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If I would have to build a million drones...

kamikaze drones don't build themselves after all

The future was bright, for a moment

Years between 2015 and 2020 marked the golden era of drones—FPV drones in particular. They were new, popular, and thousands of people believed they would change the world we live in for the better. Visionaries imagined drones could do almost anything, from obvious uses like drone delivery services and critical cargo shipments to the next big sporting events (remember when Arab sheikhs organized drone championships with a \$1M prize?). None of that really happened, of course. Drone racing isn't entertaining for the masses—drones are too small for their speed, and it's hard to cheer for your favorite pilot if you can't tell which drone is his. And don't even get me started on drone delivery services. Sure, something has been delivered by a drone somewhere, but if you expected anything on a grand scale, you'll have to wait. For a very, very, very long time.



It was supposed to be the future

There is one area in which drones have truly found success: **war**. For the first time in history—but certainly not the last—cheap drones have become an essential asset in every state's weapons arsenal. The war in Ukraine proved this beyond any doubt. When Russia invaded Ukraine in 2022, FPV drones became makeshift weapons against Russian aggression. A few years later, they are now essential players on the battlefield. If you doubt it, consider this: for 2025, the Ukrainian Ministry of Defense planned to build between 2.4 million and 5 million drones of all types, including FPV kamikaze drones. How many is Russia building? A similar number. In total, we're talking millions yearly, in a single conflict between two countries.

One million kamikaze drones mean a million batteries, a million flight controllers, a million ESCs, a million radio receivers, cameras, and VTXs—plus 4 million motors and 4 million props. Multiply this by four and you'll have the yearly “drone budget” spent in eastern Ukraine. Or rather, only half of it, since this data is from Ukraine's side alone.



Improvised kamikaze FPV drone

(observe the tape wrapped around it!)

It's no surprise that drones are so heavily used in this conflict: they're long-range, accurate, versatile, pack quite a punch, and—most importantly—cheap.

BLOODY CHEAP.

One kamikaze drone armed with a **PG-7VL** warhead (with the rocket motor removed), capable of destroying an APC and at least damaging a tank, costs around \$1,000 at retail. That's \$300 for the **PG-7VL** grenade (the kind used in **RPG-7s**), with the rest going toward the drone itself. You might not be able to buy a PG-7VL, but you can certainly build a multirotor that will carry it with no problem. When you buy in bulk (millions), the prices go down even more.



RPG-7B with PG-7VL

<https://sallyantiques.co.uk/product/soviet-rpg-7b-with-pg-7vl-rocket-old-spec-deactivation/>

Compare this with a price of a 155mm artillery shell. I was shocked to hear one-unit costs around \$8000. And you don't shoot one but dozens at a time. While artillery keeps the title of Queen Of A Battlefield, cheap replaceable drones are very far from being a curiosum or a niche, specialized weapon.



British Archer, 155mm self propelled howitzer



M107, 155mm High Explosive projectile

Let's skip long range or surveillance drones for now and concentrate on the Kamikaze Drones. The ones that emerged directly from FPV racing and freestyle drones at the very beginning of this conflict. And if kamikaze drones are direct descendants of the hobby ones, what makes them different?

Kamikaze vs recreational drone

First, let's define what a recreational FPV drone is:

The recreational FPV drone is a electrical power multirotor UAV equipped with FPV camera and radio receiver for control. It's designed for stable flight, multiple use, crash resistance, and safety in mind.

On the other hand,

Kamikaze FPV drone is a electrically powered multirotor UAV equipped with an FPV camera and remote control. It's designed to carry a warhead, withstand RF interference and fast deployment

See the difference? Nobody said **kamikaze drones** need to be radio controlled. And what's even more important, kamikaze drones have completely different priorities:

- Need to carry around 2kg of payload (RPG-7 grenade weight)
- Need to operate in moderate RF jamming conditions
- Need to be ready to fly as soon as possible.

Non-priorities:

- It's a single use device, ergo, it does not need to return and land. I would say more: after take-off and arming, it absolutely should not return to where it started. Armed warhead is an armed warhead and nobody with a sane mind will try to recover it in field conditions.
- It does not even need to be crash resistant. You crashed, too bad. Even if warhead did not explode and your kamikaze drone is intact, you **WILL NOT** try to recover it. Not only is the warhead live, but you will also put yourself under enemy fire. If it crashed, then it crashed. The safest thing a kamikaze drone can do after a crash is to self-destruct
- Acrobatics are not needed. It needs to take off, fly, make a few turns and crash. Crazy thrust to weight ratio is just a waste of resources. I'd even say that a total thrust of around 5kg is all that you need. 2kg for a warhead, 1kg for net weight of the drone and 2kg of a safety margin
- Beefy ESC, flexible FC and modularity is also a no-go

The priorities:

- RF jamming will be a thing
- Durable enough to carry 2 kg of payload
- Cheap and fast to manufacture
- Rapid deployment capable

How would I approach this problem?

Let's say you are hired as an expert by a state that wants to build their drone arsenal. Fast (of course), cheap (is there any other way?) but on a scale! Goal is simple:

YOU HAVE 3 MONTHS OF
PLANNING AND THEN
YOU NEED TO SET UP A
PRODUCTION LINE THAT
WILL CHURN OUT ONE
MILLION KAMIKAZE
DRONES READY TO FLY
EVERY YEAR.

- 83 thousand drones monthly
- 19,230 drones weekly
- 2750 drones daily
- 115 per hour, 3 shifts, 7 days a week

Your factory produces drones only, without a warhead. Warhead in the form of **PG-7VL** grenade will be installed immediately before deployment, you don't have to worry about it. Your design only needs to provide a safe and secure way to install the grenade.

How would you tackle this challenge? What would you design? How creative with the kamikaze drone concept would you be?

I have been thinking about it for some time now. And you know what? I think I came up with a slick idea that might just work...

BREAR WITH ME...

Let's get creative!

The FPV drone as we know in the FPV hobby can be described quite simply as

HD quality video transmission system, absurdly high update rate radio control, flight controller with a MCU powerful enough to handle HDMI in 1080p, ESC rated for 60A even though constant current is a third of that and absurdly overpowered brushless motors strapped to crazy rough carbon fiber frame with a battery on top.

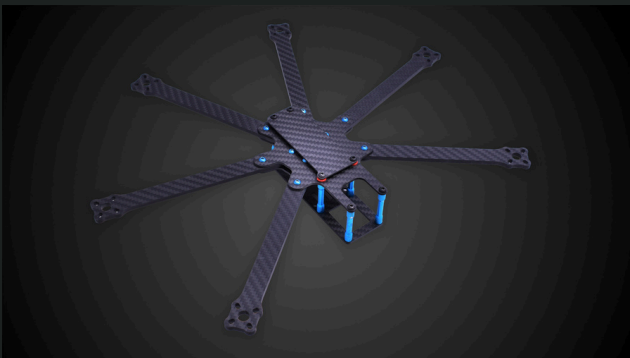
Sounds familiar? Just look at any other hobby multirotor.

But like I already discussed before, this is a hobby version of a multirotor drone. Designed to fly smoothly and survive all the crashes you can throw at them. A flying tank with a speed of Formula 1 if you will.

Kamikaze drones don't need to be flying tanks and don't need to be crazy fast. If you don't land or want to keep flying after a crash, they just don't have to be. Less is more, some might say.

If one forgets about *"how we do it"* and thinks *"how can we do it better"*, there is a full plethora of options and ideas worth exploring. Just let your creativity take the lead!

The Frame



We, FPV pilots know how to make drone frames, right?

NO!

FPV community knows how to make frames for recreational drones! Every single one is different, every one is unique, only sometimes a bigger manufacturer from China releases a small batch of “mass made” models. Only they are not “mass made” really. Not the scale we are thinking about!

But, do you know who makes “mass made” drones in huge numbers? DJI. And if you look at a DJI drone and compare it with a DIY one, differences are easy to catch.

I argue that “**classic carbon**” frame design is suboptimal. It required special materials (carbon fiber) and milling operations. Both are time, and thus money, consuming.

Carbon-fiber is hard to make and hard to work with. First, it needs to be cured and comes in flat sheets. After curing it needs milling. This produces waste, is a time-consuming process, and in general, when it comes to mass production, as long as you have other options, milling is not the desired way to go.

Small arms manufacturers discovered this around WWII. Milled steel receiver? Nope! Flat sheet metal stampings or molded polymer. Sometimes cast aluminum. Milled parts? Only when tight tolerances are a must and its a low scale production.



StG44 from the outside is mostly stamped sheet metal. Milled only around pressure bearing part (barrel, bolt, gas piston)



M1A1 Thompson was mostly milled. Guess who stopped making those as soon as simpler replacement came?

Million kamikaze drones a year are not a low scale production.

As durability requirements are low, and this is a one-way design, injection molded clam shell design is favorable if production volume is big enough (and in this case it is).

Once you figure out the clam shell design and pay for the mold (molds are expensive btw) you can mass produce fiberglass reinforced ABS frames like crazy. Cheap and fast.



LOG-S9 injection molding machine. Those things can make two or three half frames per minute. Two can get you covered for a target of a million yearly

I already hear you say: but **ABS is flimsy**. If treated like a flat sheet material, then yes. Once you start thinking about it in 3D design terms, everything gets much stiffer and more durable. Once you reinforce it with glass fiber it gets extra stiff and will work!

Quick math shows that 15-20mm thick drone arm made with ABS in shell design (2-3 mm shell thickness) will have similar stiffness as 6mm thick carbon fiber arm. With comparable weight. And still, it was made faster and cheaper.

Another advantage (besides low cost) of an injection molded frame would be:

1. You are not limited to flat sheet design and can easily improve aerodynamics
2. Battery and warhead compartments can be made in one go and be integrated into the frame
3. Clam shell design would be faster to assemble than traditional carbon fiber frame
4. No need to manually assemble multiple elements together to make a frame. Molded structural frame will have 2 pieces with snaps and hooks, plus a few extra bolts to hold it together. And if you move your head and remove the need of disassembly, you can just glue it together. Or even better, sonic weld it!

I can hear you say:

But Paweł, what if drone is damaged during transport and needs to be repaired on the field. You need a way to quickly disassemble it and put together again. Just looks at small arms. Simple disassembly is a must have for a modern rifle or a pistol.

Yes, small arms need to be field stripped quickly, cleaned, oiled and assembled again. But kamikaze drone is not a rifle:

1. Rifle, carbine, pistol is a multi-use object. Kamikaze drone, as we already established, is not
2. Small arms get dirty when in use (fowling) and not in use (dirt, mud, water). You protect a drone by carrying it in a bag/backpack sealed from environment. Try doing the same with a rifle and use it at the same time
3. Field stripping is for cleaning, not for field repairs. If rifle does not go pew pew and removing a stuck case is not fixing it, you give it to armorer, not bring out a lathe and full toolset

If a single use item is manufactured in millions, it's cheaper to ignore the need for field repairs. And you don't expect **grunts to run around with soldering irons**, or do you?

FPV and control line



Radio transmitted video and control signal might work when Eather is clear, but as soon as the other side expects kamikaze drones, RF jamming will be in place.

Fiber optics control lines are useful, but they take away flexibility of deployment. One idea is that kamikaze drones should be easily swappable between RF and fiber optics control.

On the other hand, swappable design increases complexity, maintenance and operational costs. I might even state that fiber optics only solutions will be cheaper to build (disclaimer: fiber optics control line can be built with off the shelf components) and maintain than a hot-swap systems. If you know in 80% of cases RF jamming will be active and dual control line increases costs for \$5 and manufacturing time for 30m, it's a no brainer!

*On a scale of millions, this only change will save you \$
5,000,000 and half a million work hours.*



Drone with a fiber optic cable dispenser

To put that into perspective, half a million work hours are roughly 57 years! Just by ditching a circuit you know will be useless 80% of the time.

It would be different story if both sides would not be jamming all the useful RF frequencies. Then it would make sense to use hybrid system or a swappable one. But if RF jamming is a fact, why bother! So, fiber optics for the win!

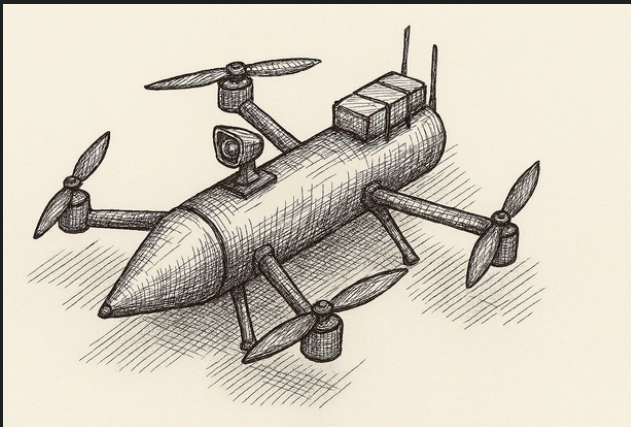
And oh, fiber optics control line is a 2 way medium with enough a bandwidth to put HD 120fps and have some left.

On top of that, if you move your head a little more, your drone should have plenty of space to hold a 1 or 2km of fiber. You already carry a cylinder (warhead) inside. Why not wind fibers around the warhead? It really does not have to be this big cylinder below your drone.

Power source

XT60 or XT90 battery connectors are widely adopted, cheap and flexible, but they have a couple issues:

- 1.Connecting power is a separate operation from installing a battery
- 2.XT60/XT90 can be easily filled with dirt, mud and gunk.



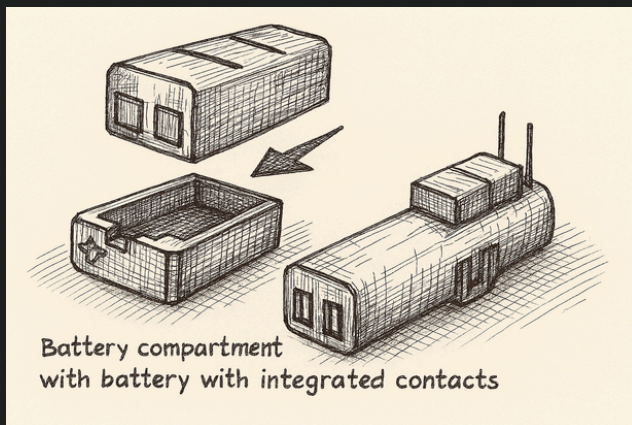
I can't draw, here, take this AI generated sketch of a kamikaze drone...

The alternative would be to design a custom battery enclosure with integrated connectors. Something like power tools batteries. Copper tabs on one side, flat copper springs on the other. Battery can be inserted and connected with one firm move.

To improve on that and to protect battery connectors from dirt, battery installation can be made 2 step:

1. Step 1 in pre installation: battery is placed and a holder and first set of hooks holds it in place in a way that it's held in place and can be removed if needed. Electricity is not connected and kamikaze drone can be moved safely
2. Step 2: with additional force applied to the battery, it latches to a second set of hooks and firmly attaches it to the drone. Electric contacts are closed; drone is powering up and preferably self-armed (warhead arms after take-off)

Such an approach allows for much faster deployment than "classic" battery with XT60 style connector. The only action needed is to push battery in and you are ready. No need to fiddle with XT60, secure the battery or even worse fight with a battery strap. Plastic hooks will be strong enough to securely hold the battery throughout the whole flight. Now that the issue of a battery connector is known, we have one more aspect to think about.



No need to connect any plugs, just push the battery in. Just like a cordless power drill!

LiPo or Li-ion?

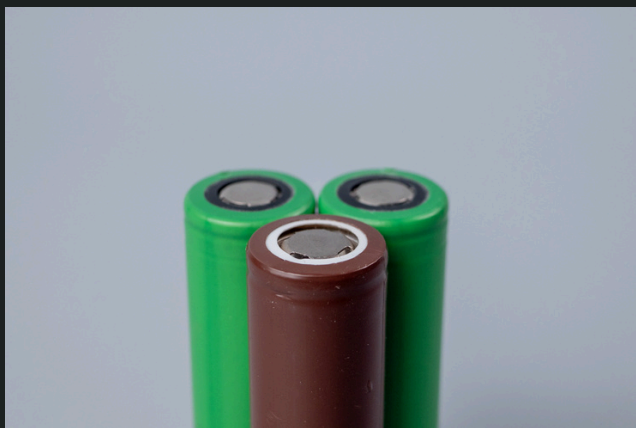
Both battery chemistries have pros and cons

	Lithium Polymer	Lithium Ion
Pros	• Widely used for drones • High current • High performance	• Used as long-range packs for drones • High energy density • Low minimum discharge voltage • Lower self-discharge
Cons	• Lower energy density • Higher self-discharge • Higher minimum discharge voltage	• Lower current • Lower performance

While recreational drones prefer **LiPo**, except for long range pilots, I would have to conclude that **Li-ion** would be more suited for the task.

For several reasons:

1. It's simpler to source **18650** or **21700** than LiPo cells as **18650** and **21700** are a de-facto industry standard
2. Lower discharge rate means batteries can be stored in charged state for a longer period
3. Higher energy density allows for a lower battery weight with the same range

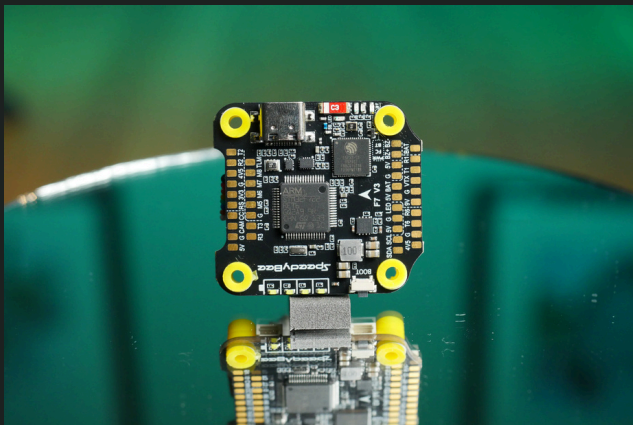


18650 Li-ion cells

The problem to overcome, however, is higher internal resistance and lower discharge current. Due to that, batteries would have to be organized as **4S2P** or **6S2P** rather than a simpler 4S or 6S. Such a battery would be rather big and bulky. Maybe 2 separate packs? On the other hand, RPG-7 grenade is not that small and there should be enough space on top of it to hold **4S2P** or **5S2P** no problem.

It does not need to be STM32, Betaflight or INAV

I know for a fact that in the last few years Chinese FC manufacturers sold gazillions of flight controllers and ESCs to both sides. Both off-the-shelf designs and some custom designs.



Moden multirotor flight controller - for hobby drones

But who said it needs to be SMT32F405 that runs Betaflight? With a scale in mind, it makes **A LOT OF SENSE** to be independent from external assembly and software sources.

I would argue it's cheaper and safer to build something in-house and port it to all possible microcontrollers. Building custom firmware for a kamikaze drone is not that hard and nobody needs all the functions Betaflight offers. Drop legacy drivers, functions you won't need and then port it to everything: ESP32, STM32, RP2040, PIC32, nRF, you name it. Hey, you can even make that work with "old" ATmegs and Arduinos. Remember Multiwii? It was Arduino and still had navigation better than Betaflight has now.

**ONCE YOU KNOW HOW,
IT'S NOT THAT HARD TO
MAKE A DRONE FLY
AFTER ALL.**

Then make peripherals board with ESC, radios (or fiber control line) and all the other electronics your design will need. And a master board containing MCU and specialized hardware, slam them together with some kind of a socket connector and done.

Can't buy STM32? Buy ESP32 and start making master boards with those. nRF got cheaper? Make nRF master boards. Are there cheaper MOSFETs? Make new peripherals boards that would accept all master boards you make.

All of that running your own software that you can even make secure with encryption keys so your enemy can't use it easily.

It will definitely take more time to design and test than to use Betaflight, but on a longer run it should be cheaper and more flexible. You have standardized template that supports all the hardware you might be able to get. And since it's relatively simple software make for only one thing and one thing only, it can be easily ported to anything that is capable of running it.

This idea of a true **All-In-One** will be also faster and cheaper than using flight controller, ESC, etc. as separate components. After all, they would have to be connected with manual labor and manual labor is slow and expensive. One pick-and-place machine will do it in a fraction of a time, and everything that will be left is to solder motor wires and battery connectors.



Fuji NXT3 pick and place machine

There is more

This e-book does not cover all the possible aspects of designing and building million kamikaze drones. I only tried to concentrate on how kamikaze drones differ from the FPV drones we know and love to fly.

Yes, kamikaze FPV drones started as make-shift grenade carriers made in mass by a desperate nation in need.

But times pass and we now have a clearer vision on what those kamikaze drones are and, what equally important, what they are **NOT**. Since in their core nature they are not FPV drones with attached grenades. Even if basic operational principles are the same, they are a separate breed. Putting kamikaze drones and FPV drones in the same basket is like stating that Komatsu 930E-4SE and Honda N-BOX are the same because both have 4 wheels



Komatsu 930E-4SE



Honda N-BOX

About me



- [FPV University](#)
- [Hacker University](#)
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- [Hacker University Newsletter](#)

I'm a technologist, educator, and long-time explorer of FPV, DIY electronics, and embedded systems. Through my YouTube channels FPV University and Hacker University, I focus on turning complex engineering topics into practical, approachable knowledge for anyone who wants to build, fly, or hack their own hardware.

On FPV University, I dive into drones, flight controllers, radio systems, and navigation software—helping pilots understand not just how things work, but why. With Hacker University, I broaden that mission into microcontrollers, sensors, and hands-on electronics, encouraging viewers to experiment, break things, and learn by doing.

I've also contributed for years to the INAV flight-control ecosystem, supporting its development through testing, documentation, and community guidance. Curiosity drives everything I create. Whether it's a drone, a circuit, or a line of code, I love helping others understand the technology that inspires them to build something of their own.