

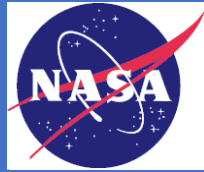
An aerial illustration of a city, likely New York City, showing a mix of urban development and vertical flight infrastructure. The image features several helipads marked with a yellow 'V' and a red helicopter, and several vertical takeoff and landing (VTOL) runways marked with a yellow 'V'. A large, modern building with a green roof and circular patterns is prominent in the center. The background shows a city skyline with tall buildings and a body of water. The overall theme is the integration of vertical flight into urban environments.

TRANSFORMATIONAL VERTICAL FLIGHT ROADMAP DEVELOPMENT WORKING GROUPS OBJECTIVES AND EXPECTATIONS

SEPTEMBER 25, 2017

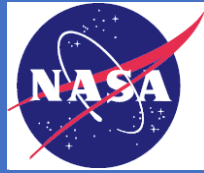
Michael Dudley
Director, NASA Aeronautics Research Institute





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:

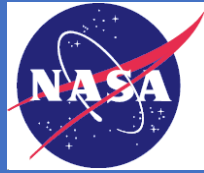
- **Provide greater operational flexibility**
- **Improve user convenience**
- **Does not degrade the environment**
- **Enhance air transportation services**

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:

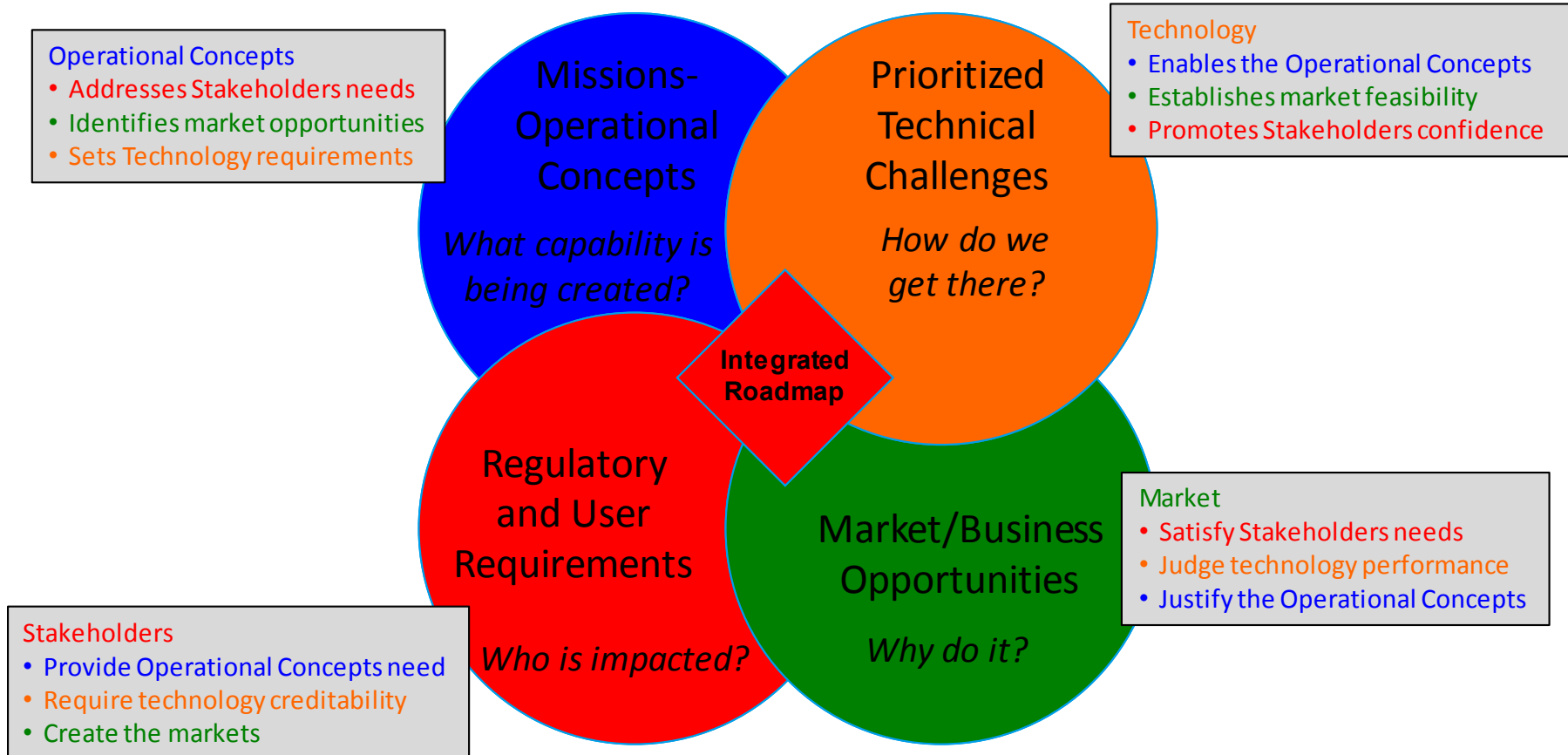
- **Operational Concepts**
- **Technology Challenges**
- **Business Opportunities**
- **Regulatory Environment**

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

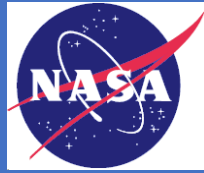
Critical Elements of an Integrated Roadmap



What – How – Who – Why



What is driving TVF?

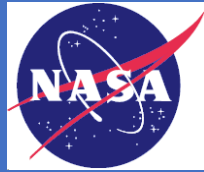


The envisioned transformation of air transportation is being driven by the convergence of:

- **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

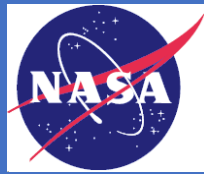
Not an exhaustive list.

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 **

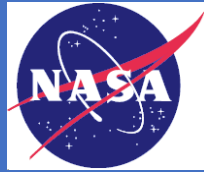
- Inform participants about developments in transformative flight design configurations, operational concepts, technology, market opportunities, and regulatory environment
- Collected participants' preliminary (un-vetted) inputs for roadmap activities to tell a compelling TVF advocacy story for stakeholder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



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

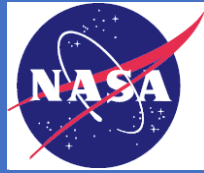
The activities have been integrated into a roadmap organized around four core mission elements and thirty topic sub-elements

- **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**



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

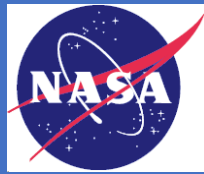


Backup Charts

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			Why							How																						
			COMMUNITY/MARKET ACCEPTANCE							TECHNOLOGY										CERTIFICATION/ REGULATIONS				INFRASTRUCTURE								
Missions Elements			Time Savings Personal Convenience	More Affordable Missions	Mission/Business Advantage	Energy Savings	Reduced Crew for Efficient Operations	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																														
		Recreational																														
Commercial	Short Range Intra-city	Urban Air-Taxi																														
		Local Package Delivery																														
		Air-Crane Lift Systems																														
	Longer Range Inter-city	Suburban/Regional transit																														
Regional Package																																
Public Services	Unique Operational Requirements	Search & Rescue																														
		Law enforcement																														
		Medivac																														
		Emergency/Humanitarian																														
		Military																														

Strong Correlation

Moderate Correlation

Mission Elements

Working Group #1: Private Intra-city

Working Group #2: Commercial Intra-city

Working Group #3: Commercial Inter-city

Working Group #4: Public Services

Topics

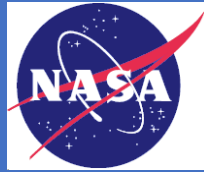
COMMUNITY/MARKET ACCEPTANCE

TECHNOLOGY

CERTIFICATION/ REGULATIONS

INFRASTRUCTURE

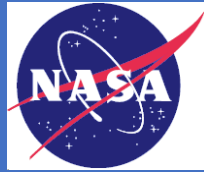
Un-vetted Roadmap – Private Intra-City



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

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Acceptance	Time Savings Personal Convenience	1. Identify Personal On-Demand (OD) VTOL concepts			Single passenger OD-VTOL for sale	Small footprint (4 sq. ft.) urban VTOL PAV design	Resting VTOL/CTOL Platforms	Out-of-service vehicle recovery and repair available			
	More affordable missions										
	Mission/Business advantage	Vehicle Agnostic Market Study	Rentable Auto Transportable PAV	Share/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.										
Greater Safety and Security		1. Industry consensus Part 23 safety standards 2. Propose reserve reqmts 3. Initial cyber security reqmts	1. Electric aircraft reliability safety and redundancy reqmts 2. Determine jurisdiction authority	Revise Part 27 "Birdstrike" for more birds at lower altitudes	Takeoff and landing autonomy demonstration in critical conditions	Ice protection for DEP w/out bleed air & min. electrical power			Air commuting remains operational in case of natural disasters (earthquake).		
	Net Environmental Benefits	Identify TVE unique environmental regulations									
Technology	VTOL specific		Disc loading vs. ground environment trades	Recreational VTOL Vehicle concepts	Integrated VTOL with hybrid electric demo	Articulating propellers for hover to high speeds					
	STOL specific										
	Autonomous systems	1. Define Autonomous Systems 2. Health and resource Mgmt systems architectures	Identify autonomous VTOL driving regulatory costs with FAA	1. Automated takeoff/landing in dense traffic 2. Com & Avionics network interoperability standards	Pilot optional autonomy systems flying approved paths to mature tech & build confidence		System Level Performance verification & validation	Fully automated Control/flight systems Demo			
	High Density Airspace Operations			Secure data/comm standards for information sharing	Vehicle to Vehicle data interlink w/GSA, Airlines				Low-cost obstacle avoidance sys. for large # of vehicles		
	Energy efficient		1. Ref. architectures (motor-controller, bus topologies) 2. Solar Electric Standards								
	High Specific Energy storage	Energy storage safety reqts/battery, hybrid, FC	Energy density targets validated by indirect 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. & distribution		Preliminary integrated component system weights (inverters, thermal, etc.)	Low inertia motors over 80 kW; 1/20th of current inertia	Benchmark best SOTA all-electric onboard network system	Standardized interchangeable Power Cells.					
	Integrated flight/propulsion control	Pilot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy precursor)	1. Autopilot integrated for simplified vehicle ops. and loss of control avoidance 2. 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	1. Sense and avoid technology demonstration 2. Light efficient environmental control	Health and resource mgmt, sys sensors, & connectivity develop			Synthetic Vision Systems				
	Affordable acquisition		Private ownership early adopters prizes	Initial hybrid VTOL/CTOL platform development					Operational discrete hybrid VTOL/CTOL platforms		
	Superior pass & community safety	1. Flight path control safety certification tech 2. Crash mgmt. systems concepts; full IFR autonomy research	1. Crash protection standards, fire suppress 2. "Pilot's associate" concepts; full IFR autonomy research	1. DEP fireproof and fire detection/protection 2. Software certification rules/process							
	Acceptable noise levels			Urban VTOL Noise Standards defined	Ultra-quiet propellers/rotors		Ultra-low noise VTOL aircraft demo	Acoustics stage N-2			
	Low emissions									Power source carbon footprint sustainability	
Certs & Regs	Manufacturing		Electric aircraft HIRF, EMI, EMP standards			Dependable flight components qualification	Electric Propulsion overhaul & repair manufacturing services	1. Manufact. System Demo 2. VTOL/CTOL Maint. Avail.	Aftermarket; resale, parts, interiors		
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts	1. Standardize Human Automation Interfaces 2. Low cost training for electric sport fixed wing VTOL	Training Services		Streamlined pilot training certification requirements	1. Low Cost fixed & rotary wing Electric Propulsion Trainer 2. Streamlined certification			
	Mission Operations	Identify new certification requirements	Avionics comm/network interoperability and new software rules standards	1. External lighting standards 2. Emergency energy mgmt. standards	Personal urban OD-VTOL ops regulations	Autonomous VTOL ops regulations	Highway safety requirements for dual-mode platforms	Certification of intelligent software			
	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optic WDM, TFCI								
Infrastructure	Urban Vertiport										
	Suburban air park										
	Airspace Comm, Nav, Surveillance systems			Define comm spectrum distrib/allocation reqmts.				Universal transponders equipage			
	Electric utility distrib & availability			Electric grid and charging infrastructure required for	Sufficient sustainable electricity generation						
	Recycle/ recharge		1. Battery lifecycle utilization Aircraft's Car > Home 2. Rapid recharge systems 3. Electric charging standards	Architecture for Standard Recharge Stations		Recycle and disposal of batteries		Electric Charging Distribution and Retail Operations			
Liability Protections			ODM and UAS Legal Services		Assign algorithm liability (autonomy, collision-terrain avoidance, etc.)	Insurance, Legal, Finance Services					

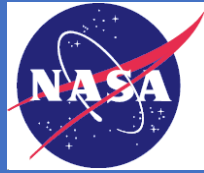
Un-vetted Roadmap – Private Intra-City



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

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Acceptance	Time Savings Personal Convenience	1. Identify Personal On-Demand (OD) VTOL concepts			Single passenger OD-VTOL for sale	Small footprint (4 sq. ft.) urban VTOL PAV design	Resting VTOL/CTOL Platforms	Out-of-service vehicle recovery and repair available			
	More affordable missions										
	Mission/Business advantage	Vehicle Agnostic Market Study	Rentable Auto Transportable PAV	Share/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.										
Greater Safety and Security		1. Industry consensus Part 23 safety standards	1. Electric aircraft reliability safety and redundancy reqmts	Revise Part 27 "Birdstrike" for more birds at lower altitudes	Takeoff and landing autonomy demonstration in critical conditions	Ice protection for DEP w/out bleed air & min. electrical power			Air commuting remains operational incase of natural disasters (earthquake).		
	Net Environmental Benefits	Identify TVE unique environmental regulations									
Technology	VTOL specific		Disc loading vs. ground environment trades	Recreational VTOL Vehicle concepts	Integrated VTOL with hybrid electric demo	Articulating propellers for hover to high speeds					
	STOL specific										
Autonomous systems	1. Define Autonomous Systems	Identify autonomous VTOL driving regulatory costs with FAA	1. Automated takeoff/landing in dense traffic	2. Com & Avionics network interoperability standards	Pilot optional systems flying to mature tech confidence	Approved pilots build					
	2. Health and resource Mgmt systems architectures										
	High Density Airspace Operations			Secure data/comm standards for information sharing	Vehicle to Vehicle Interlink w/G						
	Energy efficient		1. Ref. architectures (motor, 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 specific energy						
	Elect. Power mgmt. & distribution	Preliminary integrated component system weights (inverters, thermal, etc.)		Low inertia motors over 80 kW; 1/20th of current inertia	Benchmark b electric onboard system						
	Integrated flight/propulsion control	Pilot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy precursor)	1. Autopilot integrated for Simplified vehicle ops. and loss of control avoidance	2. Affordable Fly-by-wire	EMI optical w division multi-technology de					
	Aircraft mgmt. sys, nav, sense & avoid	Flight scenarios test & simulation	1. Sense and avoid technology demonstration	2. Light efficient environmental control							
	Affordable acquisition		Private ownership early adopters prizes	Initial hybrid VTOL/CTOL platform development							
	Superior pax & community safety	1. Flight path control safety certification tech	2. Crash mgmt. systems concepts (Fire detect								
Certs & Regs	Accordable noise levels			Urban VTOL Noise standards defined	Ultra-quiet propellers/rotors						
	Low emissions										
	Manufacturing		Electric aircraft HRF, EMI, EMP standards								
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts	1. Standardize Human Automation Interfaces	2. Low cost training for electric sport fixed wing VTOL	Training Services					
	Mission Operations	Identify new certification requirements	Avionics comm/network interoperability and new software rules standards	1. External lighting standards	2. Emergency energy mgmt. standards	Personal urban OD-VTOL ops regulations					
Infrastructure	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optic network, TFCI								
	Urban Vertiport										
	Suburban air park										
	Airspace Comm, Nav, Surveillance systems			Define comm. spectrum distrib/allocation reqmts							
	Electric utility distrib & availability			Electric grid and charging infrastructure required for		Sufficient sustainable electricity generation					
Recycle/ recharge			1. Battery lifecycle utilization Aircraft & Car > Home	2. Rapid recharge systems	3. Electric charging standards						
	Liability Protections		ODM and UAS Legal Services			Assign algorithm liability (autonomy, collision-terrain avoidance, etc.)					
Autonomous systems	2. Health and resource Mgmt systems architectures										
	driving regulatory costs with FAA										
	in dense traffic										
	2. Com & Avionics network interoperability standards										
	systems flying to mature tech confidence										
High Density Airspace Operations	Secure data/comm standards for information sharing										
	Vehicle to Vehicle Interlink w/G										
Energy efficient	1. Ref. architectures (motor, 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										
Elect. Power mgmt. & distribution	Preliminary integrated component system weights (inverters, thermal, etc.)										
	Low inertia motors over 80 kW; 1/20th of current inertia										
	Benchmark b electric onboard system										
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Aircraft mgmt. sys, nav, sense & avoid	Flight scenarios test & simulation										
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	Initial hybrid VTOL/CTOL platform development										
Affordable acquisition	Private ownership early adopters prizes										
Superior pax & community safety	1. Flight path control safety certification tech										
	2. Crash mgmt. systems concepts (Fire detect										

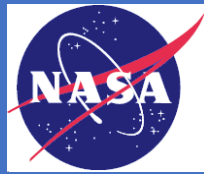
Un-vetted Roadmap – Commercial Intra-City



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

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Acceptance	Time Savings Personal Convenience	Document personal, municipal, urban TVF	American Disabilities Act exemption justifications		Autonomous urban air-taxi concepts	Recreation/Entertain (Airborne Party Limo)	Air user community acceptance	Routine VTOL Service	Elevator to Altitude in Congested Areas		
	More affordable missions	Short and very short haul concept definitions	Secure multi- and business operator commitments		Large Corporate Campus to Campus concept	Surveillance (DJI, Agri, news, fire, police, etc.)	Operational multi-passenger OD-VTOL for sale				
	Mission/Business advantage	Multi-mode Metro air-taxi business plan launched	Rentable Auto Transportable PAV		1. Package Delivery 2. Air Limo recreation service	Metro air-taxi launched			Operation without ground infrastructure	Autonomous Multi-mode User type air-ground	
	Energy savings		Airport Shuttle concept								
	Reduced crew for efficient ops.										
Greater Safety and Security		1. Industry consensus Part 23 safety standards 2. Propose reserve reqmts 3. Initial cyber security reqmts	1. Electric aircraft reliability safety and redundancy reqmt. 2. Determine jurisdiction authority	Revise Part 27 "Birdstrike" for more birds at lower altitudes	Takeoff and landing autonomy demonstration in critical conditions	IV Integrated Autonomy to minimize pilot skill, work load Isa protection for DEP w/out bleed air & min. electrical power			Air commuting remains operational in case of natural disasters (earthquake).		
	Net Environmental Benefits	Identify TVF unique environmental regulations									
Technology	VTOL specific		1. Site loading vs. ground environment trades 2. Manned VTOL urban air-taxi concepts	1. Helipad Consensus Standard 2. Dual mode platforms	Low density VTOL ATM using sUAS for demo (1 helipad/sq. mile, 10 min sequencing)	Articulating propulsors for hover to high speeds			High density NAS Integrated VTOL ATM automation demo (>10 helipads/sq. mi, 1 min sequencing)		
	STOL specific										
	Autonomous systems	1. Define Autonomous Systems 2. Health and resource Mgmt systems architectures	Identify autonomous VTOL driving regulatory costs with FAA	1. Automated takeoff/landing in dense traffic 2. Com & Autonic network interoperability standards	Demonstrate autonomous air-taxi	Automation/Machine Learning for ATC workload reduction	System Level Performance verification & validation	Fully automated Control/flight 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 interface (w/GA, Airlines, Drones)	Define factors that determine ATM services system priorities				Low-cost obstacle avoidance sys. for large # of vehicles	
	Energy efficient		1. Ref. architectures (motor-controller, bus topologies) 2. Solar Electric Standards								
High Specific Energy storage		Energy storage safety reqmts; battery, hybrid, FC	Energy density targets validate by Induct tech evolution	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. & distribution	One engine inoperative electric power back up	Preliminary integrated component system weights (inverters, thermal, etc.)	Low inertia motors over 80 kW; 1/200th of current inertia	Benchmark best SOTA all-electric onboard network system	Standardized interchangeable Power Cells.					
	Integrated flight/propulsion control	Pilot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy precursor)	1. Autopilot integrated for simplified vehicle ops. and loss of control avoidance 2. 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	1. Sense and avoid technology demonstration 2. 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		1. Flight path control safety certification tech 2. Crash mgmt. systems concepts (fire detect)	1. Crash protection standards, fire suppress 2. "Pilot's associate" 3. "Pilot's associate" for IFR autonomy	1. DEP fireproof and fire detection/protection 2. Software certification rules/process		Define passenger briefing rules/security					
	Acceptable noise levels			Urban VTOL Noise Standards defined	Ultra-quiet propellers/rotors		Ultra-low noise VTOL aircraft demo	Acoustics stage N+2			
	Low emissions									Power supply carbon footprint/sustainability	
Certs & Regs	Manufacturing		Electric aircraft HMR, EMI, EMP standards	Industrial repair parts delivery	Regulation 23 & 27 Combined	Dependable flight components qualification	Electric Propulsion overhaul & repair manufacturing services	1. Manufact. System Demo 2. VTOL/CTOL Maint. Avail.			
	Training	Identify required new training Methods	Low cost fixed & rotary wing electric trainers concepts	1. Standardize Human Automation Interfaces 2. Low cost training for electric fixed wing VTOL taxi	Training Services			1. Low Cost fixed & rotary wing Electric Propulsion Trainer 2. Streamlined certification			
	Mission Operations	Identify new certification requirements	Avionics comm/network interoperability and new software rules standards	1. External lighting standards 2. Emergency energy mgmt. standards	Combine rotorcraft and fixed wing license for new VTOL concepts	Autonomous VTOL ops regulations		Certification of intelligent software			
	Physical & Cyber Security	DEP information bus to avoid EMI fiber optic WDM, TFCN									
Infrastructure	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 reqmts.			Traffic density based dynamic datalink: low ADS-B, high Wi-	Universal transponders equipage			
	Electric utility distrib & availability				Electric grid and charging infrastructure required for						
	Recycle/ recharge		1. Battery lifecycle utilization Aircraft > Car > Home 2. Rapid recharge systems 3. Electric charging standards	Architecture for Standard Recharge Stations	Sufficient sustainable electricity generation	Battery and disposal of batteries	Energy replenishment infrastructure solution (recharge, batt. swap, other)	Electric Charging Distribution and Retail Operations			
Liability Protections			ODM and UAS Legal Services		Assign algorithm liability (autonomy, collision terrain avoidance, etc.)	Insurance, Legal, Finance Services					

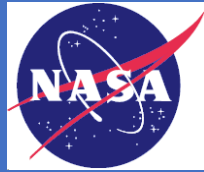
Un-vetted Roadmap – Commercial Inter-City



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

Topics	Subtopics	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Acceptance	Time Savings Personal Convenience	Alternatives configs to distributed elect. Propulsion	American Disabilities Act exemption justifications				Multi-passenger OD-VTOL for sale	Mega regional air-commuter transportation system in place	Enable Real Estate Dev. by increased Urban Sprawl		
	More affordable missions	Electric VTOL for business incubator development model	Secure multi- 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				
	Mission/Business advantage		Regional parcel delivery feeders (Cesena Caravan compatible cargo)	Mega region air-commuter business plan	1. Package Delivery 2. Mega Cities Air-Metro	Regional OD air-transport networks concepts	Regional VTOL freight transport network				Electric Hybrid T37 class air transport
	Energy savings										
	Reduced crew for efficient ops.						EV Integrated Autonomy to minimize pilot skill work load				
Greater Safety and Security		1. Industry consensus Part 23 safety standards 2. Propose reserve reqmts 3. Initial cyber security reqmts	1. Electric aircraft reliability safety and redundancy reqmt. 2. Determine jurisdiction authority	Revise Part 27 "birdstrike" for more birds at lower altitudes	Takeoff and landing autonomy demonstration in critical conditions		Ice protection for DEP w/out bleed air & min. electrical power		Air commuting remains operational incase of natural disasters (earthquake).		
	Net Environmental Benefits	Identify TWR unique environmental regulations									
Technology	VTOL specific		Disc loading vs. ground environment trades	1. Helipad Consensus Standard 2. Dual mode platforms		Articulating propellers for hover to high speeds		VTOL Regional Transport			
	STOL specific										
	Autonomous systems	1. Define Autonomous Systems 2. Health and resource Mgmt systems architectures 3. ~ zero-zero recovery demo	Identify autonomous VTOL driving regulatory costs with FAA	1. Automated takeoff/landing in dense traffic 2. Com & Avionics network interoperability standards		Automation/Machine Learning for ATC workload reduction	System Level Performance verification & validation	Fully automated Control/light systems Demo			
	High Density Airspace Operations	Civilian/Military airspace integration	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 priorities			Low-cost obstacle avoidance sys. for large # of vehicles		
	Energy efficient	Propfan and Wing Aero integration	1. Nat. architectures (motor, controller, bus topologies) 2. Solar Electric Standards		Light transport energy and propulsion systems						
	High Specific Energy storage	Energy storage safety reqts/certs; battery, hydr, FC	Energy density targets validate by indust tech evolution	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. & distribution		Preliminary integrate component system weights (inverters, thermal, etc.)	Low inertia motors over 80 KW; 1/20th of current inertia	Benchmark based GOTA all electric onboard network system	Standardized interchangeable Power Cells.					
	Integrated flight/propulsion control	Plot/vehicle interface and handling qualities demo	Aero-propulsive flight path control demo (autonomy precursor)	1. Autopilot integrated for simplified vehicle ops. and loss of control avoidance 2. Affordable Fly-by-wire	EMI optical wavelength division multiplexing technology demo	1. Integrated vehicle management systems (FCC, FADEC, electrical power) 2. 5-MW electric motor	Hover-Transition Dynamics and Control Standards				
	Aircraft mgmt. sys, nav, sense & avoid	Flight scenarios test & simulation	1. Sense and avoid technology demonstration 2. Light efficient environmental control systems	Health and resource mgmt. sys sensors, & connectivity develop		Synthetic Vision Systems					
	Affordable acquisition		40 mile, 9 passenger transport, intelligent sys hardware prize	Initial hybrid VTOL/CTOL platform development					Operational discrete hybrid VTOL/CTOL platforms		
	Superior pax & community safety	1. Flight path control safety certification tech 2. Crash mgmt. systems concepts (fire detect suppress)	1. Crash protection standards, fire suppress 2. "Wing's associate" standards; full IFR autonomy precursor	1. DEP fireproof and fire detection/protection 2. Software certification rules/process		Define passenger briefing rules/security					
	Acceptable noise levels	Define equivalent noise routes, railway/highway		Urban VTOL Noise Standards defined	Ultra-quiet propellers/rotors defined		Ultra-low noise VTOL aircraft demo	Acoustics stage N-2			
	Low emissions								Power supply carbon footprint/sustainability		
Certs & Regs	Manufacturing		Electric aircraft HIRF, EMI, EMP standards	Industrial repair parts delivery	Regulation 23 & 27 Combined	Dependable flight components qualification testing	Electric Propulsion overhaul & repair manufacturing services	1. Manufact. System Demo 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			
	Mission Operations	Identify new certification requirements	Avionics comms/network interoperability and new software rules standards	1. External lighting standards 2. Emergency energy mgmt. standards	Condense rotorcraft and fixed wing license for new VTOL concepts	Additional/modifications to CFR part 33 – navigation special conditions	Additional/modifications to CFR part 33 – navigation rule re-write	Certification of intelligent software			
	Physical & Cyber Security		DEP information bus to avoid EMI; fiber optics WDM, TDM								
Infrastructure	Urban Vertigo				Vertipoint Ground Station Standards	Vertipoint basing technology demo (maint., ops. & repair)	Infrastructure funding for Vertipoint 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		All aircraft Wx data gathering (ATM prediction model)	Define comm spectrum distrib/allocation reqmts.	Long endurance for remote high bandwidth comm (Solar?)		Traffic density based dynamic data-link; low ADS-B, high Wx-R	Universal transponders equipage			
	Electric utility distrib & availability			Electric grid and charging infrastructure required for EV's	Sufficient sustainable electricity generation						
	Recycle/recharge		1. Battery lifecycle utilization Aircraft > Car > Home 2. Rapid recharge systems 3. Electric charging standards	Architecture for Standard Recharge Stations		Recycle and disposal of batteries	Energy replenishment infrastructure solution (recharge, batt. swap, other)	Electric Charging Distribution and Retail Operations			
	Liability Protections		ODM and UAS Legal Services		Assign algorithm liability (autonomy, collision-terrain avoidance, etc.)	Insurance, Legal, Finance Services					

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