Logistics Support UAS Platform

Problem:

Go-anywhere, on-demand delivery is cost-prohibitive.

Background:

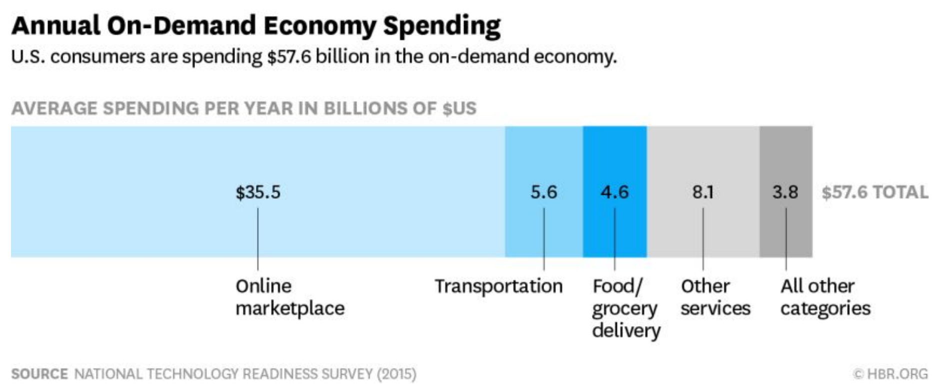
The global market for logistics surpassed $4 trillion in 2015.(1) The goods we use each day are part of a complex global supply chain. The most critical part of this supply chain is the “last mile,” comprising roughly one-quarter of the cost of everything we consume.(2)

The largest growth in logistics has come from on-demand direct delivery. Customers are increasingly willing to bear the high costs of vehicles like helicopters for logistics, something that was traditionally reserved for emergencies and exceptionally valuable cargo.(3) As a result, over $300 billion has been earmarked for helicopter procurements over the next decade.(4)

Demand for a helicopter-like vehicle at reduced size, cost and risk has not gone unnoticed by public or private industry. However, no vehicle has been able to meet the primary requirements of these rising market demands.(5)

Discussion:

Direct delivery was once reserved for emergencies and exceptionally valuable cargo, but it is now quickly becoming mainstream as part of the On-demand Economy. The rapid growth of on-demand delivery has brought on a confluence of new vehicle requirements. Skylift competes with the capabilities of helicopters and the costs of traditional ground transportation. These requirements will be defined and explained. We do not discuss the details of the payload pickup and delivery process.



Cost: **$1 per Mile**

There is a large gap between the cost of on-demand delivery and regular delivery. The USPS custom van, known as the Long Life Vehicle (LLV), can achieve a cost of only $0.33 per mile for regular deliveries, but the cost of Amazon's on-demand Same Day Delivery service jumps to $1.10 per mile.[(6)(9)(Appendix B)] These ground vehicles represent an industry pricing benchmark.

This cost differential stems from the difference between a single vehicle making multiple scheduled deliveries along an optimized route and a single vehicle making a single direct delivery to a single customer. The primary cost drivers are driver wages and fuel.[(Appendix A)] For these reasons, Amazon's Prime Air drone delivery program believes that they can offer on-demand drone deliveries for $0.75 to $1 by eliminating these factors.[(8)] Each drone delivery would equal the cost per mile of Same Day Delivery service, however, the technology to achieve this does not exist today.

If on-demand delivery costs could compete with current Same Day Delivery costs at around $1 per mile, market research indicates that 29% of online customers would be interested.[9][22] Instant delivery would significantly increase the value of a purchase for 9% of online customers.

Time: **Under 45 min.**

On-demand does not always mean instant. On-demand traditionally means "when required," which is achievable even with inefficient last mile delivery through the use of inventories, predictive modeling, and scheduling.

In the On-demand Economy, instant delivery is defined as 15-45 minutes. To truly disrupt traditional supply chains, a go-anywhere, on-demand delivery solution will need to offer both scheduled and unscheduled instant delivery.

This online-offline integration is key to achieving the frictionless transactions and user experiences the On-demand Economy requires. Usability is critical for a premium convenience. Solutions to cope with the burden of accelerating inventory and demand modeling, as well as transparency throughout the delivery process, are becoming increasingly robust.

Range: **30 Miles**

The term "last mile" is not literal, instead, it refers to the last leg of delivery. According to the United States Postal Service (USPS), 91% of "last mile" deliveries are under 30 miles.[6] This calculation was done using an optimized route plan and would represent a shorter distance for aerial vehicles engaged in direct delivery. Because UAVs utilize a direct path, known as the Haversine Distance, they are an average of 42% more efficient than ground transportation.[5] Nonetheless, we use 30 miles as a conservative estimate for a vehicle's minimum required range. This would translate to 60 miles roundtrip.

Payload Capacity: **150 pounds**

No vehicle can tackle the on-demand logistics hurdle without sufficient payload. We focus on Parcels with weights under 150 lbs., which are the highest volume weight class. Parcel delivery is a $242 billion global industry.[11]

Cargo carriers use a system of three primary weight classes:

- Full-truck-load (FTL) - items large enough to require a semi-truck
- Less-than-truckload (LTL) - items over 150 lbs. and smaller than FTL
- Parcel - items under 150 lbs.

For context, the USPS LLV has a maximum payload capacity of 1,000 lbs. and could carry up to six 150-lb. parcels.[6]

Aerial Vehicle: **VTOL, Autorotation**

There is an inherent conflict with on-demand delivery volume and other traffic on roadways. Peak demand for delivery occurs at the same time as peak traffic congestion. Aerial vehicles do not require road infrastructure, making them an ideal way to avoid hazards or route congestion.

An average UPS LLV takes 6.5 hours to cover a 20.8-mile route. The optimal cruising speed of an LLV is 55 mph, but the routes take four times longer due to traffic congestion. Time spent parked during physical delivery is the most time-intensive part of the delivery process. An aerial vehicle can eliminate these primary drivers of time and cost.

Time spent driving:	1 hr 30 min	(23% of the time)
Time spent stopped:	3 hrs 50 min	(59% of the time)
Time on break:	40 min	(10% of the time)
Pre/Post route drive time:	30 min	(8% of the time)

There are two leading types of aerial vehicles; Fixed-wing and Vertical Takeoff and Landing (VTOL).

Fixed-wing aircraft, like an airplane, are the most efficient. They use long wingspans to create lift when in motion. Unfortunately, they have a minimum control speed or v-speed. Below this minimum speed, you will lose control of a fixed-wing aircraft. It is possible to fly over a target and release a parcel with a parachute, but the inaccuracy and unpredictability of this approach present unresolved safety challenges.

Vertical Takeoff and Landing (VTOL):

Helicopters represent the standard for VTOL vehicles. They have the ability to operate at slow speeds, hover in place, and land on small platforms with precision. A helicopter could perform on-demand direct deliveries and replace the use of an LLV, if not for some practical problems.

Helicopters are large because they were designed to accommodate pilots and passengers. They are among the noisiest and most dangerous aircraft in our skies, roughly 85 times more dangerous than automobiles.(10) In addition to the risk, helicopters are costly to operate and suffer from a deficit of skilled pilots. Autonomous helicopters like the Lockheed Martin K-Max have tried to address these issues, but fail to address all of the inherent costs and risks of dated helicopter design. This is primarily because the have the same high maintenance costs and primary point of failures, like their swashplate system.

The prohibitive costs and risks associated with helicopters have led to an understandable interest in Unmanned Aerial Vehicles (UAVs), commonly called “drones.” (Appendix C) At first glance, these smaller VTOL aircraft appear to address the primary cost drivers of on-demand delivery. Except, while UAVs address the risks of having an onboard pilot, they do not offer important safety and reliability features like autorotation.

Autorotation:

Autorotation is a proven safety feature commonly found on helicopters. Instead of engine power driving the main rotor system, the rotor blades are spun at enough speed to generate lift by the action of air passing up through the rotor blades as the vehicle descends. Aircraft equipped with this mechanical failsafe can safely navigate and land even if they lose power. All that is required is sufficient air density, gravity, and the ability to find an acceptable landing area.

Autorotation is ideal for logistics because the heavier the payload, the slower the vehicle will descend when this safety feature has been triggered. The primary risk of current UAVs for logistics is their tendency to fall out of the sky or lose control due to loss of power or digital failure. The majority of UAVs cannot implement autorotation because it does not work in combination with fixed-pitch rotor blades.

Variable-pitch rotor blades can be applied to UAV design to allow for autorotation. However, no UAV has combined the required capabilities outlined in this discussion into one vehicle which makes On-demand Delivery viable.

Autonomous Delivery: **Autopliot, Sense & Avoid, Redundant Communications, Air Traffic Control**

Autonomous vehicles are leading a well-publicized revolution in land-based transportation, but an even greater autonomous revolution is taking place in our skies. Autopilots have long been a safety standard in aviation, and now, registrations for unmanned aircraft outnumber manned aircraft in our National Airspace (NAS).

The Federal Aviation Administration (FAA) has already designated the 200 – 400 ft. agl airspace as the "Drone Superhighway." The National Aeronautics and Space Administration (NASA) is developing the Unmanned Aircraft System (UAS) Traffic Management system, or UTM, to manage the flow of traffic operating in this portion of the NAS. It will eventually integrate with the FAA's NextGen Air Traffic Control system.[(13)]

Over 90% of helicopter accidents are due to pilot error.[(11)] Our government is developing these traffic management systems because they recognize that autonomous vehicles are the best way to simultaneously address both the high cost of pilot wages and the risk of pilot error. However, these systems do not solve all of the challenges associated with autonomous flight and there is a combination of technologies that must work together to develop a fully autonomous system for on-demand direct UAV delivery, without a man-in-the-loop required for mission execution.

Autopilot:

The first component that an autonomous UAV requires is an autopilot. The autopilot is the onboard brain of the vehicle. It gives the UAV the ability to coordinate all of its technologies together into one system capable of unmanned flight.

Sense & Avoid:

Sense & Avoid is a combination of sensors and software used to avoid a collision. This technology is designed to work at any speed, but the majority of hazardous obstacles occur below 200 ft. agl. This critical feature reduces risk during takeoff and landing, as well as when working with manned teams and other connected devices to perform deliveries.

Redundant Communications:

Autonomous delivery requires a two-way communications system that will connect all vehicles operating at a variety of ranges from a variety of control inputs. Beyond Visual Line of Sight, or BVLOS, operations require a reliable and redundant system of communications. In order for a UAV to go-anywhere, it requires connectivity from anywhere. Disruption Tolerant Networking (DTN) allows for UAVs to operate with intermittent signals, but an On-demand Delivery system would require persistent connections.

To ensure that UAVs stay connected when making go-anywhere deliveries, two communications technologies will be required; cellular networks and satellite-based communications.

Cellular networks are pervasive and relatively reliable. Today’s cellular networks provide coverage at distances of 5 miles, or 26,400 ft. These networks can easily provide primary connectivity for UAVs operating below the 500 ft. agl limits imposed by the FAA in the NAS.[(15)]

Satellite-based communications over networks like the Iridium constellation can provide secondary backup when vehicles travel outside of areas with sufficient cellular network coverage. In some operating environments or higher altitudes, this more costly communications option would become the primary communications network.

Air Traffic Control:

NASA UTM and FAA NextGen are excellent sources of information, but in order to operate a fleet of fully autonomous UAVs, all of the data from proprietary and public sources needs to be integrated into a comprehensive Air Traffic Control system (ATC). The resources for this system would reside in the cloud and rely on redundant communications to provide important environmental warnings, like airspace updates and weather data, to the autopilot. Communications would also aggregate data onto a central database where data from each vehicle would be stored. This data would then be assimilated to create a comprehensive, proprietary air traffic control system running in an instance on a hosted cloud.

The goal is to build an operational fleet of networked Unmanned Aircraft Systems (UASs), as opposed to individual or isolated UAVs.

Significant strides have been made in the technology of autonomous flight and navigation, but there is only one active autonomous delivery network operating in the world. That system uses a fixed-wing aircraft to deliver emergency medical packages in Rwanda.

Opportunity:

Humanitarian Aid and Disaster Relief (HA/DR) is an excellent application and point of market entry for direct on-demand UAV delivery. The high concentration of cost and risk makes such innovative technologies practical at a higher price point. The FAA also allows HA/DR organizations to employ the use of Public Status aircraft, which means that they are not limited to the use of commercial UAVs under 55 lbs.

Because HA/DR logistics refers to the processes and systems involved in mobilizing people, resources, skills, and knowledge to help vulnerable people affected by natural disasters and complex emergencies, the need for a systems approach, or global view, of the entire relief effort is critical to managing the web of interrelated mission segments. In the systems approach, all functions or activities need to be understood in terms of how they affect and are affected by, other elements and activities with which they interact.[16] These unique requirements raise the bar for market entry, requiring an operational fleet of UASs.

There are three industry-specific requirements that make the use of UASs a compelling option.

Disaster Relief Supplies:

The primary logistics challenge in Disaster Relief is the deployment of Survival Packs immediately following an emergency. The contents of these packs are customized based on a review of disaster intelligence and media reports. Health Service Support (HSS) uses situational analysis to determine whether Survival Packs need to include First Aid Kits.

Standard Survival Pack Contents:

- Empty 10-gallon water containers
- Blankets
- Lumber and plastic sheeting for shelter
- Food
- Water bladders or potable water pillow tanks (PWPTs)
- Reverse osmosis water purification units (ROWPUs)
- Water pump for removal of contaminated well water

Water is the most essential resource for survival. The most compact lightweight ROWPUs can produce around 1 gallon per minute and weigh under 250 lbs. This is critical when calculating the minimum payload requirements for an HA/DR logistics vehicle because the use of multiple vehicles or multiple deliveries cannot reduce the minimum required payload below the 200 to 250-lb. weight of the ROWPU.[17]

Demand Signal Response:

Events unfold at a rapid pace during and immediately after a disaster. The tendency is for outside agencies to send more than is needed, which itself creates large management and logistics challenges. Continuous dialog is required to ensure that the right support arrives in a timely manner. This requires a system of measuring and prioritizing Demand Signals throughout the affected area.

In order to manage this complexity, it is essential to have bulletproof communications and Demand Signal data to act quickly and dynamically. The ability to coordinate meaningful disaster response determines the mission’s success.

Infrastructure Voids:

Disaster scenarios disproportionately affect areas with limited or no infrastructure. Even in nations with robust communications and transportation development, those assets are typically disrupted in a disaster. Extensive dedicated helicopter support is usually required for the delivery of Survival Packs and movement of assets. Teams of schedulers work around the clock to maximize the use of these helicopters because delays cost lives.(18)

Solution:

Skylift has made 20 key, patent-pending breakthroughs in UAS technology. Our innovative rotor system allows more efficiency from the same specific power output. We are currently developing the first UAS to combine all of the required capabilities for go-anywhere, on-demand delivery. The Atlas 200 will be the commercial version of this vehicle designed to meet the logistics demands of the HA/DR missions.

Skylift has achieved many milestones in heavy-lift UAS design, aviation, and testing. We are now in the second iteration of our Phase II prototype. This UAS is capable of safely carrying 100-lb. payloads for 6.5-minute flights using consumer grade components.

Current Prototype ("Phase II")

(Consumer grade components)

- 50 lbs. (without batteries) or 85 lbs. (with batteries)
- Reliable 100-lb. payloads
- 2 mi. range at max payload
- 6.5 min. flight time at max payload

We are developing the next stage of this project as part of a collaborative CRADA agreement with the Naval Postgraduate School. Leveraging their assets and resources will allow us to economically develop a production vehicle capable of performing autonomous pickup and dropoff tasks. The production vehicle will be fully commercialized under public status by NAVAIR and developed under the guidance of the FAA Los Angeles Aircraft Certification Office (ACO) and the Los Angeles Manufacturing Inspection District Office (MIDO).

Production Vehicle ("Atlas 200")
(Proprietary components)

- Microturbine powertrain
- 200-lb. payload
- 65 mi. range at max payload
- 1.5 hr. flight time with max payload

Team:

The Skylift Team was founded to meet R&D challenges for the California Institute of Technology. For over two decades, our engineering team has been working on some of the automotive and aerospace industries' greatest challenges. We have the ability to design, build and test in-house.

- Reza Nemovi is an international award-winning pilot of Unmanned Aerial Vehicles (UAV) and Remote Control (RC) vehicles.
  - Builder of the first electronic conversion kit for RC helicopters
  - Creator of the drone that carried Lady Gaga at her concerts
- Robert Bartlett has 30 years of experience in motorsports with Nissan, Toyota and Porsche across multiple race series.
  - Contracted to design aircraft carrier testing model for US Navy
  - Advanced materials manufacturing for NASA Johnson Space Center

Together, their innovative vehicles are disrupting traditional aircraft design with UAV technology.

Facilities & Resources:

Skylift's corporate office is located in San Diego, CA. Our state-of-the-art R&D facility and test ground are in Kalispell, MT. This enables us to produce entire airframes in-house and minimizes our product iteration cycles. We leverage these resources to maintain the fast pace of constant innovation required to continually reduce our clients' downtime and support our vehicles for longer service cycles.

Sponsors and Collaborators:

Activities and Events:

Skylift will be demonstrating our prototype and participating in the JIFX 17-2 Event from February 13-17, 2017 at Camp Roberts. Please check our website at skyliftglobal.com for the latest updates, upcoming events, and demonstrations.

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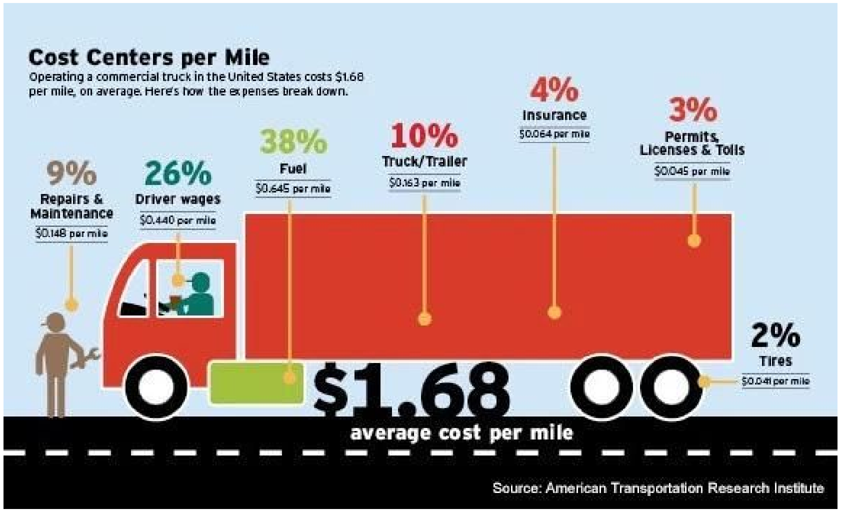
Appendix

A. Cost Centers per Mile of Trucks



B. Amazon 3PL Last Mile Logistics Costs[7]

Variable	Assumption
Average Courier/messenger average annual salary	$48,200
Fringe Benefit Rate	45%
Fully Burdened Driver Annual Salary & Benefits	$69,890
Annual Operating Days per Year	252
Weighted Average Hourly Wage Rate	$23.91
Fully Burdened Driver Cost per Hour	$34.67
Fully Burdened Cost of Driver Labor for One Day	$277.34
Length of Delivery Vehicle (Feet)	24
Variable Cost per Mile to Operate Vehicle (Excludes Driver)	$1.10

C. Cost Centers per Mile of Helicopters