REINFORCE 3D

FROM THE FIRST LINE TO THE DEPOT: ON-DEMAND REINFORCED DRONE FRAMES WITH CFIP



A QUADCOPTER CASE STUDY IN MANUFACTURING AUTONOMY: WHY IMMEDIACY, SUPPLIER INDEPENDENCE AND DEPLOYMENT FLEXIBILITY (FDM AT THE FIRST LINE, MJF IN THE DEPOT) MATTER MORE THAN GRAMS.

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Executive summary

For UAV programs it is tempting to make the headlines weight. **But weight is only one level, and rarely the decisive one.** A quadcopter whose motors each deliver around 1 kg of lift has roughly 4 kg of total lift to work with, so trimming **80 to 100 g from a frame** — real as engineering — is a small fraction of that budget. The constraints that slow programs down sit upstream of the aircraft: how fast, how independently, and how close to the point of need the structural parts can be made.

This case study shows how Reinforce3D's Continuous Fiber Injection Process (CFIP) addresses exactly those constraints. By injecting continuous carbon fiber into the cavities of a 3D-printed frame, CFIP turns reinforced, load-bearing structural-part production into something an operator **can do in-house, on demand, on standard additive hardware — from accessible FDM at the first** line (forward and remote locations) **to MJF in the depot** (series volumes and logistics support). The same design, deployable across the whole sustainment chain. As a bonus, the frame also comes out **51.5% lighter** — welcome, but not the unique reason to adopt the process.

~20–25 min	0 molds	FDM → MJF
CFIP reinforcement per frame, in-house	No tooling or external composite supply chain	One design, first line to depot

1. The real constraint: not grams, but the supply chain

A lighter airframe is always nice to have — more payload, more endurance, more range. But on a platform with about 1 kg of lift per motor, shaving roughly 80 g from a frame that a generic process would build at **165–180 g moves only a couple of percent of the available lift.** As an engineering result it is meaningful; as an operational lever it is modest. The harder problems live in how the part is produced.

Both established routes to a high-performance frame depend on an external supply chain. Machined metal and, especially, molded carbon-fiber composites need tooling, specialized equipment and skilled labor that most operators do not own. In practice that means:

- **Long lead times —** weeks of tooling and queue before the first good part, and again for every revision.
- **Supplier dependence —** minimum order quantities, external composite shops, and single points of failure in the chain.
- **No production at the point of need —** parts cannot be made or replaced near where the drones operate.

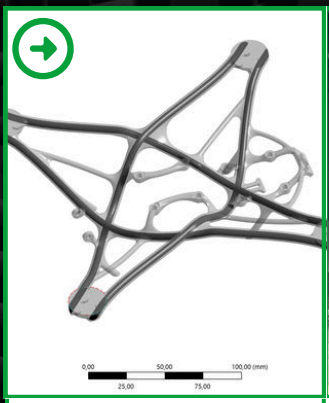
Additive manufacturing removes the geometry barrier, it prints almost any topology-optimized shape directly, but **printed polymers alone are not structural.** For UAV programs, commercial fleets and defense operators alike, the binding questions are therefore not about grams. **They are readiness to fly,** independence from outside suppliers, and the ability to manufacture fiber-grade structural parts quickly and wherever they are required.



2. The solution: CFIP

CFIP is a **patented post-processing technology** that reinforces a part after it has been manufactured. Rather than printing with fiber or laying it up by hand, CFIP injects continuous carbon **fiber and liquid resin simultaneously into hollow, tubular channels** designed into the part. Once cured, the resin acts as the mechanical interface that bonds the continuous fiber to the surrounding structure, placing high-performance **reinforcement exactly along the load paths.**

Because the fiber runs inside existing printed cavities, CFIP needs **no molds, no autoclave and no prepreg supply chain.** Reinforcement becomes an in-house, automatable step on Reinforce3D's DELTA systems — **roughly 20 to 25 minutes per frame for this part —** instead of an order placed with an external composite shop. It bridges the performance gap between plastics and metals while keeping production close, fast and under the operator's control. How it works, in four steps:



1. Design the part with **internal tubular cavities** that follow the structural load paths.



2. **Print the part** using a suitable AM process (FDM or MJF), leaving the cavities hollow.



3. **Inject continuous carbon fiber and resin** into the cavities with the DELTA system.



4. **Cure the resin** so it locks the fiber into a continuous, load-bearing composite reinforcement.

3. The part: a topology-optimized quadcopter frame

The demonstrator is a **quadcopter frame measuring 200 × 200 × 40 mm.** Its branching, skeletal geometry is the product of **topology optimization** — material is retained only where it carries load, the kind of organic shape that is impractical to mold but natural for additive manufacturing. Internal tubular cavities are routed through the structure so that, after printing, CFIP can thread continuous carbon fiber along the primary load paths.

Each frame is reinforced with **Ø4 mm continuous carbon fiber through four 400 mm channels** — 1,600 mm of fiber per drone — **injected in roughly 20 to 25 minutes.** The reinforcement is engineered into the structure, not bolted onto it, so it adds strength along the load paths without changing the frame's external envelope.

Parameter	Value
General dimensions	200 × 200 × 40 mm
Reinforcement fiber	Ø4 mm continuous carbon fiber
Cavities per frame	4 channels × 400 mm
Total fiber length	1,600 mm per drone
CFIP injection time	≈ 20–25 min per drone

Set against that backdrop, the value of producing this frame with CFIP is not mainly the grams it removes. It is what becomes possible operationally:

- **Immediacy.** A frame goes from file to reinforced, load-bearing part in hours — print, inject, cure. Parts are produced, or replaced, on demand rather than on a supplier's calendar.
- **Supplier independence.** No molds, no prepreg, no autoclave, no specialized composite vendor. Structural part production moves in-house, removing single points of failure from the supply chain.
- **Time-to-market.** A design change costs a reprint, not new tooling, so revisions that would take weeks through a composite supplier take days — and reach the field sooner.

The weight saving is real and worth **stating at under 80 g against a generic frame** in the 165–180 g range, **the CFIP frame is roughly 51.5% lighter.**

Frame	Weight	Δ
Generic / traditional composite	165–180 g	—
AM + CFIP	**< 80 g**	**−51.5%**

But on a platform with about 1 kg of lift per motor, that saving is a welcome bonus rather than the reason to adopt the process. **The reason is everything above the line:** speed, independence and control over production.

4. Deployment flexibility: from the first line to the depot

Because CFIP runs on standard additive manufacturing, the same frame design can be produced on very different hardware — which makes it a deployment strategy, not just a printer choice. The two **processes characterized in this study map naturally onto two tiers of production.**

First line:FDM at the forward edge

Accessible, rugged, low-infrastructure FDM hardware (high speed FDM/FFF printer) paired with a DELTA injection step can produce or repair reinforced frames at remote and forward locations, with a minimal logistics tail. **Six frames per building in 23 h 30 using just 57 g of PETG each** — equipment and materials that can realistically travel to where the drones operate. This is immediately where it matters most: a structural part made on site, in hours, without waiting for a response.

Second line: MJF in the depot

For series volumes and logistics support, Multi Jet Fusion at a central facility (here, contract manufacturer Pantur) **fits 23 frames into a single build,** with substantial headroom: optimized nesting and added automation **point to on the order of 69 frames per day,** and potentially three to four times that with fully optimized packing. The depot replenishes forward stocks and supplies the fleet at scale — from the same CFIP design, with no redesign between tiers.

Configuration	Packed height (mm)	Bucket height used	Units / bucket	Buckets / day	Total units / day
Whole drone	215	57%	23	3	69
Split drone	340	90%	42	2	84

	FDM (Bambu Lab X1)	MJF (at Pantur)
Frames per build	6	23
Build / print time	23 h 30	Batch (nested)
Material per frame	57 g PETG	PA powder
Deployment tier	First line — forward / remote	Second line — depot / series



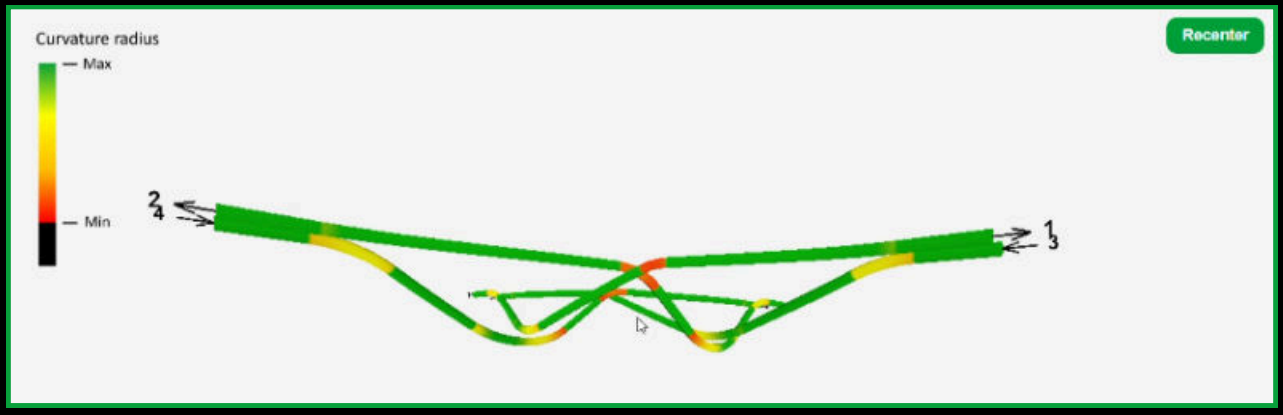
The choice between the two is the familiar **FDM-versus-MJF trade-off**, read through a deployment lens. It is not that one is better; they are suited to different tiers.

Parameter	FDM	MJF
Dimensional consistency	±0.4–0.7 mm; varies with build direction	≈ ±0.3% (min ~±0.3 mm); uniform in every axis
Isotropy	30–50% lower strength along the build (Z) axis	Near isotropic; comparable in XY and Z
As-printed finish	Visible, directional layer lines	Even matte texture (Ra ~6–10 µm)
Materials	Strong for high-temp polymers (PEEK, ULTEM, PPS)	PA12 / PA11 / TPU, repeatable datasheets
Batch throughput	Sequential — one part at a time	Whole building fused in parallel

FDM wins on accessibility, portability and speed-to-first part at the forward edge; MJF wins on repeatability, finish and parallel throughput for series production in the rear. **Three of the five parameters are simply different.** The two that matter most for a structural series — **isotropy and batch throughput** — are where MJF pulls ahead at the depot.

5. Why are forward-printed parts still structural

There is a catch to print structural parts at the first line, and it is worth naming. An FDM part is built layer by layer, and the bond between layers is its weak axis: loaded along the build direction it can **lose 30–50% of its strength.** Left there, a field-printed frame would be a prototype, not a flight part. CFIP removes exactly this weakness. Continuous carbon fiber injected along the load paths reintroduces directional strength precisely where the printed polymer is weakest — so a frame printed on an FDM machine at a remote site, then reinforced, is genuinely load-bearing rather than a stopgap**. This is what makes first-line production a real capability instead of a compromise: it is the reinforcement, not the printer, that carries the load.**



Read together, the case study points to a single shift — from buying structural parts to producing them:

- **Production on demand.** Reinforced structural parts in hours, when and where they are needed.
- **Supply-chain independence.** No molds, no prepreg, no external composite vendor — fewer single points of failure.
- **Faster time-to-market.** Iterations cost a reprint, not new tooling, and reach the field in days.
- **Deployment flexibility.** One design spans the sustainment chain — FDM at the first line, MJF in the depot.
- **Structural, not just printed.** CFIP overcomes FDM's weak axis, so even forward-produced parts are load bearing.
- **Lighter, too.** A 51.5% lighter frame comes along as a bonus on top of the operational gains.





6. Conclusion

The quadcopter frame is less lightweighting story than a manufacturing-autonomy one. CFIP lets an operator produce **fiber-reinforced, load-bearing structural parts on standard additive hardware** — on demand, in-house, and across the whole sustainment chain, from an FDM machine at the forward edge to MJF in the depot.

📩 Contact us for technical consultation or to request sample components.
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For UAV programs where fly-readiness, **supply-chain resilience and the ability to manufacture at the point of need are decisive,** that is the real advantage. **The 51.5% weight reduction** is a genuine benefit, but it is the immediacy, independence and deployment flexibility that change what an operator can do — and CFIP delivers them from the inside of the part.





Carbon fiber reinforcement, engineered for excellence