32nd Annual American Helicopter Society International Student Design Competition

GT STORK

Georgia Tech

BOEING

METU
A Complete Logistical Solution

- **Detailed route planning** (based on Clarke-Wright Savings Algorithm)
- Minimizes total distance at a **system level** by grouping deliveries
- Provides optimal logistical solution with **maximum cost savings**

**SYSTEM PERFORMANCE METRICS**

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>5,000 pkgs/day</td>
</tr>
<tr>
<td>Flight Time</td>
<td>850 hrs/day</td>
</tr>
<tr>
<td>Aerial Vehicles</td>
<td>140</td>
</tr>
<tr>
<td>Daily Fuel Consumption</td>
<td>1,373 gal (8,239 lbs)</td>
</tr>
<tr>
<td>Operators</td>
<td>8</td>
</tr>
<tr>
<td>Packages/Vehicle/Day (avg)</td>
<td>35</td>
</tr>
<tr>
<td>Maintainers</td>
<td>5</td>
</tr>
</tbody>
</table>
Detailed System Development

- 99.7% delivery rate within 2 hours
- Vehicle dispatch based on package “urgency”
- Improved system utilization rates; reduced vehicle departures with empty storage space

Dedicated maintenance pads
Mechanical arms hold/rotate vehicle for easy inspection
Drainage and ventilation

Storage for 200 vehicles
Package sorting/staging by destination
Real-time status tracking

Human-in-the-loop operation
Dispatch release authority
Automated vehicle loading

Average Delivery Time
96.2% < 90min
3.5% 0.3% > 120min

99.7% delivery rate within 2 hours
Vehicle dispatch based on package “urgency”
Improved system utilization rates; reduced vehicle departures with empty storage space
The right design for the mission

Selected from 11.8 billion combinations to meet system of system needs

Optimized through 7 iterations of design

Vehicle design driven to optimize system level solution
Vehicle Performance

**PRINCIPAL DIMENSIONS**

- **Height**: 2 ft 6 in (0.76 m)
- **Length**: 4 ft 6 in (1.4 m)
- **Wingspan / Width**: 6 ft 7 in (2.0 m)
- **Ground clearance**: 1 ft 5 in (0.43 m)
- **Maximum Gross Weight**: 105 lbs (48.1 kg)
- **Design Gross Weight**: 99 lbs (44.9 kg)
- **Useful Load**: 20 lbs (9.0 kg)
- **Fuel Weight**: 16 lbs (7.2 kg)
- **Empty Weight**: 63 lbs (28.5 kg)

**MAXIMUM WEIGHTS**

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**VEHICLE PERFORMANCE**

- **Installed Power**: 17 hp (11.5 hp = 8.6 kW)
- **DLA-112 Engine (7500 rpm)**: 8.6 kW
- **Lithium Sulfur Battery**: 2.0 Ah (at 37V)
- **Cruise Speed**: 75 kts (138.9 kph)
- **Maximum Range**: 70 sm (112 km)
- **Hover Ceiling (at design GW)**: 7200'/95ºF
- **Hover Endurance (at 6000'/95ºF)**: 2 min (at MTOGW)

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**ROTOR DIMENSIONS**

- **Airfoil Shape**: NACA 0012
- **Radius**: 10.8 in (.27 m)
- **Solidity**: 0.15

**ROTOR PERFORMANCE**

- **RPM (Hover)**: 6100
- **Figure of Merit**: 0.78
- **RPM (Cruise)**: 4745
- **Prop Efficiency**: 0.83
Major Component Layout

- Flight Avionics
- Fuel Tank (3 gal capacity)
- Lithium-Sulfur Battery (2.0Ah)
- Perception Module
- Rotor Hub (with fairing)
- Tilt-Rotor Servo Motors
- DC Motor
- Jack Screw Motor
- Engine Exhaust
- DLA-112 Engine
- Electrical Generator
Innovative Vehicle Design

Folding Front Rotors Reduce Drag in Cruise

Variable Pitch Rotor Hub

Tilt-Rotor Design

Adaptive Controls Robust to Disturbances

Automated Package Handling System

Smooth Hover-to-Cruise Transition

Wing Efficiency in Cruise Flight
Modular Design

- Decreased risk of damage during inspection and troubleshooting
- Easy access panel for maintenance personnel
- Designed to maximize vehicle availability
- Rapid component repair and replacement
- Ready for future upgrades
- Plug-and-play design using commercial off-the-shelf parts
Fitting the Customer’s Needs

DETAILED SLING LOAD MODELING
(24” x 24” package)

Generated using Georgia Tech Aerodynamic Bluff Body Model, v1.2

- Flight profile & configuration minimize oscillation
- Existing vehicle design readily accommodates lateral attachment points

PAYLOAD VERSATILITY

- Weather proof payload container
- Automated package delivery
- Accommodate various package sizes
- Maintain aircraft CG by shifting package positions
- Slingload ready; meets the needs of nonstandard package dimensions
Avionics for the Urban Environment

**SENSORS**

- GPS for primary navigation
- Stereo cameras provide see-and-avoid obstacle detection
- Image map-matching provides navigation during degraded GPS operation
- Laser rangefinder for approach/departure obstacle clearance
- On-board mapping of local area terrain and static obstacles

**COMMUNICATION**

- 3G/4G antenna utilizes existing urban infrastructure
- Continuous status tracking
- Dynamic retasking capability
- Health monitoring and emergency conditions relayed to operations center
- Human-in-the-loop provides operator override of hazardous conditions
Environmentally Friendly

- Low acoustic signature in all modes of flight
- Design supports initiatives for “friendly flying” near populated areas
- Minimal noise pollution relative to typical urban environment

HYBRID-ELECTRIC POWER

Use of internal combustion engine (ICE) plus battery power during peak power demand phases (hover)

Battery recharge during low power demand periods (cruise)

Reduction of emissions

Battery provides 2 min of flight power during engine failure

Battery power during ground operations; enables receipt of commands from operations center
Safe, Cost-Effective Solution

3-Year Life Cycle Cost: $28,645,487

Personnel - $11,700,000
Development - $10,785,075
Fuel - $5,460,412
Acquisition - $1,960,000

SAFETY FEATURES

- Redundant power sources (internal combustion and battery)
- Excess power provides safe landing during emergency
- Tilt-rotor reduces delivery time while retaining hover capability
- Variable pitch hub for responsive control input and optimal settings during hover/cruise
- Variable RPM provides control during fixed pitch condition
- Onboard database of nearest safe landing areas

Failure Rate Modeling Using Abridged Petri Nets
The innovative answer to tomorrow’s delivery needs