NASA/AHS
TRANSFORMATIVE VERTICAL FLIGHT
WG-4 PUBLIC SERVICES

PROGRESS REPORT

Johnny T. Doo  WG Lead
International Vehicle Research, Inc.

2018-01-18
Public Services Mission Elements - TVF enabled

- Examples of each mission element
- What capabilities are needed to accomplish missions

- Search and rescue,
- Law enforcement,
- Medical transport,
- Emergency/humanitarian response,
- Military operations.
**TEAM MEMBERS & AFFILIATIONS**

**Group Lead – Johnny Doo**  
International Vehicle Research, Inc.

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tr>
<td>Michael Ballas</td>
<td>Astronics AES</td>
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<tr>
<td>Alice Bogrash</td>
<td>OptiVector Ltd</td>
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<tr>
<td>Greg Bowles</td>
<td>General Aviation Manufacturers Association (GAMA)</td>
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<tr>
<td>Ivan O. Clark</td>
<td>NASA (LRC)</td>
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<tr>
<td>Mark P. DeAngelo</td>
<td>SAE INTERNATIONAL</td>
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<tr>
<td>Nathan P. Diller</td>
<td>USAF</td>
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<tr>
<td>Michael Dudley</td>
<td>NASA (ARC)</td>
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<tr>
<td>Alina Eskridge</td>
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<tr>
<td>Finch Fulton</td>
<td>United States Department of Transportation</td>
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<td>Francesco Giannini</td>
<td>Aurora</td>
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<tr>
<td>David Gonzales</td>
<td>AVA Propulsion, Inc.</td>
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<td>Todd Hodges</td>
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<td>Todd Jackson</td>
<td>FAA (Atlanta Aircraft Certification Office)</td>
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<td>Richard Kreeger</td>
<td>NASA (GRC)</td>
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<td>John Lawson</td>
<td>NASA (ARC)</td>
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<td>Arun Murthi</td>
<td>AERO&amp;SPACE USA, Inc.</td>
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<tr>
<td>Marilena D. Pavel</td>
<td>Delft University of Technology</td>
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<tr>
<td>Adam Petricic</td>
<td>GlobalMedic</td>
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<td>Sai V. Raj</td>
<td>NASA (GRC)</td>
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<td>Edward Randall</td>
<td>Randall Innovations LLC</td>
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<td>Rahul Singh</td>
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<td>Brett Simms</td>
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<td>Louis J. (BUD) Skriba</td>
<td>Gigajoule Jug Consultants</td>
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<td>Michael Thacker</td>
<td>Bell Helicopter</td>
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<td>Michael A. Tsairides</td>
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<td>Daniel M. Williams</td>
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<td>Nicole Xie</td>
<td>Pasadena City College</td>
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Team# June 2017 - 12 Jan 2018 - 30
Key Milestone and Target

- 2020 – demonstrator & trial tests
- 2022 - field deployment (production EIS) – a stretch goal
- Demo unit able to carry one-two people with semi-autonomous capability
- 25 miles R/T range – initial capability
Search & Rescue TVF

- Environment
  - Mountain Rescue
  - Water Rescue
  - Earthquake

- Operations
  - TVF – More rescue than search due to endurance limitations
  - Hybrid vehicle can do both
  - Team up with long endurance UAV for extended search & communication capabilities

- Capabilities
  - Minimum one person lift off and autonomous return
  - Small footprint / protected rotors
  - Capable of dropping life raft, medical pack, survival kit (thermos blanket, food, water etc.)
  - Automated & uneven terrain landing capabilities
  - High elevation / cold weather operations
LAW ENFORCEMENT TVF

- **Environment**
  - Urban, streets, tight space
  - City center, high rise building
  - Rural, open area, uneven terrain
  - People around

- **Operations**
  - TVF – Quick deployment (in and out)
  - Can land on street/parking lot/roof top
  - Team up with long endurance UAV for communication, command & control

- **Capabilities**
  - Minimum one person lift off and autonomous return
  - Small Footprint / protected rotors
  - Capable of deploy police personnel (multi-units)
  - Delivering medical pack, gears & equipment etc.
  - Automated & uneven terrain landing capabilities
MEDICAL TRANSPORT TVF

- Environment
  - Urban, streets, building
  - City center, hospital
  - Rural, open area, uneven terrain

- Operations
  - TVF – Quick response transportation
  - Can land on street/parking lot/roof top
  - Can be equipped with medical care unit

- Capabilities
  - Minimum one person transportation
  - One additional medical personnel on board a plus
  - Safe operations for ground personnel
  - Delivering medical pack & equipment etc.
  - Automated operations capabilities
EMERGENCY/HUMANITARIAN RESPONSE TVF

- Environment
  - Disaster area, parking lot, uneven terrain
  - Urban, roadway
  - Rural, refuge camp, logistic site

- Operations
  - TVF – Emergency response transportation
  - Can land on street/parking lot/roof top
  - Can be equipped with medical care unit
  - Food & supply delivery

- Capabilities
  - One or more person transportation
  - Additional medical personnel on board a plus
  - Safe operations for ground personnel
  - Delivering medical pack, food & supplies
  - Automated operations capabilities
MILITARY OPERATIONS TVF

- Environment
  - Battlefield, frontline, staging area
  - Open field, uneven terrain
  - Urban warfare

- Operations
  - On-demand logistics & re-supply
  - Medical evacuation
  - Distributed short-range mobility

- Capabilities
  - One to four person transportation
  - 200-800 lb payload
  - Automated operations capabilities
  - Can be managed by the frontline personnel
  - Interchangeable cargo/personnel module
MULTI-PURPOSE PUBLIC SERVICE TVF VEHICLE

**Level I**
- Target Date: 2020
- Capacity: 1-2 person
- Mission Payload: 200-400 lb
- Range: >25 mi round trip
- Cruise Speed: >60 kts
- Loiter: >3 min
- Mode: VTOL/VSTOL
- Power: Electric, hybrid or alt
- Semi-autonomous

**Level II**
- Target Date: 2022
- Capacity: 3-4 person
- Mission Payload: 600-800 lb
- Range: >30 mi round trip
- Cruise Speed: >80 kts
- Loiter: >5 min
- Mode: VTOL/VSTOL
- Power: Electric, hybrid or alt
- Fully Autonomous

**Features:**
- Modular Payload Pod
- Can Land on water (opt)
- Uneven terrain capability
- Compact operating footprint
- Transportable through regular roads
- Fail-safe critical systems
- 4G/5G data link
- BVLOS
- V2V connectivity
- Cert – special use, safer than current
<table>
<thead>
<tr>
<th>Topics</th>
<th>Subtopics</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
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<td>Identify required new training Methods</td>
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<td>Identify new certification requirements</td>
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<td>Physical &amp; Cyber</td>
<td>DEP information bus to avoid EMI; fiber optic WDM, TFCH</td>
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<td>Mission/Business advantage</td>
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<td>Reduced crew for efficient &amp; safe ops.</td>
<td>1. industry consensus Part 23 safety standards</td>
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<td>Revise Part 27 &quot;Birdstrike&quot; for more birds at lower altitudes</td>
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<td>2. Propose reserve reqmts</td>
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<td>Takeoff and landing autonomy demonstration in critical conditions</td>
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<td>3. Initial cyber security reqmts</td>
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<td>Identify TVF unique environmental regulations</td>
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<td>VTOL autonomous military logistic platform and system concept development</td>
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<td>Preliminary integrated component system weights (inverters, thermal, etc.)</td>
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<td>1. Autopilot integrated for Simplified vehicle ops. and loss of control avoidance</td>
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<td>2. Affordable Fly-by-wire</td>
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<td>Aircraft mgmt. sys, nav, sense &amp; avoid</td>
<td>Flight scenarios test &amp; simulation</td>
<td>1. Sense and avoid technology demonstration</td>
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<td>Health and resource mgmt. sys sensors, &amp; connectivity develop</td>
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<td>Development of affordable emergency response &amp; rescue vehicle &amp; system</td>
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<td>Affordable medium volume / distributed manufacturing design and production concept development</td>
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<td>Superior pax &amp; community safety</td>
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<td>Crash protection standards, fire suppress</td>
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<td>Acceptable noise levels</td>
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Certification & Regulations - Training – 2018

Identify required new training methods

Conduct first a “training need analysis” (TNA) for a future VTOL/STOL platform by defining a list of scenarios that would need to be performed by the vehicle. Identify then required new training methods enhancing the skills identified by the TNA. The practical flying skills methods may include for example navigation, loss of control, in addition to general handling. Use for example Kirkpatrick model for a first evaluation of the effectiveness of the new training methods.

► > Depends on:
  • Flight scenarios tests and simulation
  • Define Autonomous Systems

► > Enables:
  • Initial hybrid VTOL/CTOL platform development
  • Autopilot integrated for Simplified vehicle ops. and loss of control avoidance
  • Identify new certification requirements
  • Flight path control safety certification tech
Identify new certification requirements

Adherence to the safety standards set out in the regulations should be envisioned by a future VTOL/STOL operating for public services, however, operations of a public aircraft may be exempt from compliance with Federal Aviation Regulations. In this sense, the technologies to be involved in the future VTOL/STOL platform for public services should be seen as objectives that the designs should meet in the certification process. A desired probability of failure $10^{-7}$ to $10^{-8}$ (extremely remote) as in the case of airplane should be used in the design and otherwise a $10^{-6}$ (remote) probability should be applied as in the case of helicopters, This will affect the components redundancy and will affect the final MTOW of future VTOL/CTOL.

- **Depends on:**
  - Initial hybrid VTOL/CTOL platform development
  - Industry consensus Part 23 safety standards
  - Flight scenarios tests and simulation

- **Enables:**
  - Initial hybrid VTOL/CTOL platform development
  - Identify required new training methods
Acceptance - Mission/Business advantage - 2018

Multi-use Demo TVF Design Criteria & Development

Establish multi-use demo TVF design criteria & concept. Focus on small vehicle that can be designed and built in a cost effective manner and able to service multiple missions. Target size to be 1-2 person or 80-160kg payload platform with VTOL capability and 40 mile range (20 mile round trip). Near full autonomous capability & end point command/control as required; trailer-able for near-site deployment.

- **Depends on:**
  - Semi-automated public safety response, security, fire, rescue, disaster recovery autonomous system development
  - Disaster / impact area theater emergency traffic management system development

- **Enables:**
  - Demonstrate to public and user communities of TVF enabled public service; Use-and-learn in multiple applications
  - Fire fighting - deliver tools & equipment to site; evacuate trapped firemen
  - Disaster area medical pack, food & water delivery, emergency, medical evacuation
  - Military & government use – On-demand delivery of supply to frontline & single person medical evacuation
Acceptance - Mission/Business advantage - 2020

Multi-use Demo TVF Prototype Field Test Operations

- Complete the flight stability & controllability flight evaluations, and near full autonomous with sense & avoid capability tests. Coordinate with multiple agencies and end users for preliminary simulated operations with acceptable risk assessment results. Followed by real world demo deployments in multiple areas including fire fighting support & evacuation, front line logistics & medical evacuation, disaster relief medical & food/water delivery & emergency medical transport.

- > Depends on:
  - Multi-use Demo TVF Criteria & prototype Development
  - Disaster / impact area theater emergency traffic management system development
  - Electric aircraft reliability safety and redundancy reqmt.
  - Crash protection standards, fire suppress

- > Enables:
  - Initial hybrid/electric VTOL platform development field test
  - Benchmark best practice with these type of capabilities and gain field use experiences
  - Create public acceptance & understanding of potentials in technology for public good.
Investigate current cockpit technologies for inceptors and displays as well as their connection to desirable vehicle handling characteristics for a future viable VTOL/CTOL platform. Define for the future VTOL/STOL whether to have a highly augmented FCS whereby the human occupant is retained within the control loop or to have a completely automated FCS where the human occupant is not in the flight control loop. This is done in the wisdom of automation paradigm, i.e. automation it functions best when the workload is light and the task routine; when the task requires assistance or workload is high, the automatic equipment seems of least assistance”. The pilot/vehicle interface needs to be defined relative to the range of missions/tasks envisioned to be performed with the VTOL/STOL. Assessment of the handling qualities in these missions can be done in simulation exercises.

- **Depends on:**
  - Define Autonomous Systems
  - Health and resource Mgmt. systems architectures
  - Flight scenarios tests and simulation

- **Enables:**
  - Initial hybrid VTOL/CTOL platform development
  - Autopilot integrated for Simplified vehicle ops. and loss of control avoidance
  - Identify required new training methods
  - Identify new certification requirements
Flight scenarios test & simulation

- Define the critical flight scenarios to be performed by a future VTOL/CTOL platform for public services and connect these to the initial design requirements. An attempt to reconcile all these scenarios would oblige to envelop them in a sole set of requirements with direct consequences on the system design. Consider within the aim of flight scenarios tests & simulation also the issues of safety, reliability, platform availability, etc.

- **Depends on:**
  - Semi-automated public safety response, security, fire, rescue, disaster recovery
  - Initial hybrid VTOL/CTOL platform development

- **Enables:**
  - Pilot/vehicle interface and handling qualities demo
  - Identify required new training Methods
  - Identify new certification requirements
  - Autopilot integrated for Simplified vehicle ops. and loss of control avoidance
Preliminary integrated component system weights (inverters, thermal, etc.)

- Preliminary baseline electric power management and distribution systems will be defined for several types of vehicle classes, and will include breakdowns of all necessary components. The systems definitions will account for the integration of all components, interfaces, and supporting systems required to deliver the vehicle’s stored energy to the primary mechanical driver (fan/propeller shaft).

- **Depends on:**
  - Identify TVF EMS OPS for Fast/Efficient Remote VTOL Access
  - Energy storage safety regs/certs; battery, hybrid, Fuel Cell
  - Ref. architectures (motor, controller, bus topologies)
  - Crash protection standards, fire suppress

- **Enables:**
  - Initial hybrid VTOL/CTOL platform development
  - Benchmark best SOTA all-electric onboard network system
  - Crosscutting – appears in all four roadmap mission elements
Preliminary integrated component system weights (inverters, thermal, etc.)

- Preliminary baseline electric power management and distribution systems will be defined for several types of vehicle classes, and will include breakdowns of all necessary components. The systems definitions will account for the integration of all components, interfaces, and supporting systems required to deliver the vehicle’s stored energy to the primary mechanical driver (fan/propeller shaft).

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  - Crash protection standards, fire suppress

- Enables:
  - Initial hybrid VTOL/CTOL platform development
  - Benchmark best SOTA all-electric onboard network system
  - Crosscutting – appears in all four roadmap mission elements
Sense and avoid technology demonstration

Develop and integrate sense & avoid system demonstrators based on multi-sensor and artificial intelligent enhanced obstacle and object recognition and decision/action capable software. Demonstrated capabilities at this level is not expected to be 100% full proof, but with enough practical capabilities to be able to integrate into development platform for trial and further enhancement work. The sensor package could include visual, infrared, ultrasonic Lidar and other camera/sensor technology, integrated into such system that can complement each other and to allow safe operations in various weather condition.

- **Depends on:**
  - Define Autonomous Systems
  - Health and resource mgmt. systems architectures

- **Enables:**
  - Initial hybrid VTOL/CTOL platform development
  - Autopilot integrated for Simplified vehicle ops. and loss of control avoidance
  - Flying Soldier PAV Controls/Autonomy concepts
Semi-automated public safety response, security, fire, rescue, disaster recovery

- Develop architectures for semi-automated public safety response systems that take advantage of highly automated or autonomous vertical flight capable vehicles. Systems will operate with minimal operator intervention and respond faster and more safely than current systems. Architectures will consider unique operational constraints, public demands/expectations, implementation costs, and user compatibility.

- > **Depends on:**
  - Define Autonomous Systems
  - Health and resource Mgmt. systems architectures
  - Crash protection standards, fire suppress

- > **Enables:**
  - First responder disaster relief
Initial hybrid VTOL/CTOL platform development

- Integrate latest technologies into viable VTOL/CTOL platform capable of early applications and deployment especially in the Public Service segment. Platform could be either VTOL or CTOL configuration and provide new capabilities than existing vehicles. System would include efficient core engine, compact generator, power management system, weight efficient battery pack and battery management system. Medium to long range telemetry and data link capabilities needed for many applications; platform payload would include sensor suits for surveying functions as well as deployable payload for rescue and disaster relief capabilities. Systems could be partially or fully autonomous and start as unmanned / optional pilot system for logistic support leading to people capable platform. Platform should be able to operate with minimal operator intervention and training for cost effective and practical deployment.

- Depends on:
  - Preliminary integrated component system weights
  - Health and resource Mgmt. systems architectures
  - Crash protection standards, fire suppress

- Enables:
  - First responder disaster relief, emergency/humanitarian response
Technology – Affordable Acquisition - 2020

Affordable medium volume / distributed manufacturing design and production concept development

Leverage experiences & manufacturing technology from low volume automobile production and 3-D printing methodology to enable affordable TVF vehicle be produced at a 2-3x lower cost than current general aviation aircraft. Develop design and production concept that leverage the 3-D printing methods to allow vehicle be fabricated at multiple locations around the world for local deliveries to meet the regional demands. Design for producibility not only for more cost effective production but to significantly simplify the structural and system architecture leading to safer and better performing platform.

▶ > Depends on:
   • Development of affordable emergency response & rescue vehicle & system
   • Affordable Fly-by-Wire
   • Preliminary integrated component system weights (inverters, thermal, etc.)

▶ > Enables:
   • Develop and manufacture cost effective TVF type vehicles
   • Break the current high cost of person-carrying flying barrier
   • Global development / Regional supply to meet and tailor for local requirements
   • Mass deployment of TVF vehicles for public service, local transportation and other applications
LACK OF ACCESS IS A MAJOR CHALLENGE FOR SEARCH, RESCUE AND RELIEF OPERATIONS

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<th>Challenges</th>
<th>Courtesy Google Images</th>
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<td>Flooded roads</td>
<td>![Image of flooded roads]</td>
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<td>Destroyed roads and bridges</td>
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<td>Congested or lack of airports</td>
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<td>Destroyed ports</td>
<td>![Image of destroyed ports]</td>
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<td>Remote locations</td>
<td>![Image of remote locations]</td>
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<tr>
<td>High altitudes</td>
<td>![Image of high altitudes]</td>
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<tr>
<td>Forest fires</td>
<td>![Image of forest fires]</td>
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<td>Volcanic ash</td>
<td>![Image of volcanic ash]</td>
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<tr>
<td>Earth tremors</td>
<td>![Image of earth tremors]</td>
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<tr>
<td>Chaotic relief efforts</td>
<td>![Image of chaotic relief efforts]</td>
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</tbody>
</table>
Local Rescue & Disaster Relief – TVF Enabled

Communication & Theater Management

Rescue on Demand

California Wildfire

Houston Harvey

Transport & Logistics on Demand
Regional Logistics & Distribution

Hybrid Airship 70mph 47,000lb

Wi-Fi & Cell Phone Communications, data link

Puerto Rico Maria hurricane
Global Logistics & Disaster Relief

Boeing WIG concept - can carry 1400 tons cargo @ 240 knots over a distance of 10,000 nm.
How do we get enough TVF vehicle where and when needed?

- Vehicles are designed and produced with modular capabilities, standardized datalink and full autonomous capabilities
- Owners & organizations register their vehicles for emergency use
- Responsible agency or authority can activate the use with user permission (authorization code)
- Theater command will organize the use of the vehicles (may change out payload modules) as part of the coordinated emergency operations
- Return the vehicle (washed and cleaned) to the owner with a Thank You note.
MOVING FORWARD

- Increase collaboration efforts among working groups
- Multi-use platform development
- Path for special application cert and approval
- Early demonstrations and field test
- Longer term development & wide adoption for various public uses

Contact info: Johnny T. Doo  
(251) 753-0075  
jdoo@ivr-global.net