JON'S HANGAR

BUSA 1/3-Scale L-4 Grasshopper

Battery Bay Research Overview

Mock Battery Development, Physical Fit Testing, and 9K–12K Battery Screening

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Project record prepared for the L-4 electric-power-system evaluation and publication through Jon's Hangar

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Purpose of This Workbook

This workbook documents the battery-sizing research for the restored Balsa USA 1/3-scale L-4 Grasshopper electric conversion.

The goal was not simply to find a battery with the largest capacity. The real problem was more practical:

> *What 6S batteries in the 9,000–12,000 mAh range can physically fit as a pair inside the actual airplane, provide adequate electrical capability for the planned 12S power system, preserve cooling and ESC space, and remain serviceable through the existing fuselage access?*

The final answers came from a combination of measurements from the actual airplane, Balsa USA plan geometry, full-size physical mock batteries, repeated trial fitting, manufacturer specifications, independent secondary sources, dimensional tolerance review, battery-orientation studies, weight and energy comparisons, and ESC voltage limitations.

How to read this workbook

This is an engineering fit study, not simply a battery shopping list. A battery appears in the primary comparison only after its geometry, electrical compatibility, and source quality have been considered together.

How We Got Here

The Original Battery-Bay Question

The L-4 is being converted to electric power using a planned 12S system made from two 6S battery packs connected in series.

The forward fuselage provides substantial internal volume, but it is not a simple rectangular battery compartment. The fuselage narrows toward the firewall, the floor rises toward the nose, and access for normal battery changes is through the cockpit-side former rather than through a large removable top opening.

The battery system also shares this forward fuselage area with the ESC and the planned cooling path. Battery selection therefore could not be based on capacity alone.

- Could two packs physically coexist in the bay?
- Could each pack be loaded and removed through the intended access?
- Would sufficient space remain for the ESC?
- Could cooling airflow still move through the bay?
- Would the added capacity justify the added battery weight?

Early Mock-Battery Work

The first step was to create full-size mock batteries representing several capacity classes. Early mockups included nominal examples for 8,000, 9,000, 10,000, and 12,000 mAh packs.

Those early mock dimensions were useful for understanding the packaging problem, but they also exposed an important weakness in the original method: battery capacity does not correspond to one standard physical size.

Two batteries with the same stated capacity can have radically different proportions. One manufacturer may make a pack long and flat, another short and tall, while another uses a nearly square cross-section. This became increasingly obvious as the research expanded into 9K, 10K, 12K, 14K, and 16K battery families.

Each battery model has its own geometry. Capacity alone does not determine whether it will fit.

That realization changed the project from generic capacity-class mockups toward model-specific research and fit screening.

Why the Physical Mockups Mattered

Computer dimensions and CAD envelopes are useful, but this fuselage is tapered and three-dimensional. A battery that appears to fit on paper may still fail in the actual airplane.

- It may not pass through the access opening.
- It may clear the bay aft but interfere with the narrowing fuselage farther forward.
- It may fit by itself but not coexist with the second 6S pack.
- It may consume the space needed for wiring, connectors, or retention straps.
- It may crowd the ESC or obstruct the intended airflow path.

For that reason, full-size lightweight battery mockups were created for actual trial fitting in the airplane. The mockups were intended only to reproduce external dimensions, not battery weight.

Several iterations were required while attempting to make very light 3D-printed boxes. Some closed-top designs became unnecessarily heavy or produced large unsupported roof surfaces in the slicer. That was a useful fabrication lesson in its own right:

A dimensional mock battery does not need to structurally imitate a real battery. It only needs to preserve the external envelope accurately enough to test installation geometry.

The 10K Mock Became the Breakthrough

A pair of 10K-class mock batteries measuring approximately 186 × 70 × 69 mm each was tested in the actual L-4.

Physical result
Two 10K mock batteries could be made to fit in the airplane with substantial remaining clearance for the ESC.

This was the first strong physical confirmation that the planned two-pack 12S system was practical. More importantly, it established a useful working dimensional boundary.

The successful mock demonstrated that a battery with approximately 186 mm maximum length and 70 mm maximum tray width could be accommodated in the proven arrangement. Height was found to be far less restrictive than width.

The 12K Mock Failed — but for an Important Reason

The next test used a pair of larger 12K-class mock batteries measuring approximately 202 × 77 × 77 mm each. A pair would not fit in the bay, even when staggered.

At first glance, that could have been interpreted to mean that 12,000 mAh batteries were simply too large for the airplane. The physical test showed something more useful: the real problem was primarily width, not length and not available height.

The 12K mock represented a deliberately conservative, broad 12K battery envelope. It did not represent every actual 12,000 mAh battery on the market. This discovery led directly to the next phase of research.

Allowing the Battery to Rotate Changed the Results

The L-4 has considerably more vertical space than the initial mock battery cross-sections required. Therefore, a battery does not necessarily have to lie on its broad face; it can be rotated around its long axis.

For example, a battery published as 183 × 77 × 58 mm does not necessarily require a 77 mm-wide tray. If turned on edge, its working footprint becomes 183 × 58 mm, with the 77 mm dimension becoming vertical.

That simple orientation change dramatically increased the number of viable 12K batteries.

Orientation rule used in this workbook
Length = published long dimension. Tray width = the smaller of the two remaining cross-sectional dimensions. The larger cross-sectional dimension becomes vertical, provided the actual L-4 bay has sufficient height.

The Proven Footprint

The successful 10K mock established the working physical envelope used for this spreadsheet:

Working fit boundary
Maximum battery length: approximately 186 mm Maximum tray width: approximately 70 mm The battery may be rotated so the smaller cross-sectional dimension becomes tray width.

Height is treated as secondary for this phase because the airplane has substantially more vertical clearance than the candidate batteries require.

This does not mean every battery exactly 186 × 70 mm should automatically be purchased. Real installations must still account for manufacturing tolerance, protective shrink wrap, wire exits, connector orientation, foam or padding, battery straps, tray structure, and practical insertion/removal clearance.

The 186 × 70 mm figure is a physically demonstrated fit boundary, not a recommended zero-clearance tray specification.

Why Generic Battery Envelopes Were Abandoned

Earlier in the study, broad composite envelopes were created to represent entire capacity classes. Research eventually showed that batteries from roughly 8K through 16K could collectively span dimensions approaching 232 mm in length, 88 mm in width, and 77 mm in height.

Those values are useful for understanding the market, but they do not describe one real battery. A universal tray designed around the extreme dimensions would be much larger than necessary and could compromise cooling, weight, ESC placement, serviceability, and battery retention.

Select real batteries first, then design the tray around a carefully chosen dimensional family.

Research Method

The battery research was conducted model by model. For each candidate, multiple sources were sought wherever possible, with preference given to direct manufacturer or brand-owner data.

1. Manufacturer or brand-owner product page
2. Manufacturer-issued datasheet
3. Established distributor or independent retailer
4. Secondary technical listing or user-supplied documentation

Whenever possible, at least two specification sources were compared. After the dimensional shortlist was established, a separate independent-performance research pass looked for exact-model bench tests, internal-resistance data, load testing, voltage sag, usable capacity, and temperature behavior. When only same-family or same-brand proxy data existed, it was labeled as proxy evidence rather than applied directly to the candidate pack. When two credible specification sources disagreed, the workbook generally uses the more conservative dimension or weight rather than the more favorable number.

This was intentional. For a fit study, it is safer to assume a battery is slightly larger rather than slightly smaller.

Why Source Disagreement Matters

Battery dimensions are not always as precise as the published numbers suggest. Manufacturers sometimes publish tolerances of ±2 mm, ±3 mm, ±5 mm, or general dimensional variation. Retailers may also copy older specifications, and product pages for the same battery family can conflict.

When that occurred, the battery was flagged, treated conservatively, or excluded from the primary recommendation if the uncertainty threatened the proven 186 × 70 mm footprint. A battery that nominally fits with only 1 mm of clearance deserves much more scrutiny than one that leaves 15–20 mm.

What the 9K–12K Study Found

The research shows that several batteries between 9,000 and 12,000 mAh fit comfortably inside the proven footprint. The reviewed candidates include compact packs from Zeee, HRB, MaxAmps, Tattu, Lumenier, Urbattery, Turnigy, and ETOP.

Central finding

12,000 mAh itself is not too large for the L-4. The failed 12K mock was too large because of its geometry.

Several real 12K batteries are considerably narrower when rotated, allowing them to fit inside the same basic footprint that was physically proven by the successful 10K mock pair.

The HRB 12K Discovery

One of the strongest results of the study was the HRB 6S 12,000 mAh 25C pack, published at approximately 180 × 70 × 51 mm.

When rotated so the 51 mm dimension becomes tray width, its effective installation footprint becomes approximately 180 × 51 mm, with the 70 mm dimension vertical. That fits comfortably inside the physical boundary established by the successful 10K mock.

A pair therefore provides 12,000 mAh capacity, approximately 532.8 Wh nominal 12S system energy, reasonable physical margins, and substantially more capacity than the original 10K baseline.

Current 12K leader

The HRB 6S 12,000 mAh 25C became the strongest 12K candidate identified during this stage of research, subject to final battery-in-hand verification and electrical testing.

Why Battery Weight Matters

Increasing capacity is not free. Larger packs add weight, and the use of two batteries magnifies that increase. The comparison therefore includes weight per pack, pair weight, pair weight in pounds, watt-hours per pack, total 12S pair energy, and approximate Wh/kg.

This allows a meaningful comparison between more capacity and more airplane weight. For a large Cub/L-4, additional battery weight is not automatically unacceptable, but it should produce a meaningful improvement in usable flight time or power-system margin.

The highest-capacity battery is not automatically the best battery.

C-Rating and Current Capability

The spreadsheet records published C-ratings and the current capability implied by those ratings. For example, a 12 Ah battery rated at 25C corresponds to 300 A of theoretical published continuous capability.

These values are useful as screening information, but they should not be treated as laboratory-verified performance. C-ratings are manufacturer claims, and there is no single hobby-industry test standard that makes a 100C label from one brand directly comparable with a 100C label from another.

The current L-4 power-system study uses approximately 105 A as the conservative planning ceiling. At that current, a 10,000 mAh pack mathematically requires about 10.5C, an 11,000 mAh pack about 9.5C, and a 12,000 mAh pack about 8.75C. Those values show why a well-made 20C–30C battery can already provide substantial theoretical headroom for this airplane.

Once a battery has enough real current capability for the airplane, additional advertised C-rating becomes secondary. The final decision should place greater weight on fit, battery mass, usable energy, voltage sag,

temperature behavior, connector and wire capability, reliability, and measured performance in the actual installation.

Independent Performance Research

A second research pass attempted to locate independent performance testing for each 9K–12K battery on the shortlist. That search produced an important finding: large 9,000–12,000 mAh 6S UAV-style packs are poorly represented in public controlled battery-test databases. Most detailed independent testing concentrates on smaller packs used in RC cars, EDF aircraft, speed models, and other high-current applications.

Where an exact-model controlled test could not be found, the research did not substitute a smaller battery and present the result as though it applied directly. Instead, evidence was classified according to how closely it matched the candidate battery.

- Exact-model controlled bench testing — strongest evidence when available.
- Exact-model operational or field evidence — useful, but not equivalent to a controlled bench test.
- Same-family or same-brand proxy testing — useful for judging how cautiously to treat the printed C-rating, but not transferable as an exact numeric result.
- Manufacturer-only performance claims — retained as provisional specifications until independently verified.

The independent tests that were available reinforced the need for caution. Some smaller packs carrying very high published C-ratings measured far below the label when evaluated using internal resistance, voltage sag, usable capacity, and temperature. Those results do not prove how a different 9K–12K pack from the same manufacturer will perform, but they do show why the printed C-number should not be the primary ranking factor for this L-4.

> *For this airplane, the more useful question is not "Which battery has the largest C-rating?" but "Which battery can comfortably deliver the approximately 105 A we may require while remaining cool, stable, reliable, and reasonably light?"*

Because exact independent testing is limited, the final verification process continues after purchase. Each battery selected for flight should have its cell internal resistance recorded when new under consistent conditions, then be checked during conservative ground testing for voltage sag and temperature before it is accepted for routine flight use.

Why LiHV Batteries Were Excluded

Some high-voltage lithium polymer batteries fit physically and appear attractive. However, the current L-4 power system is based around the Castle Phoenix Edge HV 160 ESC and a conventional 12S standard-LiPo system.

Battery type	Nominal 6S voltage	Max V/cell	One 6S full	Two 6S in series
Standard LiPo	22.2 V	4.20 V	25.2 V	50.4 V
LiHV	≈22.8–23.1 V	4.35 V	26.1 V	52.2 V

A fully charged 12S LiHV system can therefore reach approximately 52.2 V, exceeding the current 50.4 V design ceiling of the Castle Edge HV 160.

For that reason, physically suitable LiHV packs were deliberately excluded from the primary recommendations. A LiHV option would require a deliberate re-evaluation of the ESC and charging strategy rather than a simple battery substitution.

Relationship to ESC Cooling

The battery study is tied directly to the L-4 cooling-system design. The current airflow concept is:

Cowl inlet → firewall inlet → ESC → battery bay → cockpit/former transfer opening → under-floor avionics plenum → aft fuselage exit

The ESC is intended to receive the coolest incoming air first. Battery size therefore matters because an oversized pack can crowd the ESC, block airflow, force tighter wiring bends, or reduce service clearance.

The successful 10K mock pair was especially encouraging because it left substantial remaining ESC clearance. That result is one reason the study does not simply pursue the physically largest battery that can be forced into the bay.

What This Workbook Is Intended to Do

This workbook is intended to serve as a decision-support document. It allows candidate batteries to be compared by capacity, manufacturer, published dimensions, rotated installation footprint, remaining fit margin, battery and pair weight, nominal energy, energy density, published current capability, connector type, source references, and independent-performance evidence where it could be found.

The workbook also records batteries that were deliberately excluded and explains why. That matters because an excluded battery may later become viable if a different ESC is selected, the tray arrangement changes, the power requirement changes, or a manufacturer revises the product.

What This Workbook Does Not Claim

- It does not claim that every listed battery will fit every possible tray design.
- It does not replace an actual battery-in-hand check.
- It does not guarantee that manufacturer dimensions are exact.
- It does not establish final flight duration.
- It does not determine the final center of gravity.
- It does not independently prove published C-ratings.
- It does not treat same-brand or same-family proxy tests as exact measurements of a candidate battery.
- It does not yet select the final battery.

Instead, the study establishes a defensible shortlist based on the actual airplane and the best available published data.

Current Working Conclusions

At this stage of the project, several conclusions can be considered established.

- The L-4 can accommodate a pair of batteries within the successful 10K-class physical envelope while preserving meaningful room for the ESC.
- The failed broad 12K mock did not prove that 12K batteries are impossible.

- The failure was caused primarily by battery width.
- Because vertical space is available, many batteries can be rotated onto a narrower face.
- That makes several real 12K batteries viable.
- The HRB 6S 12,000 mAh 25C is the most promising 12K candidate identified so far.
- The leading 9K–10K candidates remain valuable because they offer lower weight, easier packaging, and more cooling margin.
- The printed C-rating should not be used as the primary ranking factor once a pack has adequate real current capability for the L-4.
- At the 105 A planning ceiling, the required C-rate is modest: approximately 10.5C for 10K, 9.5C for 11K, and 8.75C for 12K packs.
- Independent exact-model bench data are sparse for large 9K–12K 6S packs, so final acceptance must include measurements on the actual batteries purchased.

The final choice should be made by comparing flight time gained against weight added and installation margin lost.

Recommended Next Steps

1. Create or obtain a battery-specific mockup of the leading 12K candidate, especially the HRB 12K.
2. Trial-fit two batteries in the exact intended orientation.
3. Confirm actual ESC clearance and airflow space.
4. Verify connector and wire routing.
5. Confirm that each battery can be loaded and removed through the intended cockpit access.
6. Determine the fore/aft adjustment range required for center-of-gravity tuning.
7. Finalize the motor/propeller combination and measure full-power current.
8. Reconfirm the selected battery's current requirement against that measured demand.
9. Record cell internal resistance for each new pack under consistent conditions and establish a baseline.
10. Perform a conservative ground-load check of voltage sag and battery temperature before accepting the packs for flight.
11. Select the final battery family only after fit, weight, energy, current, and measured pack behavior have all been considered.
12. Only then design the permanent battery shelf and removable carriers.

Why This Research Is Being Preserved

This document and its companion spreadsheet are intended to become part of the permanent Jon's Hangar L-4 project record. The value of the research is not simply the final battery selected; the more useful story is how the decision evolved.

We began with broad capacity assumptions. Physical mockups exposed the limits of those assumptions. The airplane itself showed that width was the real constraint. Rotating the battery changed the available options. Manufacturer research then showed that batteries with the same capacity can have completely different shapes. Finally, electrical limits eliminated some batteries that fit mechanically.

The airplane did not ask for a 10K battery or a 12K battery. It asked for a battery with the right geometry, weight, voltage, current capability, cooling relationship, and serviceability.

That progression is the real conclusion of this study—and the reason the work is worth preserving.

Suggested Jon's Hangar Framing

For publication on Jon's Hangar, this research is better presented as an engineering deep dive—a Rabbit Hole—rather than merely as a spreadsheet download.

Suggested article title
The Battery Bay Rabbit Hole — Why Capacity Wasn't the Real Problem

A useful opening idea for the website is:

We initially thought the question was whether the L-4 could carry two 12,000 mAh batteries. The mockups showed that was the wrong question. What mattered was not capacity—it was shape.

That framing gives the spreadsheet context and turns the battery-selection work into a project story rather than a static product-comparison table.