Working Group Update

MANUFACTURING, INTEGRATED STRUCTURES, & COMMUNITY IMPACT (MISC)

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Scope

- Manufacturing
  - Reduced costs for both “low” and “high” volume production runs
  - New manufacturing techniques (e.g., additive manufacturing)
- Integrated Structures
  - Improved modeling and analysis capabilities
    - Reduce design cycle / certification time and cost
    - Reduce maintenance costs / increase aircraft availability
  - Advanced structures/materials
    - Can the structure do more than carry loads? (e.g., store energy, self-heal, morph)
    - Can we reduce structural weight?
- Community Impact
  - Increase public acceptance
    - Ensure safety for both occupants and bystanders on ground
    - Acceptable acoustic environment
  - Encourage adoption / increase utilization
    - Enable more “all weather” capabilities
    - Reduce vehicle down time
    - Reduce operational barriers

On-Demand Mobility Goals

10 Prioritized Feasibility Barrier Goals

Ease of Certification	Affordability	Safety	Ease of Use	Door to Door Trip Speed	Average Trip Delay	Community Noise	Ride Quality	Efficiency	Lifecycle Emissions
Metric Time/Cost Required	Metric Total Operating Cost/Pax Mile	Metric Fatal Accidents per Vehicle Mile	Metric Required Operator Training Time & Cost	Metric mph	Metric Time	Metric Perceived Relative Annoyance @ Community Stand-off Distance	Metric Passenger Comfort Index	Metric Energy/Pax Mile	Metric Total Emissions /Pax Mile

MISC Contributions to ODM Goals

Ease of Certification Metric Time/Cost Required

- Potential to reduce certification requirements for other technologies with improved “stopgap” safety systems
- Improved modeling may reduce need for extensive physical testing
- “Handbooks” to help enable certification of new manufacturing processes

MISC Contributions to ODM Goals

Safety
Metric
Fatal Accidents per Vehicle Mile

- Improved “stopgap” safety systems to complement other technologies (e.g., SVO-related technologies)
- Reduced risk of flying with unsound structure
  - Structural health monitoring/modeling
  - Improved material damage tolerance

MISC Contributions to ODM Goals

Affordability

Metric
Total Operating Cost/Pax Mile

- Reduced system weights can lead to reduced acquisition costs
- Improved modeling and monitoring of structures can reduce costs
  - Acquisition costs (i.e., design, certification)
  - Operating costs (i.e., reduced maintenance)
- Improved safety and reduced damage in crashes reduces depreciation costs

MISC Contributions to ODM Goals

Ease of Use

Metric
Required Operator Training Time & Cost

- Only minor impacts
  - Safety technologies could reduce required pilot certification requirements (e.g., less off-nominal training required)
  - Structural monitoring/modeling reduces required operator knowledge/time for inspections

MISC Contributions to ODM Goals

Door to Door Trip Speed

Metric
mph

- Potential for more direct routes / desirable altitudes
  - Anti-ice coatings to fly through instead of around known icing conditions
  - Improved safety systems (i.e., parachutes, airbags) to reduce concerns of low flight over populated areas
- Multi-mode vehicles
  - Reduced mode change time
  - May be enabled with morphing structures

MISC Contributions to ODM Goals

Average Trip Delay
Metric Time

- Weather penetration
  - e.g., anti-icing
- Improved aircraft availability
  - Better scheduling of maintenance downtime
    - e.g., monitoring or modeling indicates repair/replacement in advance
  - Reduced maintenance downtime
    - e.g., damage tolerant structures

MISC Contributions to ODM Goals

Community Noise

Metric
Perceived Relative Annoyance @ Community Stand-off Distance

- Metrics to quantify the perception of noise
- Noise reduction technologies
- New tools to enable design for low perceived noise
- Reduced vehicle weights can lead to lower noise

MISC Contributions to ODM Goals

Ride Quality

Metric
Passenger Comfort Index

- Decreased cabin noise
- Indirect impacts possible through
  - morphing structures
  - improved actuators that may help enable gust load alleviation systems

MISC Contributions to ODM Goals

Efficiency

Metric
Energy/Pax Mile

Lifecycle Emissions

Metric
Total Emissions /Pax Mile

- Reduced structural weight
- Increased electrical transmission efficiency

Investment List: Example Subset

- Manufacturing
  - Flexible robotic manufacturing
    - Replace many manual labor tasks with robotic stations
    - Robotic stations can be programed to do many different tasks
    - Small production runs could employ a small number of robotic stations, each serving multiple functions
    - Large production runs could employ many robotic stations, each serving a small number of functions
  - Additive manufacturing handbook
    - Define “best practices” for design and inspection
    - Determine sufficient factors of safety for different processes
  - Additive manufacturing of subsystems (e.g., fuel cells, electric motors)
  - New additive manufacturing methods (e.g., liquidjet printing, robotic direct fiber placement)

Investment List: Example Subset

- Integrated Structures
  - Multi-functional structures with energy storage (e.g., M-SHELLS)
    - Instead of having separate structure and energy storage systems, combine them to save vehicle weight
    - Poorer structure than conventional structure and poorer energy storage capability compared to conventional means, but net reduction in overall weight
    - Distribution of energy storage may reduce electricity transmission weight/losses and increase reliability through redundancy
  - Improved modeling of composite structures
    - Develop improved, high-fidelity progressive damage analysis methods for composite materials to predict onset and propagation of damage
    - Utilize tools to develop more structurally efficient designs and/or reduce design/certification time with less physical testing than currently required
  - Morphing structures / advanced actuators
    - Change vehicle characteristics (e.g., wing camber) throughout mission to be more advantageous for different phases of flight
    - May help enable multi-mode vehicles that can safely fly and drive on roads
  - Damage-tolerant / “self-healing” composites
    - Damage from accidental damage (e.g., dropping tools), high voltage electrical shortages, projectiles, etc. can be automatically mitigated

Investment List: Example Subset

- Community Impact: Safety enhancements
  - Extremely low altitude aircraft parachute
    - Aircraft parachutes serve as safety backup in case of off-nominal situation, decreasing aircraft acceleration to safe levels prior to ground impact
    - Current aircraft parachutes require altitude/airspeed to successfully deploy and are not applicable to VTOL aircraft operating close to people at low altitudes
    - Low altitude parachute systems can eliminate “coffin corner”/“dead man’s curve” for VTOL operations and reduce risk of damage to objects on ground
  - External aircraft airbag
    - Provides absorption of energy during crash while reducing structural deformation to enable safe egress post-crash
    - Reduction in damage to objects on ground upon landing
    - Can be utilized as a “life jacket” to keep aircraft afloat in water, reducing chances of drowning if aircraft crashes over water
  - Energy absorbing composites
    - Crash loads are absorbed by the structure while enabling safe egress post-crash

Investment List: Example Subset

- Community Impact: Acoustics
  - Noise metrics for ODM vehicles
    - Current certification metrics assume conventional aircraft and operations, but ODM aircraft and missions may differ significantly
    - Need to assess the human perception of noise to make practical ODM vehicles that can operate in close proximity to people with minimal annoyance
    - Metrics could be used in vehicle design and certification as well as assessment of airspace models
  - Noise modeling tools
    - Novel vehicle configurations or airspace usage will require new tools to effectively predict noise for both occupants and those on ground
    - New metrics will require new tools to predict perceived noise to enable effective vehicle and airspace design
  - Noise control technologies
    - For operations near humans, noise levels must be reduced from current SOA aircraft/rotorcraft levels
    - Many possible ways to reduce noise including rotor design/operation, acoustic liners, and active control

Investment List: Example Subset

- Community Impact: increased utilization
  - Anti-ice coatings based on nano-materials
    - Small aircraft (particularly those with low utilization) cannot afford weight penalty, cost of current de-icing systems
    - Coatings well-matched to lower-than-transonic speeds (i.e., won't wear away)
    - Ideally paired with electric propulsion's ability to run at higher powers for short periods of time to climb through potential icing conditions
  - Digital twin
    - Multi-physics, probabilistic simulation of aircraft used to predict performance and failures in physical aircraft prior to flight
    - Predictions can be used to make "no go" decisions, enable condition-based maintenance, and inform risk management
  - Smart hangar
    - Couple onboard sensors and external non-destructive evaluation techniques to assess vehicle health while in the hangar
    - Provides frequent, automatic inspections to identify problems early when repairs may be less costly and reduce manual inspection time

BACKUPS

Investment List (1 of 3)

- Manufacturing
  - Flexible robotic manufacturing
  - Additive manufacturing handbook
  - New additive manufacturing methods (e.g., liquidjet printing, robotic direct fiber placement)
  - Additive manufacturing of subsystems (e.g., fuel cells, electric motors)

Investment List (2 of 3)

- Integrated Structures
  - Multi-functional structures with energy storage
  - Improved modeling of composite structures
  - Damage-tolerant / “self-healing” materials
  - Morphing structures / advanced actuators
  - Polyimide aerogels for primary wing structures
  - Multi-functional structures with cryogenically cooled electricity transmission
  - Modular structures and design methods for these structures
  - New nano-structure materials or other “superstructures” with improved material properties

Investment List (3 of 3)

- Community Impact
  - Safety enhancements
    - Extremely low altitude aircraft parachute
    - External aircraft airbag for improved survivability and flotation
    - Crashworthy structural design using energy absorbing composites
    - Advanced aircraft recovery parachute technologies (e.g., steerable parachutes, autonomous activation, extractor motor control, etc)
  - Acoustics
    - Noise metrics for ODM vehicles (to determine perceived noise)
    - Noise modeling tools
    - Noise control technologies (e.g., liners, active control)
  - Increased utilization
    - Anti-ice coatings
    - Digital twin
    - Smart hangar