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RPPR Final Report

as of 16-Aug-2022

Agency Code:

Proposal Number: 77602SDICR

Agreement Number: W911NF-20-1-0331

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Report Date: 30-Sep-2022

Date Received: 15-Aug-2022

Final Report for Period Beginning 15-Sep-2020 and Ending 30-Jun-2022

Title: Palledrone: Unmanned Aerial System Solution for Last-Mile Logistics Applications

Begin Performance Period: 15-Sep-2020

End Performance Period: 30-Jun-2022

Report Term: 0-Other

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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 1

STEM Participants: 1

Major Goals: As stated in the project solicitation, the goals of the I-CORPS @ DoD program are to; 1- Spur the transition of fundamental research with potential defense relevance to the marketplace 2- To encourage collaboration between academia and industry 3- And to train students, faculty, and other researchers to understand innovation and entrepreneurship. The program also has three desired outcomes: 1- A clear go/no go decision regarding viability of products and services 2- Should the decision be to move the effort forward, a transition plan to do so 3- An understanding of what kind of minimum viable product demonstration would be required by key partners and customer segments.

The research team has worked toward the stated goals and made progress as presented in the accomplishments section of this report.

Accomplishments: Reporting Period Jul 31, 2021 -Jul, 31, 2022

During the reporting period, the team had several accomplishments that can be broken into the categories of business development and fundraising, customer discovery and technical. The work undertaken directly benefited from the NSF I-CORPS experience.

Business Development & Fundraising

During the reporting period, the team has worked with the Atlanta Technology Development Center (ATDC) to develop financial projections for the commercialization of Palledrone. The team also worked with ATDC to develop a pitch deck and have pitched to several seed and pre-seed investors such as In-Q-Tel, Kern Venture Group, Salt Lake City Ventures, Scout VC, Anzu Partners, and several angel investors. The final pitch deck can be seen in the supporting documentation. The team also partook in a number of incubators and accelerators such as the Rice Business Plan Competition, the Creative Destruction Laboratory, and the Black Ambition Prize Competition. Each of these pitches/events has allowed the team to strengthen their argument for the commercialization of Palledrone.

Customer Discovery

Along with strengthening the commercialization argument for Palledrone, the team has worked with ATDC and secured two distributors (C4i Communications and Engineered Robotics) that are interested in selling and procuring customers for Palledrone as a tactical resupply drone and a weaponized precision engagement drone. These distributors operate in 14+ countries. The team has also received a Letter of Intent (LOI) from C4i for three

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Palledrones, which equates to roughly \$810,000 in revenue. However, the LOI requires that the team demonstrates an improved Palledrone with 30 miles of range with a 100 lb payload. The current prototype, Palledrone-RX, is battery-powered and can carry 100 lbs up to 5 miles. In order to satisfy the requirements of the LOI, the team must raise roughly \$1.0 M in funding to develop an improved Palledrone, Palledrone-EX. Palledrone-EX will be equipped with a gas-powered engine along with smaller batteries, which will allow the vehicle to carry 100 lbs of cargo up to 30 miles.

The team has also gained interest from the U.S Military during the Joint Interagency Field Experimentation (JIFX) event. During this event, the team's current heavy-lift UAS prototype, Palledrone-RX, completed several flights with 50 and 100 lbs of cargo. A simulated belt-fed machine gun was also attached to the vehicle to demonstrate the vehicle's ability to be weaponized. The last flight that Palledrone completed at JIFX was a roughly 3 mile flight carrying roughly 25 lbs of cargo. During this flight an electrical issue caused the vehicle to land prematurely. The team has since investigated this issue and is now making changes to Palledrone-RX so that the issue does not occur again. Outside of gathering valuable flight data, the demonstration provided the team with the opportunity to speak with representatives of the U.S. Army's Robotics Research and Development center (Carlos Legoas), the U. S. Navy's Sealift command as well as private companies such as AT&T's Drone Operations Department and Microsoft's Digital Advisor, Dave Nobles. Although these groups were interested in a heavy-lift UAS, they were not able to provide the funding needed to create the next generation Palledrone, Palledrone-EX. The majority of these groups also stated that a longer-range vehicle is needed, on the order of 20+ miles.

Prior to JIFX, the team had several conversations with potential customers such as DroneUp, Walmart, UPS, and Target. These companies showed interest in using heavy-lift drones for commercial less-than-truckload logistics (LTL); however, they were not interested in pilot programs or funding the project unless the vehicle had all of the FAA certifications necessary to deliver LTL packages. At the time, no companies had successfully completed all of the FAA certifications needed for package deliveries using drones over 55 lbs.

Technical

During the reporting period the team has collected over 8 hrs of flight time using Palledrone-RX. Several tests aimed at varying the performance of Palledrone-RX have been completed. These test include hover endurance with 110 lbs, rotor failure fault tolerance, robustness to external disturbances and robustness to communication losses. One of the tests, the hover endurance test can be viewed using the following link: <https://youtu.be/bLHAaJxoLIY>. These results of these tests showed that palledrone can hover with 110lbs of payload for roughly 8 minutes, which in forward flight would equate to a range of roughly 5 miles. Tests involving the vehicles ability to maintain flight when communication to the ground control system and the transmitter are disconnected were successful, meaning the vehicle can complete a mission without communicating to either device. Physical robustness tests proved that the vehicle could withstand a motor failure and damage from foreign objects without resulting in a crash that totaled the vehicle.

During the reporting period, the team has implemented a unique rotor configuration and control system onto Palledrone-RX that allows the vehicle to rotate without translating and translate without rotating. This combination of this rotor configuration and control system is called Direct Force Control (DFC). DFC has been studied in the past by the members of the team but to the team's knowledge, Palledrone is the largest vehicle that DFC has been implemented on. Tests showing Palledrone using DFC can be seen here: <https://www.youtube.com/watch?v=y0-qE5LhqrA>.

Electrical issues became apparent after numerous flights with durations over 12 minutes. These issues became more clear when the vehicle is placed in an area with a significant amount of fine sand particles. The current hypothesis is that there are some electrical interference caused between the vehicle's batteries and its motors. The vehicle uses carbon fiber propellers, which when operating generate static electricity that is believed to be causing some sort of interference involving the Electronic Speed Controllers. This electrical interference results in one or more motors shutting off during flight. This phenomenon is more apparent when operating in heavily sandy areas, which the team believes to be due to the fact that more static electricity is created due to the vehicle's rotors colliding with the sand particles. This issue is discussed in a paper published in the AIAA aviation forum [1].

Summary

Although the team made great strides in developing Palledrone and generating interest amongst customers and securing a Letter of Intent for three drones, the Venture Capitalists that we spoke to did not have confidence in the

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market. As previously mentioned, the current prototype of Palledrone, Palledrone-RX, does not have the range needed for our potential customers. Funding of roughly \$ 1M would be needed to continue the Palledrone project. The team is currently applying to grants such as the NSF Seed-Fund in order to continue the project.

References

[1] Epps, J. T., Bershadsky, D., Haviland, S., Johnson, E. N., and J. Irizarry (2022). The development and flight testing of a group-3, ultra-lift, UAS for the research and development sector. In AIAA AVIATION 2022 Forum (p. 3636).

Training Opportunities: Nothing to Report

Results Dissemination: The team disseminated related technical work at the 2022 American Institute of Aeronautics and Astronautics (AIAA) Forum.

Epps, J. T., Bershadsky, D., Haviland, S., Johnson, E. N., J. Irizarry (2022). The development and flight testing of a group-3, ultra-lift, UAS for the research and development sector. In AIAA AVIATION 2022 Forum (p. 3636).

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: The team submitted a patent application for Semi-Coaxial-B Configuration. The application document can be found as a PDF upload.

PARTICIPANTS:

Participant Type: PD/PI

Participant: Javier Irizarry

Person Months Worked: 4.00

Project Contribution:

National Academy Member: N

Funding Support:

CONFERENCE PAPERS:

Publication Type: Conference Paper or Presentation

Publication Status: 1-Published

Conference Name: AIAA AVIATION 2022 Forum

Date Received: 15-Aug-2022 Conference Date: 27-Jun-2022

Date Published: 01-Jul-2022

Conference Location: Chicago, IL & Virtual

Paper Title: The development and flight testing of a group-3, ultra-lift, UAS for the research and development sector

Authors: Epps, J. T., Bershadsky, D., Haviland, S., & Johnson, E. N.

Acknowledged Federal Support: **N**

PATENTS:

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Intellectual Property Type: Patent

Date Received: **15-Aug-2022**

Patent Title: Semi-Coaxial-B Configuration

Patent Abstract:

Patent Number: 63/268,010

Patent Country: USA

Application Date: 15-Feb-2022

Application Status: 1

Date Issued: 01-Jan-2001

Partners

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I certify that the information in the report is complete and accurate:

Signature: Javier Irizarry

Signature Date: 8/15/22 10:05PM

Georgia Institute of Technology
Final Report Supporting Documentation
Grant Number W911NF-20-1-0331
Javier Irizarry, Ph.D., P.E. Project Director/Principal Investigator

ROTOR X Palledrone Pitch Deck

ROTOR X

Seeking \$ 1M in funding

On time, on target logistics

www.rotor-x.us

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CONFIDENTIAL

ROTOR X

The Problem

Air support is scarce and expensive

Air support provides a drastic advantage on the battlefield



- Traditional attack or scout helicopters can cost tens of millions of USD to buy and operate
- Skilled pilots hard to find
- These factors lead to the demand of air support being high but the supply being limited

Traditional resupply methods can cost lives

60% of U.S. combat casualties (2013) were related to resupply operations



- 78% of infantry soldiers do not feel confident with current resupply systems
- Combat air support does not usually provide logistics support
- Resupply using wheeled vehicles can be dangerous and slow due to IEDs
- **Current events shows logistics is king: poor logistics is costing Putin progress in his war on Ukraine**

Small drone platforms only provide ISR

Current drones have small cargo capacity, thus reducing functionality



- Current drones are only equipped for ISR
- Only a few heavy lift drones exist but they aren't fielded

2

The Solution: Palledrone-EX

Resupply

- 30 mi w/ 100 lbs of cargo
- 205 mi w/ 10 lbs of cargo
- VTOL: No runway needed
- Fully autonomous
- ISR capable
- BVLOS communications
- Encrypted transmission signal
- Wide angle camera



Combat

- Gimbaless precision target engagement
- 7.62 machine gun (e.g., M60 x 1,500 rds)
- Automatic grenade launcher (e.g., Mk47 x 60 rds)
- Rocket pod (e.g., Hydra x 6 rfts)
- Smoke Pot (e.g., M4A2 x2)
- Loitering munition/mothership
 - 12 x Switchblade 300
 - 2 x Switchblade 600
 - 1 x loitering munition with up to 100-150 lbs warhead (warhead roughly equivalent to AGM-65)



Competitive Advantage

Multi-functional

Tactical resupply and target engagement



- No COTS heavy-lift drones available
- Easy loading and unloading of cargo
- Novel power efficient rotor configuration increases flight range, durability

Patented Technology

Efficient rotor configurations
Unique maneuverability



- **Direct Force Control** eliminates need for large gimbal for precision target engagement
- **Patented efficient rotor configuration**

Advisors

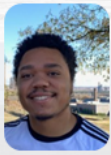
Advisors from major companies in the industry



Leading manufacturer of military UAS

- RotorX have advisors at large mobility organizations such as Mitsubishi Electric and AeroVironment
- RotorX is in the process of forming partnership with key industry players

Team



Jeremy Epps

Georgia Tech Ph.D. candidate in aerospace engineering, 6+ yrs of experience in UAS



Stephen Haviland

Georgia Tech Ph.D. candidate in aerospace engineering, 10+ years of experience with UAS



Dmitry Bershadsky, Ph.D

Ph.D. in aerospace engineering from Georgia Tech, Lockheed Martin, 15+ years of experience with UAS



Tyler Magruder

Sales Leader 25 years of domestic and international sales



Lam Tran

Business development with 15+ years working with high growth startups

Where our work has gone



Progress

Palledrone-RX



Battery powered prototype
 ✓ 100 lbs @ 5 mi

Palledrone-EX

Internal combustion engine
 range extender
 100 lbs @ 30 mi



Palledrone-MGK



Added belt fed firearm,
 rocket propelled and other
 munitions

Competition

Company	RotorX	Malloy (UK)	Harris Aerial	Bell	Elroy Air
Max Payload (lbs)	150	400	50	100	500
Max Range (mi)	205	43	120	35	300
Fault-tolerant/ GPS-denied/ Repair Speed	+++	+--	---	---	---

Joint Interagency Field Experimentation



Palledrone prior to takeoff at JIFX 2022



Palledrone carrying 100 lbs of payload while at JIFX



Palledone with a simulated belt-fed firearm attached



Palledone flying with a simulated belt-fed firearm attached