Acknowledgements

• This study is being performed on behalf of the NASA Aeronautics Research Mission Directorate (ARMD). The team assembled to conduct this effort includes various representatives from government and industry; National Aeronautics and Space Administration (NASA), Modern Technology Solutions, Inc. (MTSI), and Aerospace Corporation.
Purpose

• To develop an analytical tool designed to calculate projections for the demand and economic benefit from operating civil and commercial unmanned aircraft systems (UAS) within the National Airspace System (NAS).

Scope

• **Region**: US-based Markets only
• **Airspace**: All Airspace Classes
• **Use Cases**: Commercial and civil (excludes military and hobbyist)
• **Duration**: Projections should look out far enough to observe forecast stabilization

Assumptions

• Federal, State and local authorities won’t establish unfriendly laws preventing the adoption of UAS (assumes Federal Pre-emption)
• The FAA will continue to move forward with UAS Policy / Regulation implementation
• Standards Development Organizations will create the necessary standards needed to certify UAS airspace integration enabling technologies
Study Approach & Timeline

UAS demand forecast accuracy is highly dependent on the ability to receive quality inputs from the entire UAS community to include: government, industry and broad commercial-user interest groups.
**Objective:** To gain an appreciation for the vast array of UAS business cases and key drivers that will impact demand and market adoption.

**Approach:**
- Conduct Literature Search
- Review previous UAS Forecasts
- Interview Gov’t and Industry Stakeholders

**Results / Benefits:**
- Most likely UAS business cases identified
- Key drivers impacting adoption timeframe (e.g. Public Acceptance, Technology Maturity, Levels of Automation, Regulatory Timeframe)
- How to handle different UAS CONOPs (e.g. multi-day missions vs dozens of flights per day)
- Best Analytical Framework for study defined
- Best metrics used to quantify UAS demand & economic benefit
### Aviation Market Categories used in Study

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Markets</strong>*</td>
<td></td>
</tr>
<tr>
<td>Privately Owned</td>
<td>General Aviation Aircraft owned and operated by individuals or corporations (e.g. Cessna, Piper Cub, Learjet)</td>
</tr>
<tr>
<td>Airlines</td>
<td>Commercial air carriers that offer a service to transport people to and from airports across the country and internationally (e.g. United, American, Delta, SouthWest)</td>
</tr>
<tr>
<td>For Hire</td>
<td>Aircraft that is rented by the hour, day, week to provide a service to anyone willing to pay the negotiated fee (e.g. sightseeing helicopter, NetJets)</td>
</tr>
<tr>
<td>Cargo</td>
<td>Aircraft used to transport freight to and from airports across the country and internationally (e.g. FedEx, DHL, UPS)</td>
</tr>
<tr>
<td><strong>New UAS Enabled Markets</strong></td>
<td></td>
</tr>
<tr>
<td>HALE</td>
<td>Expanding unmanned aircraft market that operates over both rural and urban settings, well above traditional manned aircraft at high altitudes (&gt;60K ft), for very long endurance (days/weeks/months) missions.</td>
</tr>
<tr>
<td>IFR-Like</td>
<td>Expanding UAS market that increases traditional densities of the NAS, performs long distance and/or long endurance missions at a higher altitudes (18K ft - 60K ft); integrating exclusively with cooperative aircraft.</td>
</tr>
<tr>
<td>VFR-Like</td>
<td>Early UAS market that will operate BVLOS over rural and populated areas at altitudes below critical NAS infrastructure (10K ft – 18K ft); routinely integrating with cooperative and non-cooperative general aviation aircraft.</td>
</tr>
<tr>
<td>Urban Passenger Transport</td>
<td>Newly emerging market that requires high density VTOL operations for on demand, affordable, quiet, fast, transportation of people in a scalable and conveniently accessible verti-port network.</td>
</tr>
<tr>
<td>Low Altitude Urban</td>
<td>Rapidly expanding market that uses fixed wing and VTOL UAS operating below 400 ft and BVLOS to deliver packages and offer a wide range of services to high density urban settings.</td>
</tr>
<tr>
<td>Low Altitude Rural</td>
<td>Emerging market that includes fixed wing and VTOL UAS, ranging in size and capability, that operate beyond visual line of sight (BVLOS) in Class G airspace and above low-risk rural locations.</td>
</tr>
<tr>
<td>VLOS</td>
<td>Growing existing market, partially enabled by Far Part 107, that includes visual line-of-sight (VLOS) fixed wing and VTOL UAS (&lt;55 lb) operating below 400 ft.</td>
</tr>
</tbody>
</table>

*Traditional Markets are the categories the FAA has historically tracked for manned aviation.
** UAS Enabled Market Categories are based largely on projected topics for periodic policy / regulatory releases
**UAS-Enabled Market Categories used in Study**

1. **Research & Analytical Framework**

**HALE** Low risk BVLOS ops above IFR-controlled airspace. (E.g. Internet Service Provider)

**IFR-LIKE** Moderate risk BVLOS ops within IFR-controlled airspace, integrated with traditional air traffic and ATM services. (E.g. Long-distance Cargo Transport)

**VFR-LIKE** High risk BVLOS ops below NAS infrastructure, integrated with both cooperative and non-cooperative aircraft. (E.g. Border Surveillance, Regional Cargo Delivery)

**LOW ALT. RURAL** Low risk BVLOS rural operations integrated with General Aviation aircraft (E.g. Linear Inspection)

**LOW ALTITUDE URBAN** Moderate risk BVLOS small UAS operations over populated areas using UTM services

**TOP OF URBAN AIRSPACE**

**TOP OF CLASS G**

**VLOS**

Very low risk VLOS rural/urban operations. (E.g. Infrastructure Inspection, Agriculture)

**500' AGL**

**Terminal Airspace**
Objective: To develop an analytical tool that facilitates the forecasting of UAS demand and economic benefit across various UAS market categories.

Approach:

- **UAS Demand**: Utilize a standard S-curve technology adoption calculation reliant on 4 variables
  - Estimated start year of new technology
  - Estimated fast-growth year (~10% of market)
  - Estimated takeover year (~90% of market)
  - Estimated total market saturation level (Either as a percentage of the existing market or estimated total of a new market)

- **Economic Benefit**: Modify the existing Aerospace Corporation-developed Cumulative UAS Benefit to the Economy (CUBE) Tool

Results / Benefits:

- Tool allows for quick prediction adjustments by simply adjusting the input variables
- Input values can be based upon subject matter expert (SME) input or from rigorous business-case-based demand projections
**Objective:** To generate defensible UAS demand forecasts for each aviation market category based on community supplied inputs and rationale. Periodically update UAS Demand forecasts as new data becomes available.

**Approach:**
- **Ph. 1:** Develop notional demand curves for each category to validate tool works properly
- **Ph. 2:** Work with Gov’t & Industry to elicit inputs related to specific markets and business cases
- **Ph. 3:** Adjust UAS demand forecasts based on Ph. 2 inputs & validate results

**Results / Benefits:**
- Ability to visualize projected growth rates across categories
- Assess impacts to traditional aviation markets
- Identify opportunities to enable faster growth and adoption
**Objective:** To determine the forecasted economic benefit and return on investment (ROI) for each aviation market. Compare results of the economic analysis across markets to identify the markets that provide the largest overall benefit to the nation.

**Approach:**
- **Ph. 1:** Conduct financial analysis to determine ROI multipliers for each UAS business case
- **Ph. 2:** Develop initial ROI curves for each category to validate the tool works properly
- **Ph. 3:** Work with Gov’t & Industry to elicit inputs; use to refine tool & validate results

**Results / Benefits:**
- Ability to convert use-case demand values into economic revenue
- Provides insight into which aviation markets provide the largest return on investment potential
- Tool allows different economic multipliers to be used for each unique business case
Sample Results for 2 Representative Use Cases

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Market Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package Delivery</td>
<td>Low Altitude Urban</td>
</tr>
<tr>
<td>Internet Service Provider</td>
<td>HALE</td>
</tr>
</tbody>
</table>
## UAS Demand: Package Delivery

### Use Case: Package Delivery

![Image of package delivery drones](image)

### Supporting Research:

<table>
<thead>
<tr>
<th>Sub Use Cases</th>
<th>Calculated Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parcels</td>
<td>38.5 million per day</td>
</tr>
<tr>
<td>Prepared Food</td>
<td>3 million per day</td>
</tr>
<tr>
<td>Groceries</td>
<td>166 thousand per day</td>
</tr>
<tr>
<td>Flowers</td>
<td>82 thousand per day</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>41.8 million per day</strong></td>
</tr>
</tbody>
</table>

### UAS Demand:

![Graph showing UAS demand over years](image)

**Date Projections:**

<table>
<thead>
<tr>
<th>Start year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> 2019</td>
<td>(Initial ops, trial cases)</td>
</tr>
<tr>
<td><strong>B</strong> 2026</td>
<td>(Regs/Infrastructure finalized)</td>
</tr>
<tr>
<td><strong>C</strong> 2040</td>
<td>(Country-wide ops)</td>
</tr>
<tr>
<td><strong>D</strong> 2044+</td>
<td>(Market saturation)</td>
</tr>
</tbody>
</table>
**UAS Economic Benefit: Package Delivery**

### Assumptions:
- Vehicle design life = 1 yr
- Av. delivery time = 0.5 hrs
- Return/Recharge time = 1.5 hrs
- Utilization = 60%
- Operational days/yr = 365
- Vehicle specifications
  - VTOL
  - Distribution hub to receiving vessels or custom location
  - Distance: 10 mile radius
  - Speed: Up to 50 mph
  - Altitude: 200-500 feet
  - Payload capacity: 5 lbs
- Not Included:
  - Development Costs
  - Infrastructure Costs
  - Sunk costs

### Key Findings:
- Feasible for Business case to close
- Closure timing dependent on customer willingness to pay delivery surcharge
- Other...
Use Case: HALE Internet Service Provider

Economic Benefit:

Key Findings:

- The Internet Service Provider (ISP) Use Case does not close for a single payload HALE system.
- For this Use Case to be viable, consider the following:
  - Add additional payloads to have multiple funding streams.
  - Charge higher service charge (may not be feasible if there are cheaper alternatives).
  - Business case may be limited to areas of world without existing infrastructure.
## UAS Enabled Market Representative Use Cases

### Progress to Date

### TRADITIONAL MARKETS

<table>
<thead>
<tr>
<th>Existing Routes</th>
<th>Airlines- % of Existing Routes</th>
<th>For Hire- % of Existing Routes</th>
<th>Cargo- % of Existing Routes</th>
<th>Gen Aviation- % of Existing Routes</th>
</tr>
</thead>
</table>

### NEW MARKETS

#### HALE
- High Alt. ISP/Comm
- High Alt. Science Monitoring

#### IFR-Like
- New Regional Cargo
- sUAS Monitoring
- ISP/Comm
- Thin/Short Haul Passenger

#### VFR-Like
- New Intermediate Cargo
- Area Science Monitoring
- Area First Responder
- Area Infrastructure Surveillance
- Border Patrol
- Area Science Monitoring
- Area Surveillance

#### Low Alt

- Rural Package Delivery
- Precision First Responder
- Linear Infrastructure Inspection
- Precision Science Monitoring
- Photogrammetry
- Advertising
- Agriculture

#### Urban Passenger
- Urban Air Taxi (Point to Point)
- Urban Vehicle (Owner Operated)
- Urban Commuter (Set Routes)
- Urban Ambulance

#### Low Alt Urban
- Urban Package Delivery
- Urban Surveillance/Traffic/News
- Urban Infrastructure Inspection
- Urban First Responders

#### VLOS
- Aerial Photography
- Security/Emergency Mgmt
- Aerial Filming/News
- Advertising/Entertainment
- Structural/Inspection/Survey

Initial Research | Demand Results | Economic Benefit | Data Validation
Questions

Points of Contact:

Jak Linkel
jak.linkel@mtsi-va.com
703-564-3842

Jennifer Noble
jennifer.j.noble@aero.org
703-812-0614
Only use the 2 slides that follow if we receive the final Cargo economic benefit data in time for the conference.
## Sample Results for 3 Representative Use Cases

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Market Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Package Delivery</td>
<td>Low Altitude Urban</td>
</tr>
<tr>
<td>Internet Service Provider</td>
<td>HALE</td>
</tr>
<tr>
<td>Regional Cargo Transport</td>
<td>IFR-Like</td>
</tr>
</tbody>
</table>
Use Case: Regional Cargo Transport

Economic Benefit:

Key Findings:
- Tbd
- Tbd