

Outline



Motivation for Transformative Vertical Flight (TVF) Roadmap development

TVF Roadmap Development Process

Roadmap Status Update

Summary of Working Group Deliverables

Motivation for TVF Roadmap development



A community of Aerospace professionals ranging from technologist to business entrepreneurs recognized that emerging technologies can transform air transportation by enabling a vision for new aviation systems that:

- Provide greater operational flexibility
- Improve user convenience
- Does not degrade the environment
- Enhance air transportation services

To engage stakeholder support there needs to be a compelling story that articulates how all critical elements necessary to achieve acceptance of a TVF vision will be addressed:

- Operational Concepts
- Technology Challenges
- Business Opportunities
- Regulatory Environment

A TVF Roadmap can be a valuable tool to tell this story

Critical Elements of an Integrated Roadmap



What – How – Who – Why

Integrated Roadmap

Operational Concepts

- Addresses Stakeholders needs
- Identifies market opportunities
- Sets Technology requirements

Missions-

Operational Canagerts

What capability is

Regulatory

and User

Requirements

Who is impacted?

Prioritized Technical Challenges

How do we get there?

Market/Business
Opportunities

Why do it?

Technology

- Enables the Operational Concepts
- Establishes market feasibility
- Promotes Stakeholders confidence

Stakeholders

- Provide Operational Concepts need
- Require technology creditability
- Create the markets

Market

- Satisfy Stakeholders needs
- Judge technology performance
- Justify the Operational Concepts

What is driving TVF?



The envisioned transformation of air transportation is being driven by the convergence of:

- Emerging Technologies
 - Automated/Autonomous Systems
 - Electric Propulsion and airframe integration
 - New types of energy storage systems
- Societal demands
 - Affordable on-demand air mobility
 - Relief from ground and air traffic congestion
- Business opportunities
 - Urban and regional air taxi services
 - Manufacture of new vehicle types and systems
- Possible relaxation to some operational constraints
 - Alternatives/better utilization of existing infrastructure
 - Enhanced air traffic management (ATM) systems/practices

Not an exhaustive list.

TVF Roadmap Development Process



- 1. Engage the Aerospace community to determine interest (TVF Workshop 1)
- 2. Identify the What How Who Why: (TVF Workshop 2)
 - Operational Concepts
 - Technology
 - Business Opportunities
 - Regulatory Frameworks
- 3. Collected suggested activities and timeframes needed to enable new TVF capabilities and systems (TVF Workshop 3)
- 4. Defined a mission oriented TVF Roadmap architecture
- 5. Establish Working Groups (WGs) to vet proposed activities through frequent virtual meetings (Training at TVF Workshop 4)
- 6. Assemble WG products into a Roadmap that is updated and released annually for TVF advocacy (TVF Workshop 5, Jan 18-20, San Francisco) www.vtol.org/aeromechanics

Summary of AHS/AIAA/SAE/NASA Transformative Vertical Flight (TVF) Workshops



Workshop 1: August 2014 – Washington, DC,

- Identified the existence of a multi-disciplined community interested in TVF
- Established a consensus that further collaborations were warranted

Workshop 2: August 2015 – NASA Ames, Moffett Field, CA *

- Assembled a community of interest to advocate for TVF development
- Identified high-level TVF requirements for the What How Who Why
- Initiated TVF Roadmap development

Workshop 3: September 2016, – Hartford, CT **

- Inform participants about developments in transformative flight design configurations, operational concepts, technology, market opportunities, and regulatory environment
- Collected participants' preliminary (un-vetted) inputs for roadmap activities to tell a compelling TVF advocacy story for stakeholder buy-in

Workshop 4: June 2017, - Denver, CO **

- Formed four mission oriented roadmap development Working Groups
- Breakout session to practice WG processes
- * https://nari.arc.nasa.gov/tvf
- ** www.vtol.org/transformative

Roadmap Status Update



Workshop 3 participants identified over a hundred activities needed to realize a transformed air transportation system

The activities have been integrated into a roadmap organized around four core mission elements and thirty topic sub-elements

- Private Recreational Vehicles
- Commercial Intra-city (Short range ~ 5 75 miles)
- Commercial Inter-city (Longer range ~ 50 150 miles)
- Public Services (Medical, fire, disaster, enforcement)

Working Groups (WGs) have been established for each mission element

- Currently 31 WG members (seeking more)
- WG website https://nari.arc.nasa.gov/wghome
- Created WG virtual meeting space https://ac.arc.nasa.gov/tvf

Summary of Working Group Deliverables



Consensus definition/description for Roadmap activities

- Develop concise activity definition title
- Write a paragraph description that identifies dependencies
 - What precursor activities are enablers
 - What depends on the activity's success
- Assess the validity of the expected timing

Reconcile the activity definitions across the WG's

WG leads serve as inter-group liaison

Be prepared report out the WG's progress at the TVF Workshop 5, Jan 18-20, San Francisco, CA

Reasonable progress, not a finished roadmap

Reference materials



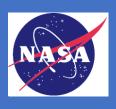
Download a copy of:

- Roadmap Version 5.2
- Mission Element Topic Relevance Matrix Version 1.2.1

https://nari.arc.nasa.gov/tvf-roadmap-matrix

Identify a couple of activities you would like to discuss in the breakout session

Backup Charts



Backup Charts

Roadmap Mission Element - Topic Relevance Matrix Un-vetted Roadmap Charts

Mission Element - Topic Relevance Matrix



Transformative Vertical Flight (TVF) Working Group Mission Elements - Topics/Subtopics Relevance Matrix

	What					Wh	ıy			How																							
				C	OMMI AC		r/MA ANCE									TEC	HNOL	.OGY							RTIFIC EGUL				IN	FRAS	TRUC	TURE	
	Missions Elements		Time Savings Personal	More Affordable	Mission/Business	Energy Savings	Reduced Crew for	Greater Safety and	Security Net Environmental Benefits		VTOL Specific	STOL Specific	Autonomous Systems	High Density Airspace Operations	Energy Efficient	High Specific Energy Storage	Electric Power mgmt. and Distribution	Integrated Flight & Propulsion Control	Aircraft Mgmt. Sys, Nav., Sense & Avoid	Affordable Acquisition	Superior Passenger & Community Safety	Acceptable Noise Levels	Low Emissions	Manufacturing	Training	Mission Operations	Physical & Cyber Security	Urban Vertiport	Suburban Air Park	Airspace Comm., Nav.,	Surveillance systems Electric Utility Distrib. & Availability	Recycle and Recharge	Liability Protections
Private	Short Range Intra-city	Personal Transportation			+																	4											
		Recreational																															
Commercial	Short Range Intra-city	Urban Air-Taxi																															
		Local Package Delivery																															
		Air-Crane Lift Systems																															
	Longer Range Inter-city	Suburban/Regional transit								Г																		Ш					
		Regional Package																															
Public Services	Unique Operational	Search & Rescue		Т																													
	Requirements	Law enforcement																															
		Medivac																															
		Emergency/Humanitarian																										Щ					
		Military																										lL_					
					orrelat																												
			Mod	derat	e Corr	elatio	ın				-																			+	+	+	-
				+		+		+			+	\dashv	\neg																	+	+	+	
				Mi	ssion	Elem	ents									Topi	ics																
								rivat	e Intra-	city						-		TY/MA	RKET /	CCEP	TANCE												
					_				nercial I	•	ity					TECH	NOLO	GY															
				Wo	rking	Group	#3: C	omm	nercial I	nter-c	ity					CERT	IFICAT	ION/ I	REGULA	TION	S												
				Wo	rking	Group	#4: P	ublic	Service	25						INFR	ASTRU	CTURE															

Un-vetted Roadmap – Private Intra-City



Private Intra-City (Short range) Personal Transportation and Recreational

opics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	Time Savings Personal	1. Identify Personal On-			Single passenger OD-VTOL for	Small footprint (4 sq. ft.)	Renting VTOL/CTOL Platforms	Out-of-service vehicle			
	Convenience More affordable	Demand (OD) VTOL concepts			sale	Urban VTOL PAV design		recovery and repair available			
	missions										
	Mission/Business advantage	Vehicle Agnostic Market Study	Rentable Auto Transportable PAV	Shares/Partnerships in Vehicle Ownership Use	Single passenger OD-Elect VTOL for sale	Multi-passenger OD-VTOL for sale	Operational multi-passenger OD-VTOL for sale	Providing loans to buy VTOL/CTOL Vehicles			
	Energy savings										
	Reduced crew for efficient ops.										
		1. industry consensus Part 23	Electric aircraft reliability	Revise Part 27 "Birdstrike" for	Takeoff and landing autonomy	ice protection for DEP w/out			Air commuting remains		
	Greater Safety and Security	safety standards 2. Propose reserve regmts 3. Initial cyber security regmts	safety and redundancy reqmt. 2. Determine jurisdiction authority	more birds at lower altitudes	demonstration in critical conditions	bleed air & min. electrical power			operational incase of natural disasters (earthquake).		
	Net Environmental Benefits	Identify TVF unique environmental regulations	actionty								
			Disc loading vs. ground	Recreational VTOL Vehicle	Integrated VTOL with hybrid	Articulating propulsors for					
chnology	VTOL specific		environment trades	concepts	electric demo	hover to high speeds					
	STOL specific										
		Define Autonomous Systems	Identify autonomous VTOL driving regulatory costs with	Automated takeoff/landing in dense traffic	Pilot optional autonomy systems flying approved paths		System Level Performance verification & validation	Fully automated Control/flight systems Demo			
	Autonomous systems	Health and resource Mgmt systems architectures	FAA	Com & Avionics network interoperability standards	to mature tech & build confidence						
	High Density Airspace Operations			Secure data/comm standards for information sharing	Vehicle to Vehicle data Interlink w/GA, Airlines					Low-cost obstacle avoidance sys, for large # of vehicles	
			1. Ref. architectures (motor,								
	Energy efficient		controller, bus topologies) 2. Solar Electric Standards								
	High Specific Energy storage	Energy storage safety regs/certs; battery, hybr, FC	Energy density targets validate by indust tech	Fuel Cell Based Air Vehicle	400 Wh/kg energy storage specific energy	Structural Batteries feasibility Demo			800 Wh/kg onboard specific energy storage	Structural Batteries for Hybrid VTOL/CTOL Platform Demo	1200 Wh/kg battery specific energy
	Elect. Power mgmt. &		Preliminary integrated component system weights	Low inertia motors over 80 kW; 1/20th of current inertia	Benchmark best SOTA all- electric onboard network	Standardized interchangeable Power Cells.					
	distribution	Pilot/vehicle interface and	(inverters, thermal, etc.) Aero-propulsive flight path	Autopilot integrated for	system EMI optical wavelength	Integrated vehicle	Hover-Transition Dynamics				
	Integrated	handling qualities demo	control demo (autonomy	Simplified vehicle ops. and	division multiplexing	management systems (FCC,	and Control Standards				
	flight/propulsion control		precursor)	loss of control avoidance 2. Affordable Fly-by-wire	technology demo	FADEC, electrical power)					
	Aircraft mgmt. sys, nav,	Flight scenarios test & simulation	Sense and avoid technology demonstration	Health and resource mgmt. sys sensors. & connectivity			Synthetic Vision Systems				
	sense & avoid	Simulation	Light efficient environmental control	develop							
	Affordable acquisition		Private ownership early adopters prizes	Initial hybrid VTOL/CTOL platform development						Operational discrete hybrid VTOL/CTOL platforms	
		Flight path control safety	Crash protection standards,	DEP fireproof and fire						VIOLYCIOE placionns	
	Superior pax & community safety	certification tech 2. Crash mgmt. systems	fire suppress 2. "Pilot's associate"	detection/protection 2. Software certification							
		concepts (Fire detect	standards; full IFR autonomy	rules/process Urban VTOL Noise Standards	Ultra-quiet propellers/rotors		Ultra-low noise VTOL aircraft	Annustins stone Na2			
	Acceptable noise levels			defined	outs-quet properers/rotors		demo	Acoustics stage 14-2			
	Low emissions									Power source carbon footprint sustainability	
ts & Regs	Manufacturing		Electric aircraft HIRF, EMI,			Dependable flight	Electric Propulsion overhaul &	1. Manufact. System Demo	Aftermarket; resale, parts,		
		Identify required new training	EMP standards Low cost fixed & rotary wing	1. Standardize Human	Training Services	components qualification	repair manufacturing services Streamlined pilot training	VTOL/CTOL Maint. Avail. Low Cost fixed & rotary	interiors		
	Training	Methods	electric trainers concepts	Automation Interfaces 2.Low cost training for electric			certification requirements	wing Electric Propulsion Trainer			
	_			sport fixed wing VTOL				2. Streamlined certification			
	Mission Operations	Identify new certification requirements	Avionics comm/network interoperability and new	External lighting standards Emergency energy mgmt.	Personal urban OD-VTOL ops regulations	Autonomous VTOL ops regulations	Highway safety requirements for dual-mode platforms	Certification of intelligent software			
	Physical & Cyber Security		software rules standards DEP information bus to avoid	standards							
	r-nyarcal & Cyber security		EMI; fiber optic WDM, TFCH								
rastructure	Urban Vertiport										
	Suburban air park										
	Airspace Comm, Nav, Surveillance systems			Define comm spectrum distrib/allocation regmts.				Universal transponders equipage			
	Electric utility distrib &			Electric grid and charging infrastructure required for	Sufficient sustainable electricity generation			-			
	availability		Battery lifecycle utilization	infrastructure required for Architecture for Standard	electricity generation	Recycle and disposal of	-	Electric Charging Distribution			
	Recycle/ recharge		Aircraft > Car > Home 2. Rapid recharge systems	Recharge Stations		batteries		and Retail Operations			
			Electric charging standards ODM and UAS Legal Services		Assign algorithm liability	Insurance, Legal, Finance					
			OUM and UAS Legal Services		Assign algorithm liability (autonomy, collision-terrain	Insurance, Legal, Finance Services		1			1

Un-vetted Roadmap – Private Intra-City



Private Intra-City (Short range) Personal Transportation and Recreational

Topics	Subtopics	2017	2018	2019	20		2021	2022	2023	2024	2025	2026		
Acceptance	Time Savings Personal Convenience	Identify Personal On- Demand (OD) VTOL concepts			Single passeng sale	er OD-VTOL for	Small footprint (4 sq. ft.) Urban VTOL PAV design	Renting VTOL/CTOL Platforms	Out-of-service vehicle recovery and repair available					
	More affordable													
	missions Mission/Business	Vehicle Agnostic Market Study	Rentable Auto Transportable	Shares/Partnerships in Vehicle	e Single passeng	er OD-Elect	Multi-passenger OD-VTOL for	Operational multi-passenger	Providing loans to buy					
	advantage		PAV	Ownership Use	VTOL for sale		sale	OD-VTOL for sale	VTOL/CTOL Vehicles					
	Energy savings													
	Reduced crew for efficient ons.													
		Industry consensus Part 23 safety standards	Electric aircraft reliability safety and redundancy regnt.	Revise Part 27 "Birdstrike" for more birds at lower altitudes	Takeoff and lar demonstration		Ice protection for DEP w/out bleed air & min. electrical			Air commuting remains				
	Greater Safety and Security	2. Propose reserve regmts	2. Determine jurisdiction	. more birds at lower altitudes	conditions	in critical	power			operational incase of natural disasters (earthquake).				
	Net Environmental	 Initial cyber security reqmts Identify TVF unique 	authority		-									
	Benefits	environmental regulations												
Technology	VTOL specific		Disc loading vs. ground environment trades	Recreational VTOL Vehicle concepts	Integrated VTC electric demo	L with hybrid	Articulating propulsors for hover to high speeds							
			environment trades	concepts	electric demo		nover to nigh speeds							
	STOL specific	Define Autonomous	Identify autonomous VTOL		Pilot antional			System Level Performance	Fully automated Control/flight					
	utonomous systems	Systems 2. Health and resource Mgmt	driving regulatory costs with	in dense traffic 2. Com & Avionics network	systems flying	proved paths		verification & validation	systems Demo					
	atonomous systems	Health and resource Mgmt systems architectures	FAA	 Com & Avionics network interoperability standards 	to mature tech confidence	build								
	igh Density Airspace			Secure data/comm standards	Vehicle to Veh	e data irlines	Autonome	ous systems	Systems			atory costs with	in dense traffic	systems flyin
	perations		1. Ref. architectures (motor,	ior mornison signing	internit wy Co	ii iiii Ci	Autonomic	ous systems		resource Mgmt	FAA		2. Com & Avionics network	to mature tee
	nergy efficient		controller, bus topologies) 2. Solar Electric Standards						systems archit	tectures			interoperability standards	confidence
	ligh Specific Energy	Energy storage safety regs/certs; battery, hybr, FC	Energy density targets validate by indust tech	Fuel Cell Based Air Vehicle	400 Wh/kg end specific energy	y storage	High Done	ity Airspace	_				Secure data/comm standards	Vehicle to Ve
	torage	regs/certs; battery, nybr, FC	Preliminary integrated	Low inertia motors over 80	Benchmark be	SOTA all-			l				for information sharing	Interlink w/G
	lect. Power mgmt. & istribution		component system weights (inverters, thermal, etc.)	kW; 1/20th of current inertia	electric onboar system	network	Operation	S					for information sharing	interlink w/G
		Pilot/vehicle interface and	Aero-propulsive flight path	1. Autopilot integrated for	EMI optical wa	length					1. Ref. archit	ectures (motor,		
	ntegrated ight/propulsion control	handling qualities demo	control demo (autonomy precursor)	Simplified vehicle ops. and loss of control avoidance	division multip technology der	ting	Energy eff	icient	l		controller, be	us topologies)		
		Flight scenarios test &	Sense and avoid technology	Affordable Fly-by-wire Health and resource mgmt.			Life gy en	referre	l		2. Solar Elect	ric Standards		
	ircraft mgmt. sys, nav,	simulation	demonstration	sys sensors, & connectivity										
	ense & avoid		Light efficient environmental control	develop			High Spec	ific Energy	Energy storage safety		Energy densi	ty targets	Fuel Cell Based Air Vehicle	400 Wh/kg e
	ffordable acquisition		Private ownership early adopters prizes	Initial hybrid VTOL/CTOL platform development			storage		regs/certs; ba	ttery, hybr, FC	validate by ir	dust tech		specific energ
		Flight path control safety certification tech	Crash protection standards, fire suppress	DEP fireproof and fire detection/protection							Preliminary i	ntegrated	Low inertia motors over 80	Benchmark b
	uperior pax & ommunity safety	2. Crash mgmt. systems	2. "Pilot's associate"	2. Software certification			Elect. Pow	er mgmt. &	l				kW; 1/20th of current inertia	electric onbo
		concepts (Fire detect	standards; full IFR autonomy	rules/process	HISTORIAN STATE	mallers/rotors	distributio	in .	l			ystem weights	kw; 1/20th of current mertia	
	Acceptable noise levels			defined	Oitra-quiet pro	pellersyrotors	distributio				(inverters, th	ermal, etc.)		system
	Low emissions								Pilot/vehicle is	nterface and	Aero-propuls	ive flight path	1. Autopilot integrated for	EMI optical w
Certs & Regs			Electric aircraft HIRF, EMI,				Integrated	ı	handling quali	ities demo	control demo	(autonomy	Simplified vehicle ops. and	division multi
-2.10 w mg3	Manufacturing		EMP standards					oulsion control			precursor)		loss of control avoidance	technology d
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts	Standardize Human Automation Interfaces	Training Service	es	night/pro	pulsion control			,,		2. Affordable Fly-by-wire	
	Training			Low cost training for electric sport fixed wing VTOL									2. Alloradole 117 by Wile	
	Mission Operations	Identify new certification	Avionics comm/network interoperability and new	External lighting standards Emergency energy mgmt.	Personal urban	OD-VTOL ops			Flight scenario	os test &	1. Sense and	avoid technology	Health and resource mgmt.	
	mission Operations	requirements	software rules standards	 Emergency energy mgmt. standards 	regulations		Aircraft m	gmt. sys, nav,	simulation		demonstration	on	sys sensors, & connectivity	
	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optic WDM, TFCH				sense & av		I		2. Light effici	ent	develop	
Infrastructure							Schise de di	·oiu	l		environment			
astructure	Urban Vertiport												Little Land Land Land	
	Suburban air park						Affordable	acquisition	I		Private own		Initial hybrid VTOL/CTOL	
	Airspace Comm, Nav,			Define comm spectrum distrib/allocation regests			Allordable	. ocquisition	l		adopters priz	res	platform development	
	Surveillance systems Electric utility distrib &		 	Electric grid and charging	Sufficient susta	sinable			1. Flight path	control safety	1. Crash prot	ection standards,	1. DEP fireproof and fire	
	availability		Battery lifecycle utilization	infrastructure required for Architecture for Standard	electricity gene	eration			certification to	,	fire suppress		detection/protection	
	Recycle/ recharge		Aircraft > Car > Home	Architecture for Standard Recharge Stations			Superior p		Crash mgm		2. "Pilot's ass		Software certification	
	,		Rapid recharge systems Electric charging standards		`		communit	y safety						
	Liability Protections		ODM and UAS Legal Services		Assign algorith	m liability			concepts (Fire	detect	standards; fu	II IFR autonomy	rules/process	
	County Protections				avoidance, etc.	.)								

Un-vetted Roadmap – Commercial Intra-City



Commercial Intra-City (Short range) Urban Air-Taxi, Local Package Delivery, Heavy Lift Systems

opics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Acceptance	Time Savings Personal	Document personal, municipal, urban TVF	American Disabilities Act exemption justifications		Autonomous urban air-taxi concepts	Recreation/Entertain (Airborne Party Limo)	Air uber community acceptance	Routine VTOL Service	Elevator to Altitude in Congested Areas		
	Convenience More affordable	Short and very short haul	Secure muni- and business		Large Corporate Campus to	Surveillance (Oil, Agri., news,	Operational multi-passenger		Congested Areas		
	missions Mission/Business	concept definitions Multi-mode Metro air-taxi	operator commitments Rentable Auto Transportable		Campus concept 1. Package Delivery	fire, police, etc.) Metro air-taxi launched	OD-VTOL for sale		Operation without ground	Autonomous Multi-mode	
	advantage	business plan launched	PAV		2. Air Limo recreation service	metro an -tax resirence			infrastructure	Uber type air-ground	
	Energy savings										
	Reduced crew for efficient ops.		Airport Shuttle concept			EV Integrated Autonomy to minimize pilot skill, work load					
		1. industry consensus Part 23	Electric aircraft reliability	Revise Part 27 "Birdstrike" for	Takeoff and landing autonomy	Ice protection for DEP w/out			Air commuting remains		
	Greater Safety and Security	safety standards 2. Propose reserve regmts	safety and redundancy reqmt. 2. Determine jurisdiction	more birds at lower altitudes	demonstration in critical conditions	bleed air & min. electrical power			operational incase of natural disasters (earthquake).		
	Net Environmental	3. Initial cyber security reqmts Identify TVF unique	authority								
	Benefits	environmental regulations									
echnology	VTOL specific		Disc loading vs. ground environment trades Manned VTOL urban air- tasi concents	Helipad Consensus Standard Dual mode platforms	Low density VTOL ATM using sUAS for demo (1 heliport/sq. mile, 10 min sequencing)	Articulating propulsors for hover to high speeds			High density NAS integrated VTOL ATM automation demo (>10 heliports/sq mi, 1 min sequencing)		
	STOL specific		tali concepts						sequencing		
	310c specific	Define Autonomous	Identify autonomous VTOL	Automated takeoff/landing	Demonstrate autonomous air-	- Automation/Machine	System Level Performance	Fully automated Control/flight			
	Autonomous systems	Systems 2. Health and resource Mgmt systems architectures	driving regulatory costs with FAA	in dense traffic 2. Com & Avionics network interoperability standards	taxi	Learning for ATC workload reduction	verification & validation	systems Demo			
	High Density Airspace Operations		Data rights/mgmt. controls (connectivity, collection, assurance, sharing, security)	Secure data/comm standards for information sharing	Vehicle to Vehicle data Interlink (w/GA, Airlines, Drones).	Define factors that determine ATM services system prioritie				Low-cost obstacle avoidance sys. for large # of vehicles	
	Energy efficient		Ref. architectures (motor, controller, bus topologies)								
	High Specific Energy	Energy storage safety regs/certs; battery, hybr, FC	Solar Electric Standards Energy density targets validate by indust tech	Fuel Cell Based Air Vehicle	400 Wh/kg energy storage specific energy	Structural Batteries feasibility			800 Wh/kg onboard specific	Structural Batteries for Hybrid VTOL/CTOL Platform Demo	1200 Wh/kg battery speci energy
	storage	regs/certs; battery, hybr, FC One engine inoperative	evolution Preliminary integrated	Low inertia motors over 80	Benchmark best SOTA all-	Standardized Interchangeable			energy storage	VTOL/CTOL Platform Demo	energy
	Elect. Power mgmt. & distribution	electric power back up	component system weights (inverters, thermal, etc.)	kW; 1/20th of current inertia	electric onboard network system	Power Cells.					
	Integrated flight/propulsion control	Pilot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy precursor)	Autopilot integrated for Simplified vehicle ops. and loss of control avoidance Affordable Fly-by-wire	EMI optical wavelength division multiplexing technology demo	Integrated vehicle management systems (FCC, FADEC, electrical power)	Hover-Transition Dynamics and Control Standards				
	Aircraft mgmt. sys, nav, sense & avoid	Flight scenarios test & simulation	Sense and avoid technology demonstration Light efficient environmental control	Health and resource mgmt. sys sensors, & connectivity develop			Synthetic Vision Systems				
	Affordable acquisition			Initial hybrid VTOL/CTOL platform development						Operational discrete hybrid VTOL/CTOL platforms	
	Superior pax & community safety	Flight path control safety certification tech Crash mgmt. systems concepts (Fire detect)	Crash protection standards, fire suppress "Pilot's associate" standards; full IFR autonomy	DEP fireproof and fire detection/protection Software certification rules/process		Define passenger briefing rules/security					
	Acceptable noise levels	- Concepts (in a detect	January, Inc. of Controlly	Urban VTOL Noise Standards defined	Ultra-quiet propellers/rotors		Ultra-low noise VTOL aircraft demo	Acoustics stage N+2			
	Low emissions			ou med			dello			Power supply carbon footprint/sustainability	
ts & Regs	Manufacturing		Electric aircraft HIRF, EMI, EMP standards	Industrial repair parts delivery	Regulation 23 & 27 Combined	Dependable flight components qualification	Electric Propulsion overhaul & repair manufacturing services	2. VTOL/CTOL Maint. Avail.			
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts	Standardize Human Automation Interfaces	Training Services			Low Cost fixed & rotary wing Electric Propulsion			
				Low cost training for electric fixed wing VTOL taxi			1	Trainer 2. Streamlined certification			
	Mission Operations	Identify new certification requirements	Avionics comm/network interoperability and new	External lighting standards Emergency energy mgmt.	Combine rotorcraft and fixed wing license for new VTOL	Autonomous VTOL ops regulations		Certification of intelligent software			
	Physical & Cyber Security		software rules standards DEP information bus to avoid	standards	concepts						
			EMI; fiber optic WDM, TFCH								
rastructure	Urban Vertiport				Vertiport Ground Station Standards	Vertiport basing technology demo (maint., ops. & repair)	Infrastructure funding for Vertiport metro air vehicles				
	Suburban air park				Air Park Ground Station Standards	Air Park basing technology demo (maint., ops. & repair)	Infrastructure funding for Air Park metro air vehicles				
	Airspace Comm, Nav, Surveillance systems			Define comm spectrum distrib/allocation regmts.		priestey ope. or repair)	Traffic density based dynamic datalink: low ADS-B, high Wi-	Universal transponders equipage			
	Electric utility distrib &			Electric grid and charging infrastructure required for	Sufficient sustainable electricity generation						
	availability		Battery lifecycle utilization	Architecture for Standard	and Section 1	Recycle and disposal of	Energy replenishment	Electric Charging Distribution			
	Recycle/ recharge		Aircraft > Car > Home 2. Rapid recharge systems 3. Electric charging standards	Recharge Stations		batteries	Infrastructure solution (recharge, batt. swap, other)	and Retail Operations			
	Liability Protections		ODM and UAS Legal Services		Assign algorithm liability (autonomy, collision-terrain	Insurance, Legal, Finance Services					

Un-vetted Roadmap – Commercial Inter-City



Commercial Inter-City (Longer range) Suburban/Regional transit, Regional Package Distribution

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	Time Savings Personal	2017	American Disabilities Act	2015	2020	2021	Multi-passenger OD-VTOL for	Mega regional air-commuter	Enable Real Estate Dev. by	2023	2020
Acceptance	Convenience		exemption justifications				sale	transportation system in place	Increased Urban Sprawl		
	More affordable missions	Alternatives configs to distributed elect. Propulsion	Secure muni- and business operator commitments		Large Corporate Campus to Campus concept	On Demand Air Ferry, no bridge river crossing/island hop	Operational multi-passenger OD-VTOL for sale				
		Electric VTOL for business	Regional parcel delivery	Mega region air-commuter	Package Delivery	Regional OD air-transport	Regional VTOL freight				Electric Hybrid 737 class
	Mission/Business advantage	Incubator development model	feeders (Cessna Caravan	business plan	2. Mega Cities Air-Metro	networks concepts	transport network				transport
	-		comparable cargo)								
	Energy savings										
	Reduced crew for					EV Integrated Autonomy to minimize pilot skill, work load					
	efficient ops.	1. industry consensus Part 23	Electric aircraft reliability	Revise Part 27 "Birdstrike" for	Takeoff and landing autonomy	Ice protection for DEP w/out			Air commuting remains		
	Greater Safety and	safety standards	safety and redundancy regmt.	more birds at lower altitudes	demonstration in critical	bleed air & min. electrical			operational incase of natural		
	Security	Propose reserve regmts Initial cyber security regmts	Determine jurisdiction authority		conditions	power			disasters (earthquake).		
	Net Environmental	Identify TVE unique	ostnorty								
	Benefits	environmental regulations									
			Disc loading vs. ground	Helipad Consensus Standard		Articulating propulsors for		VTOL Regional Transport			
Technology	VTOL specific		environment trades	Dual mode platforms		hover to high speeds		VIOL Regional Transport			
	STOL specific										
	STOL specific										
		Define Autonomous Systems Health and resource Mgmt	Identify autonomous VTOL driving regulatory costs with	Automated takeoff/landing in dense traffic		Automation/Machine Learning for ATC workload reduction	System Level Performance verification & validation	Fully automated Control/flight systems Demo			
	Autonomous systems	systems architectures	FAA	2. Com & Avionics network				,			
		3. ~ zero-zero recovery demo		interoperability standards							
	High Density Airspace	Civilian/Military airspace integration	Data rights/mgmt. controls (connectivity, collection,	Secure data/comm standards for information sharing	Vehicle to Vehicle data Interlink (w/GA, Airlines,	Define factors that determine ATM services system priorities				Low-cost obstacle avoidance sys. for large # of vehicles	
	Operations		assurance, sharing, security)		Drones).						
	Farm officient	Prop/Fan and Wing Aero Integration	Ref. architectures (motor, controller, bus topologies)		Light transport energy and propulsion systems						
	Energy efficient	integration	Solar Electric Standards		propulsion systems						
	High Specific Energy	Energy storage safety	Energy density targets validate	Fuel Cell Based Air Vehicle	400 Wh/kg energy storage	Structural Batteries feasibility			800 Wh/kg onboard specific	Structural Batteries for Hybrid VTOL/CTOL Platform Demo	
	storage	regs/certs; battery, hybr, FC	by indust tech evolution		specific energy	Demo			energy storage	VTOL/CTOL Platform Demo	energy
	Elect. Power mgmt. &		Preliminary integrated component system weights	Low inertia motors over 80 kW; 1/20th of current inertia	Benchmark best SOTA all- electric onboard network	Standardized interchangeable Power Cells.					
	distribution		(inverters, thermal, etc.)		system						
	Integrated	Pilot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy	Autopilot integrated for Simplified vehicle ops. and loss	EMI optical wavelength division multiplexing	Integrated vehicle management systems (FCC,	Hover-Transition Dynamics and Control Standards				
	flight/propulsion control		precursor)	of control avoidance	technology demo	FADEC, electrical power)					
		Flight scenarios test &	Sense and avoid technology	Affordable Fly-by-wire Health and resource mgmt. sys		2. 5-MW electric motor	Synthetic Vision Systems				
	Aircraft mgmt. sys, nav,	simulation	demonstration	sensors, & connectivity			Synthetic Vision Systems				
	sense & avoid		Light efficient environmental control systems	develop							
			40 mile, 9 passenger	Initial hybrid VTOL/CTOL						Operational discrete hybrid	
	Affordable acquisition		transport, Intelligent Sys hardware prize	platform development						VTOL/CTOL platforms	
		Flight path control safety	Crash protection standards.	DEP fireproof and fire		D. Francisco Control Control					
	Superior pax &	certification tech	fire suppress	detection/protection		Define passenger briefing rules/security					
	community safety	Crash mgmt. systems concepts (Fire detect suppress)	"Pilot's associate" standards; full IFR autonomy precursor	Software certification rules/process							
		Define equivalent noise routes,	Total Initiautonomy precursor	Urban VTOL Noise Standards			Ultra-low noise VTOL aircraft	Acoustics stage N+2			
	Acceptable noise levels	railway/highway		defined	Ultra-quiet propellers/rotors		demo	Acoustics stage N+2			
										Power supply carbon	
	Low emissions									footprint/sustainability	
erts & Regs			Electric aircraft HIRF, EMI, EMP	Industrial repair parts delivery	Regulation 23 & 27 Combined	Dependable flight components	Electric Propulsion overhaul &	Manufact, System Demo			
	Manufacturing		standards			qualification testing	repair manufacturing services	2. VTOL/CTOL Maint. Avail.			
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts		Training Services			Low Cost fixed & rotary wing Electric Propulsion Trainer			
		Methods Identify new certification	electric trainers concepts Avionics comm/network	External lighting standards	Combine rotorcraft and fixed	Additions (modification: 1- CCC	Additions/modifications to CFR	Electric Propulsion Trainer Certification of intelligent			
	Mission Operations	requirements	interoperability and new	Emergency energy mgmt.	wing license for new VTOL	part 33 - navigation special	part 33 - navigation rule re-	software			
			software rules standards	standards	concepts	conditions	write				
	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optic WDM, TFCH								
Infrastructure	Urban Vertiport				Vertiport Ground Station Standards	Vertiport basing technology demo (maint., ops. & regair)	Infrastructure funding for				
					Air Park Ground Station		Vertiport metro air vehicles Infrastructure funding for Air				
	Suburban air park				Standards	Air Park basing technology demo (maint., ops. & repair)	Park metro air vehicles				
	Airspace Comm, Nav,		All aircraft WX data gathering	Define comm spectrum	Long endurance for remote	Juneary oper according	Traffic density based dynamic	Universal transponders			
	Surveillance systems		(ATM prediction model	distrib/allocation regmts.	high bandwidth comm (Solar?)		datalink: low ADS-B, high Wi-Fi	equipage			
	Electric utility distrib & availability			Electric grid and charging infrastructure required for EV's	Sufficient sustainable electricity generation						
	ovanionity .		Battery lifecycle utilization	Architecture for Standard		Recycle and disposal of	Energy replenishment	Electric Charging Distribution		 	
	Recycle/ recharge		Aircraft > Car > Home	Recharge Stations		batteries	Infrastructure solution	and Retail Operations			
	necycle/ recharge		Rapid recharge systems Electric charging standards				(recharge, batt. swap, other)				
			ODM and UAS Legal Services		Assign algorithm liability	Insurance, Legal, Finance					
	Liability Protections				(autonomy, collision-terrain	Services					
					avoidance, etc.)					1	

Un-vetted Roadmap – Public Services



Public Services

Search Rescue, Law enforcement, Medevac, Emergency/Humanitarian, Military

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
ceptance	Time Savings Personal	2027	2020	2025	2020		2022	2020	2021	2020	2020
ceptance	Convenience										
	More affordable	Identify TVF enabled Science/Sensor Packs multi-	Rapid Emergency and Medical supply delivery	Demo for agriculture and wildlife management	Security Surveillance Services (cloud cameras)						
	missions	function payloads									
	Mission/Business	Sensor data collection services (management, availability,	FMEA, redundancy mgmt., safety process	Identify missions Ops. for Security, DHS-INS/Border	Search & Rescue Demo	Flying Soldier QuadDARPA- ARL Controls/Autonomy	TVF enabled data acquired available for sale				
	advantage	safety, logistics)	sarety process	Patrol, Military		ARL Controls/Autonomy	available for sale				
	Energy savings										
	Reduced crew for efficient ops.	Identify TVF EMS OPS for Fast/Efficient Remote VTOL									
	emcient ops.	1. industry consensus Part 23	Electric aircraft reliability		Takeoff and landing autonomy	First responder disaster relief		Emergency positioned			
	Greater Safety and	safety standards 2. Propose reserve regmts	safety and redundancy reqmt. 2. Determine jurisdiction		demonstration in critical conditions			Escape/Medevac			
	Security	Propose reserve regmts Initial cyber security regmts	2. Determine jurisdiction authority		conditions						
	Net Environmental		-								
	Benefits										
Technology	VTOL specific										
	STOL specific										
	310E specific										
		Define Autonomous Systems Health and resource Mgmt		Semi-automated public safety response, security, fire, rescue,	Flying Soldier PAV Controls/Autonomy concepts						
	Autonomous systems	systems architectures		disaster recovery							
		3. ~ zero-zero recovery demo									
	High Density Airspace										
	Operations										
	Energy efficient		Ref. architectures (motor, controller, bus topologies)								
	High Specific Energy		Energy density targets validate								
	storage		by indust tech evolution								
	Elect. Power mgmt. &		Preliminary integrated								
	distribution	Pilot/vehicle interface and	component system weights	Autopilot integrated for							
	Integrated	handling qualities demo		Simplified vehicle ops. and loss							
	flight/propulsion control			of control avoidance							
		Flight scenarios test &	Sense and avoid technology	Affordable Fly-by-wire Health and resource mgmt. sys			Synthetic Vision Systems				
	Aircraft mgmt. sys, nav,	simulation	demonstration	sensors, & connectivity			Synthetic vision systems				
	sense & avoid		Light efficient environmental control systems	develop							
			control systems	Initial hybrid VTOL/CTOL							
	Affordable acquisition			platform development							
		1. Flight path control safety	Crash protection standards,	DEP fireproof and fire							
	Superior pax &	certification tech 2. Crash mgmt. systems	fire suppress	detection/protection							
	community safety	concepts (Fire detect suppress)									
	Acceptable noise levels										
	Low emissions										
rts & Regs	Manufacturing		Electric aircraft HIRF, EMI, EMP								
	Menorectoring		standards								
	Training	Identify required new training Methods									
		Identify new certification		External lighting standards							
	Mission Operations	requirements									
	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optic WDM, TFCH	Identify TVF enabled security, law enforce, military threats							
			EMI, HOEF OPEIC WUM, THCH	naw enforce, military threats			-				
rastructure	Urban Vertiport										
	Orbari veraport										
	Suburban air park										
	Airspace Comm, Nav,		All aircraft WX data gathering.				Internet/comm platforms to				
	Surveillance systems		ATM prediction models				replace/augment towers		1		
	Electric utility distrib &										
	availability										
			Battery lifecycle utilization Aircraft > Car > Home								
	Recycle/ recharge		2. Rapid recharge systems						1		
			3. Electric charging standards						1		
	Liability Protections										
			1	1	I	1	1	1	1	1	1