

New propulsion systems, no long-term experience

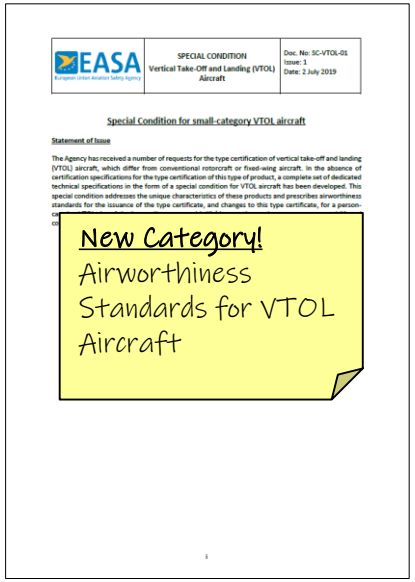
(Unknown) Weather Dependency

Urban Heat Islands, operation of lightweight aicrafts

3. Regulatory Framework

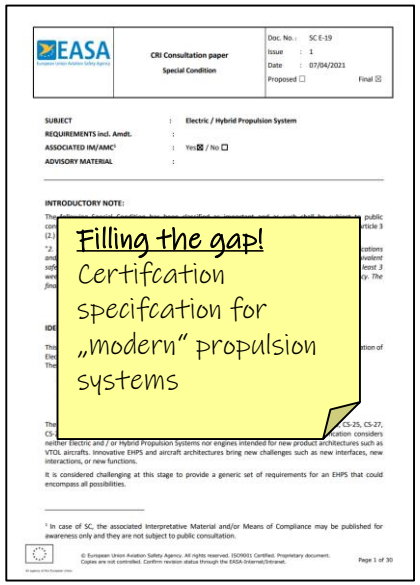


Part 21 Light

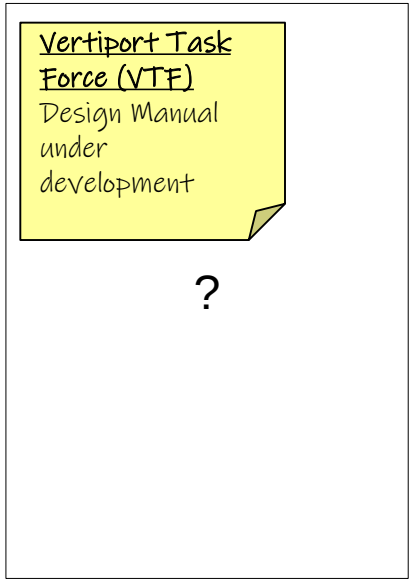


SC-VTOL-01

MOC-SC-VTOL



SC E-19



Vertiport Design Manual

4. Challenges due to Missing Terminologies
UAM Ground Infrastructure

Aerodrome Airparks Vertiplaces *Vertistation*

Vertihub VTOL-ports UAM Aerodrome Drone Terminal

Vertidrome

Opportunity Hub pocket Airport *sky node*

UAM Vertiport Vertiport Vertibase

greenfield mobility hub

Vertipad *VTOL Vertiports* Vertistop

4. Challenges due to Missing Terminologies
On-demand

ICAO [3]:

"On-demand, **non-scheduled** flights on **short notice** for the carriage by air of passengers, freight or mail, or any combination thereof for remuneration usually performed with **smaller aircraft** including helicopters (typically no more than 30 seats). Also includes any **positioning flights** required for the provision of the service"

[3] International Civil Aviation Organization, Ed., *Reference manual on the ICAO statistics programme*, 5. ed. Montreal: International Civil Aviation Organization, 2013.

Transportation Science [4]:

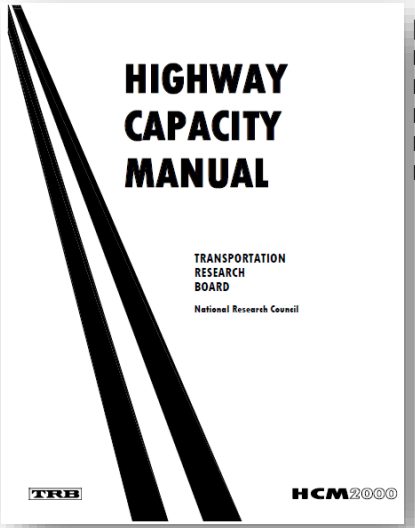
„Mobiliy-on-demand-System (MODS):
- Operates **without schedule**
- Is **bookable by an app**
- Offers a **real-time dispatching** based on a routing algorithm
- Anticipates **ride-pooling**
- Conducted by a **driver with a special license** for the transport of passengers"

[4] T. Bonus, M. Schmettow, J. Grippenkoven, and A. König, 'Der tatsächliche Bedarf hinter bedarfsgesteuerten Angeboten: Analyse des Nutzenbeitrags von Eigenschaften des Bedienkonzepts von Mobility-on-demand Systemen', presented at the 26. Verkehrswissenschaftliche Tage, Dresden, Mar. 2018. Accessed: Nov. 17, 2020. [Online]. Available: https://www.researchgate.net/publication/324064594_Der_tatsachliche_Bedarf_hinter_bedarfsgesteuerten_Angeboten_Analyse_des_Nutzenbeitrags_von_Eigenschaften_des_Bedienkonzepts_von_Mobility-on-demand_Systemen

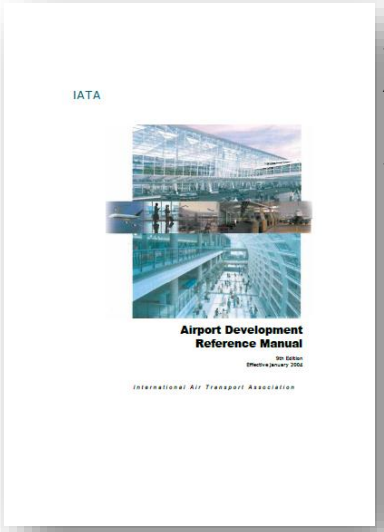
5. „*Vertidrome-in-the-lab*“
Performance Assessment of a Vertidrome‘s Airside Operation

How do we decide if a vertidrome satisfies our requirements from an operational perspective?

Level of Service Concept

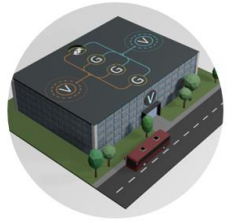


[5] Transportation Research Board, Highway Capacity Manual 2000. Washington, D.C: Transportation Research Board, National Research Council, 2000.



[6] International Air Transport Association, *Airport Development Reference Manual*, 9th ed. Montreal: International Air Transport Association, 2004.

UAM



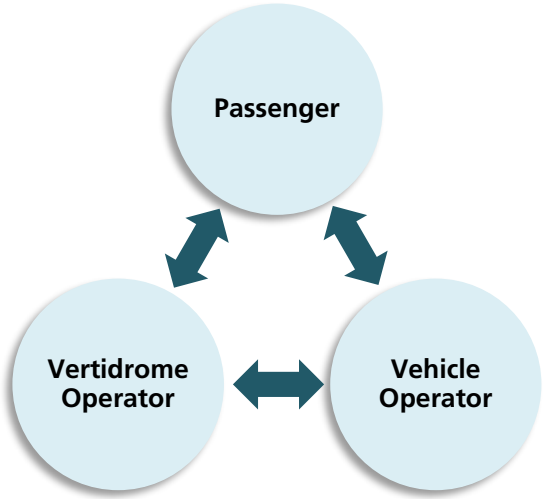
Vertidrome Airside Level of Service

VALoS

[7] K. Schweiger, F. Knabe, and B. Korn, ‘Urban Air Mobility: Vertidrome Airside Level of Service Concept’, presented at the AIAA AVIATION 2021 FORUM, VIRTUAL EVENT, Aug. 2021. doi: 10.2514/6.2021-3201.

5. „*Vertidrome-in-the-lab*“
Performance Assessment of a Vertidrome‘s Airside Operation

Who?



What?

Delay

Punctuality

How?

Vertidrome Airside Level of Service (**VALoS**)		Reference	Stakeholder Requirements: **Passenger**	**VTOL Vehicle**	**Vertidrome**	
	☺	Flow [Processed Operations per Time Interval]	$\varnothing\ d_{PAX}$	$t_{AFT} - t_{NFT}$	$\geq 95\ \%$ Flights $\leq d_{TF}$	Metric
	☺		≤ 2 Minutes	≤ 5 Minutes	$d_{TF} = 2.5$ Minutes	Objective
	☹		$\varnothing\ d_{PAX}$	$t_{AFT} - t_{NFT}$	$< 95\ \%$ Flights $\leq d_{TF}$	Metric
	☹		> 2 Minutes	> 5 Minutes	$d_{TF} = 2.5$ Minutes	Objective

Nomenclature

d=delay
t = time (duration)
AFT = actual flight time
NFT = nominal flight time
TF = total flight
PAX= passenger

[7] K. Schweiger, F. Knabe, and B. Korn, ‘Urban Air Mobility: Vertidrome Airside Level of Service Concept’, presented at the AIAA AVIATION 2021 FORUM, VIRTUAL EVENT, Aug. 2021. doi: 10.2514/6.2021-3201.

5. „*Vertidrome-in-the-lab*“ Performance Assessment of a Vertidrome‘s Airside Operation

Basis?

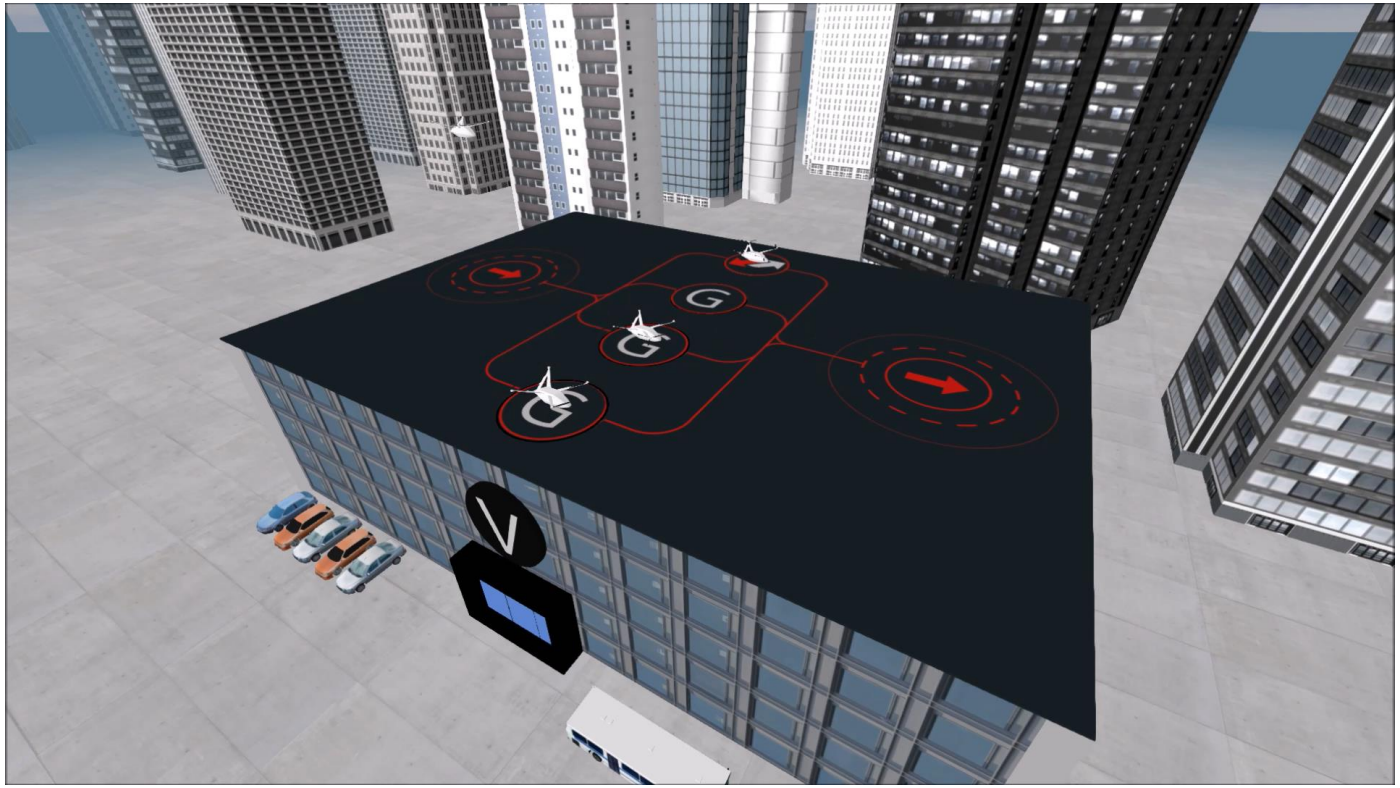
Discrete Event Based Simulation (DES)

Demand Distribution

[8] K. O. Ploetner et al., “Long-term application potential of urban air mobility complementing public transport: an upper Bavaria example,” CEAS Aeronautical Journal, Aug. 2020, doi: 10.1007/s13272-020-00468-5.

Vertidrome Layout and Operational Concept

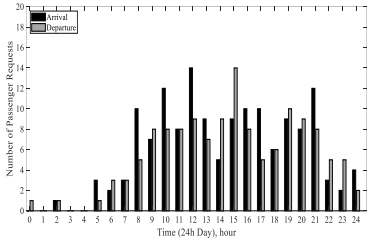
[9] K. Schweiger, F. Knabe, and B. Korn, “UAM Vertidrome Airside Operation: What needs to be considered?,” presented at the Delft International Conference on Urban Air-Mobility (DICUAM), Virtual Conference, Mar. 2021



Animation by T.Dreyzehner, T.Stephani (FL-PAS), 3D Vehicle Model provided by P.Weiand (FT-HUB)

5. „*Vertidrome-in-the-lab*“
Performance Assessment of a Vertidrome‘s Airside Operation

Example: Vertiport @ Munich Trade Fair



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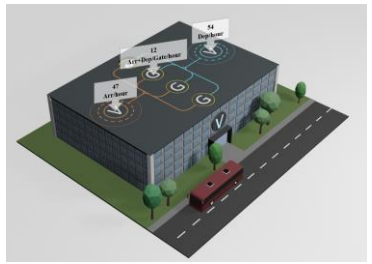

[7] K. Schweiger, F. Knabe, and B. Korn, ‘Urban Air Mobility: Vertidrome Airside Level of Service Concept’, presented at the AIAA AVIATION 2021 FORUM, VIRTUAL EVENT, Aug. 2021. doi: 10.2514/6.2021-3201.

VALoS: Vertiport at Munich Trade Fair - Volatile Demand Distribution

Flow		Occurrence		PAX		VTOL		Vertidrome			Occurrence		PAX		VTOL		Vertidrome	
Processed Operations per 15 Minutes		#		[Min]		[Min]		[%]			#		[Min]		[Min]		[%]	
Setting 4 (4Gates)	1	Arrival	22	22	0	0.5	0	0	100	100	Departure	22	23	0	0.5	0	0	100	100
	2		37	39	0	0.6	1.1	0	100	100		37	36	0	0.6	0	0	100	100
	3		43	44	0.1	0.6	1.1	0	98.4	100		44	46	0.1	0.7	0	0	100	100
	4		29	26	0.1	0.6	2.3	0	99.1	100		22	20	0.1	0.8	0	0	100	100
	5		7	7	0.2	0.7	2.3	0	100	100		8	8	0.3	0.9	0	0	100	100
	6		4	4	0.6	1.1	2.3	0	100	100									
	7		1	1	1.0	1.4	2.3	0	100	100									
Setting 5 (3 Gates)	1	Arrival	21	20	0	0.6	0	0	100	100	Departure	21	22	0	0.5	0	0	100	100
	2		36	38	0.1	0.6	1.1	0	98.6	98.7		37	37	0.1	0.7	0	0	98.6	98.6
	3		45	48	0.3	0.9	1.1	0	94.1	95.1		43	45	0.3	0.8	0	0	96.9	100
	4		30	26	0.4	1.0	2.3	1.4	91.7	95.2		25	22	0.5	1.2	0	0	96.0	97.7
	5		7	7	1.1	1.5	2.3	1.4	80	82.9		7	7	0.8	1.3	0	0	88.6	94.3
	6		3	4	2.4	2.5	2.3	1.4	55.6	66.7									
	7		1		0.4		1.0		100										

[7] K. Schweiger, F. Knabe, and B. Korn, ‘Urban Air Mobility: Vertidrome Airside Level of Service Concept’, presented at the AIAA AVIATION 2021 FORUM, VIRTUAL EVENT, Aug. 2021. doi: 10.2514/6.2021-3201.

6. Summary and Outlook

Summary:

(1) Vertiport State of the Art
(2) Regulatory Framework
(3) Evaluation of a Vertidrome‘s airside capability to process a specific demand forecast

Insights about:

- **Lack of terminologies and regulations** regarding the development of UAM ground infrastructure
- **Complexity** of the **interaction** between different stakeholders and a vertidrome‘s infrastructure components
- **VALoS** = Vertidrome Airside Level of Service Framework
  - Maximum/ critical **flow rates achieved** during an operational day
  - **Utilization** of each infrastructure **component** (Heat map)
  - **Potential bottlenecks**
  - **Capability** of the vertidrome design and its corresponding operational concept

Outlook:

(1) A Vertidrome‘s Airside Level of Service (**VALoS**) under **weather constraints**
(2) Analysis of **Sequencing** and **Scheduling** approaches
(3) **Interface** to other HorizonUAM research groups (UAM network, vehicle design, demand analysis, etc.)

Thank you for your attention!

“The U.S. and Western Europe often view airports as nuisances and environmental threats rather than as critical infrastructure to compete and prosper. This has resulted in their maligning and neglecting airports while Asia and the Middle East invest heavily to leverage them. Such malign neglect comes at the long-term economic peril of the West.” **John D. Kasarda**