SimpleUAVs

SimpleUAVs Heavy Lift Multi-Copter Proposal

Unmanned Aerial Systems Flight and Payload Challenge

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ABSTRACT

The Unmanned Aerial Systems Flight and Payload contest is for a heavy lift RPV / UAV that can demonstrate takeoff, climb to 50ft of altitude and transition to a test area, hover for as long as possible, then return to land at the takeoff location. As my entry to this competition I propose to do the following.

I will design, build, and test multirotor UAV/UASS similar my existing test platform design but much larger as follows:

- The proposed UAV will be of an electric powered ultralight carbon and 3D printed X8 octo-copter design using 8 high-efficiency out-runner brushless motors with lightweight folding carbon propellers on dual power systems for redundancy.
- The flight controller will be a PIXHAWK 2.1 or DJI A3 and GPS with Futaba RC T-FHSS radio control.
- A backup radio link be used in case of emergency to disable the UAV power systems and to deploy an BRS to ensure a safe recovery in case of in-flight catastrophic failures.
- The UAV will FPV and contest specified video cameras and RF transmitters, as well as on-board video recorders.
- All ground support equipment required for safe UAV operation.
- Fuel Cell power systems from Ballard Power are being considered but are not included in the proposed UAV design because I need to gain familiarity with the system and do not have pricing information available at this time. If included expected flight times would triple.

The expected performance of the proposed UAV with contest specified payload weights is:

- 25 minutes hover time with 10lb. payload
- 35 minutes hover time with 15lb. payload
- 45 minutes hover time with 20lb. payload

Note: *Larger payloads could be carried but the all-up-weight would exceed the 55lb limit.*

I can build the proposed UAV system (UAS) in 2-4 weeks depending on other commitments (I am also submitting to the HeroX/Boeing PAV design contest) and vendor stock. Testing and video production per the contest rules will take 2 more weeks, weather permitting.

I have been designing, building, and operating multi-rotor and fixed wing AUVs for film, photo, news gathering, SAR, survey, and emergency relief missions worldwide for over 7 years, almost all my own design. I have a software, a shop, and the equipment required to design and fabricate almost anything in-house. And I am a pilot (though out of currency), and AMA member of long standing, and I can get a 107 endorsement when required. I have the experience and expertise (or have it in-house) to be meet the requirements of this contest. I hope I'll have the opportunity to do so and advance to Phase II and III.

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Project Description

Shortly after Hurricane Maria struct Puerto Rico emergency relief supplies started arriving in the port, but could not be delivered to where they were needed the most. The hurricane devastated the infrastructure (roads, power grid, phone lines, bridges, etc) of the island making it nearly impossible to get to most of the island at all, let alone in trucks. And the terrain precluded relief air drops for the most hard-hit areas. It was weeks, sometimes months, before the many areas received even the most basic of supplies: food and water.

Watching the news reports of the devastation of Puerto Rico caused me to reflect on a project we did for the Thai army following the devastating floods of 2011, the design of a Heavy-Lift Multi-Rotor UAS that could deliver emergency supplies to areas cut off by the floods. That design was for a 16 rotor H-frame that could left 50kg and transport it 10 miles and return via First Person View (FPV) RC control.

Last November I decided the launch a project which would eventually develop a very large vehicle roof mounted multi-rotor. This UAV was designed to autonomously deliver 100kg of relief supplies 20 miles over hostile terrain, and that could also be reconfigured for terrain mapping, search and rescue (SAR), and small fire fighting. The project consisted of 3 phases.

- Phase 1 consists of a small carbon and 3D printed TPU Octo-Copter (8 rotor) with an open frame which would be used to develop the required software, ground control systems, and procedures. This Octo-Copter has been built and is currently flyable.
- Phase 2 consists of an all metal 55lb max takeoff weight vehicle roof mountable Octo-Copter that would be legal to fly under AMA rules. The design criteria for this phase is a UAV that can lift 10kg and fly LOS and minimal BVLOS via FPV. This UAV has been designed, but construction has not yet started.
- Phase 3 consists of the Very-Heavy-Lift carbon molded vehicle roof transportable Octo-Copter capable of carrying 100kg of relief supplies 20 miles autonomously, all ground support systems, and off-road or military vehicle integration.

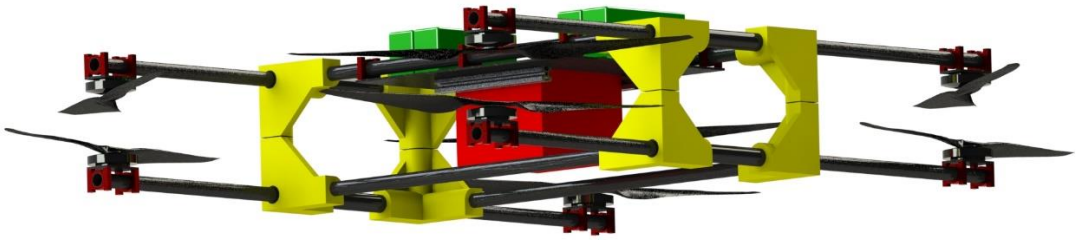
But I've run into a funding problem. I've funded Phase 1 myself, but cannot continue to Phase 2 or Phase 3 without external funding. Then I found out about this contest and realized that a modified version of my Phase 1 design had the potential to win the competition.

The Design

The proposed UAS for this contest is an open H-frame octo-copter that:

- Is all electric, powered by off-the-shelf Li-Ion batteries of more than 20000mAh capacity (varies depending on load)
- Uses 8 1000W class motors with 27-30 in diameter 2 or 3 bladed high efficiency carbon fiber folding propellers
- Has a H-frame built of carbon tubes, carbon plate, aluminum machine brackets, and 3D printed parts out of PetG, ABS, carbon, steel, and TPU.

- Is based on a Pixhawk 2.1 flight controller, IMU, and uBlox M8 or better GPS (with DJI A3 as backup)
- Uses Futaba or FrSKY S-Bus FHSS based RC (I currently use both) for positive control
- Is capable of mounting and controlling an NEX size or smaller gimbal
- Can autonomously complete any programmed mission including autonomous takeoff and landing
- Has a dedicated end-of-flight radio system that cuts power and launches a ballistic recovery parachute (BRS) on command or in case of a catastrophic on-board failure
- Has mounting points for contest payloads as defined in the contest rules
- Has permanently mounted HD First-Person-View camera and wireless transmitters
- Has real-time telemetry, flight status, programming, and control wireless radio model links to ground station.
- Can controllably land safely with any single failure of an IMU, GPS, Motor, ESC, propeller, battery, power system (degrades to quad-rotor), or frame component and with any dual failure of motor, propeller, esc, or GPS system.
- Video cameras and downlink as required by contest rules



Rough Design of Proposed Octo-Copter

The proposed UAS will include the following ground support equipment:

- Mission control case mounted system including control computer, joystick interface, wireless modem for control and telemetry, and mission video display as required by the contest rules.
- Tracking antenna array and omni-direction antennas for diversity telemetry and video downlinks
- Futaba or FrSky 2.4 GHz RC transmitter capable of no less than 14 independent channels. 433 MHz can be used if BVLOS long range flight is require
- Sufficient battery chargers required to charge one set of flight batteries in less than 1 hour
- Sufficient spare batteries for 3 consecutive flights

According to my calculations (using eCalc.com) the proposed UAS system will be capable of:

- Flight time of 25 minutes with 20 lb. payload plus takeoff, transition, and landing.
- Flight time of 35 minutes with 15 lb. payload plus takeoff, transition, and landing.
- Flight time of 40 minutes with 10 lb. payload plus takeoff, transition, and landing.

The entire UAS system will be packable for shipment in no-larger than a 6ft x 4ft x 3ft container due to the following design features:

- All motor arms are removable, slot into support tubes in the center frame with positive capture removeable lock pins, and are packable connected to the center frame longitudal frame tubes using foam supports.
- The propellers are foldable to support packing without removal from the motor/arm assembly
- Ground support equipment will consist of three (3) airtight cases:
    - Battery charging and storage
    - Ground Support and RC Transmitter
    - Antenna Array and Video Display
- The center frame is 900mm x 400mm x 250mm when the arms are disconnected and 100mm wider with the arms stowing for packing

Note about Radio Control

The contest rules specify FHSS 2.4 Ghz protocol will be used for RC control. The proposed system is compliant with this rule via the use of Futaba RC radio equipment. However, we I believe there is a better option and have built it in to the BOM, on budget. FHSS is used by Futaba on their cheaper Radio Control 2.4Ghz systems. Higher end Futaba radios, and older high-end radios, use the FASST protocol, or like the proposed 18SZH FASSTTest. The FASST protocol is spread spectrum frequency hopping like FHSS, but it switches frequencies 100 time faster and has half the latency. FASST also utilizes faster diversity antenna switching, more advanced error correction, and is bidirectional (thus enabling TX based telemetry). FASST is a far more advanced 2.4Ghz spread spectrum technology then FHSS. See https://www.futabarc.com/technology/fasst.html for more information.

As for FrSky, I have a Taranis I use for Drone Racing. I can use it if the Futaba 18SZH needs to be dropped from the project for budget reasons. However, I prefer the Futaba menu system over the open source system used in the FrSky radios. And the FrSky is only FHSS.

Construction and Facilities

I have all the equipment required to build the proposed UAS system and skill in-house. My partners and I run a private Makerspace which includes 9 3D printers, 2 CNC Cutters, a Laser Cutter, a 5 axis CNC Mill, an engine thrust and torque test cell, welders, plasma cutters, and a fully equipped shop, and 3D design expertise in Solidworks and Fusion 360. There a very few things we couldn't build or fabricate in our facilities.

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Bill of Materials

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	Item	No.	Model	Price	Total
Power System					
	esc	8	T-Motor Flame 80A Opto	$120.00	$960.00
	Motor1	8	T-Motor U85 Lite	$300.00	$2,400.00
	prop	4	T-Motor G29x9.5 2 Blade x 2	$375.00	$1,500.00
Electronic					
	FC	1	Pixhawk V2.1	$250.00	$250.00
	GPS	1	N8 Gps (HERE)	$57.00	$57.00
	Modem	1	RFDESIGN 900Mhz Telemetry Modem	$220.00	$220.00
	LIDAR landing	1	MakerFocus Short Range LIDAR	$45.00	$45.00
	Optical Flow	1	PX4FLOW Optical Landing Sensor	$65.00	$65.00
	Pitot/Static	1	PX4 Pitot System	$100.00	$100.00
	Receiver	2	FUTABA R3008SB	$65.00	$130.00
	PDB	2	Power Distibution and 5v and 12v power supply	$20.00	$40.00
Video					
	Connex HD system	1	HD Video Downlink System	$1,300.00	$2,600.00
	Contest Camera	1	NTSC Camera	$30.00	$30.00
	2.4GHz Video TX	1	200mw TX	$10.00	$10.00
	2.4GHz Video Diversity	1	2 channel diversity video reciever	$80.00	$80.00
	7 in Video Display	1	7 In Portable Display	$100.00	$100.00
	FPV Goggles	1	FPV Goggles	$300.00	$300.00
	Pelican Case	1	Case	$100.00	$100.00
Frame					
	Carbon Tubes	6	1in I.D x 10 ft	$300.00	$1,800.00
	Carbon Plate	2	4mm x 400mm x 500mm	$200.00	$400.00
	Aluminum Extrusion	1	1in square	$10.00	$10.00
	Brackets	22	25mm Aluminum Tube Brackets	$2.00	$44.00
	TPU	4	Roll 3D Printer Filement TPU	$30.00	$120.00
Battery					
	20000mAh 6s	16	Multistar 6sp1 20000wAh 10c	$209.00	$3,344.00
	Charger	8	6S 10A Li-Ion Charger	$40.00	$320.00
	Pelican Case	1	Case	$100.00	$100.00
BRS					
	Flight Terminator	1	Flight Power Termination System and Radio	$200.00	$200.00
	BRS	1	Ballistic Recovery System	$1,800.00	$2,000.00
Misc					
	10ga Wiring	1	100ft 10ga	$30.00	$30.00
	12ga Wiring	1	100ft 8 ga	$30.00	$30.00
	Servo Extension	10	1m Extension	$10.00	$100.00
	Power Connectors	12	XT90 Power Connector	$1.00	$12.00
	Tracking Gimbal	1	Antenna Gimbal	$100.00	$100.00
	Tripods	2	4ft Heavy Tripod	$100.00	$200.00
	Directional Antennas	4	2.4Ghz and 5.8Ghz high gain antennas	$40.00	$160.00
	RC Transmitter	1	Futaba 18SZH	$1,306.00	$1,306.00
Totals					$19,263.00

Team Member Biographies

Jeff Zika

Jeff is an American disabled Navy veteran born in Milwaukee, WI in 1967. After graduating high school in Richfield, MN he joined the Navy. After a year in the Navy, he was selected by the Secretary of Defense to attend the United States Naval Academy. After leaving USNA, Jeff was stationed onboard the US Midway, and then the USS Kitty Hawk where he participated in combat operations in the Persian Gulf and Somalia. After leaving the US Navy in 1993 Jeff went back to school for a Computer Engineering add on degree at the University of Washington. In 1994 Jeff joined Microsoft as a Technical Test Lead for MSN, MSNBC, MCIS, and then Exchange. After 5 years Jeff left Microsoft and started consulting projects for Worldcom, F3, Motorola, Gigamedia (Taiwan), Rolta (India), and EDS. In late 1999 Jeff joined Digital Equipment as the lead architect on the Comcast Roadrunner project. Digital was in the meantime bought by Compaq so when his project ended Jeff went to Compaq Malaysia as the Lead Architect for Maxis.Net. After the Maxis project, Jeff returned to the US, left Compaq, and entered private practice consulting for Telenor, EDS, Milvets, and Lexus (US). After 9/11 Jeff went back to Compaq Malaysia to upgrade and re-architect Maxis.net. In 2002, after HP bought Compaq, Jeff was transferred to Singapore as the Microsoft Solutions Practice Manager. In Singapore he developed projects for Citi, the Singapore Government, various Hospitals, and several FABS. Jeff left HP in late 2003 and again returned to the United States to take a year off. In 2004 Jeff went back to Microsoft for 6 months, then immigrated to Thailand right after the Tsunami hit. The next year was spent volunteering for Tsunami cleanup and starting a seaplane airline in Phuket, Destination Air. He left Destination Air in 2006 and went back to Malaysia working as a trainer for Microsoft Solutions Architects at Getronics Bhd. In 2008 Jeff returned to Thailand to start AirGO Siam ltd as a aircraft parts logistics company and signed contracts with the Thai Air Force, Thai Army, Air Asia, Orient Thai, Coco Seaplanes, and Thai Airways. In 2010 Jeff semi-retired to focus on personal projects, primarily in photography and sailing. In 2011, with Thai partners, Jeff formed the linked companies JazCamAP, KISSCopters, and AeroEyes which were focused on Sports Photography, MultiRotor design and build, and Multirotor Film Production companies respectively. These companies in cooperation were the first to use Multirotors, in this case MikroKopter 6XLs, to film an offshore event, Phuket Race Week and to fly from a boat at sea. They also developed the FPV single pilot film technique. Over the next 4 years covered marine sports and motorsports events in the region (BIRA, King's Cup, Top of the Gulf, Rajamudda, Monsoon Cup, etc) and political unrest. During this period Jeff designed, built, test, and operated over 100 UAVs, multi-rotor and fixed-wing. In 2016 Jeff returned to the United States again and started SimpleUAVs (sole proprietor) to develop UAVs. In April 2016 Jeff was a founding member of FPV Racing Seattle, a AMA and MultiGP sanctioned drone racing promoter and is currently the safety officer and a board member. In late 2016 Jeff suffered medical problems and had to retire from racing. Since then and throughout 2017 Jeff has provided media coverage of Drone Racing events in and around the Seattle area and in September 2017 was selected to be the media representative for MultiGP and covered the World Championship Drone Race event at the Reno Air Races.

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Jeff Zika's Key Experience and Expertise

- 7 Years Multi-Rotor operation, design, integration, and build experience and Over 35 years Radio Control (RC) modeling experience including Drone Racing, IMAC, Slope Racing, Soaring, and Off-Road Cars competition
- Aircraft and UAV 3D design expertise in Solidworks, Fusion 360, Inventor, 3Dmax, Rhino, and others
- Expert in 3D design for 3D printing or CNC cutting using Solidworks and Fusion 360
- Expertise in 3D printer design, building, and operation with FDA and custom metal printing process
- Over 30 years photography and video experience including publication in major magazines, several covers and winning the United States Embassy in Thailand Thai/American Friendship photo competition.
- Over 30 Years as Private Pilot w/IFR (PPL) and over 500 hours Pilot-in-Command of manned aircraft and over 4000 hours unmanned.
- Expertise with the following Multi-Rotor flight controller systems:
    - DJI WKM, A1, A2, A3, Naza V1, and Naza V2
    - MikroKopter
    - ArduCoptor and ArduRover (DIYDrones) on Arduino, PX4, Pixhawk, and Linux
    - Raceflight V1, V2, V3
    - Betaflight on various flight controllers
- Expertise with DJI, Mikrokopter, and Ardu (Mission Planner, ROS, QControl) ground control systems and required systems
- Expertise using Laminar Research X-Plane to simulate and test UAV airframes and Hardware-in-Loop (HIL) flight controllers and flight control software
- Over 35 years membership in the Academy of Model Aeronautics (AMA) and 2 years in MultiGP
- Former member of AOPA, EAA, and Warbirds of America
- Built and test flew 2 RV-8 homebuilt experimental aircraft
- Experience with FAA aircraft certification process

Portfolio and References

More Information and samples of Jeff Zika's work can be found at the following websites

- LinkedIN https://www.linkedin.com/in/jeff-zika-54503b1
- Flickr https://www.flickr.com/photos/jazcamap/albums
- Youtube https://www.youtube.com/user/jazcamvideo/videos
  https://www.youtube.com/channel/UCJCXs4pBhSh7-YQW0cz5icA