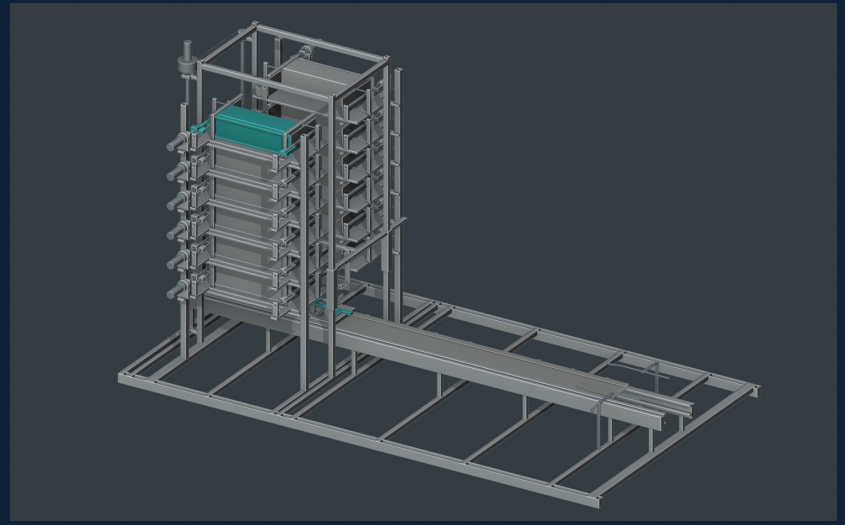
DEPARTMENT OF MECHANICAL ENGINEERING

VOLLEY

A Commanded Electromagnetic CubeSat Deployment Mechanism



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Guide: Vikas Gulia

From the delivery problem to the engineering result

Problem and objectives

- Problem, prior work and design objectives

Mechanism and evaluation

- Mechanism, models, numerical checks and mission results

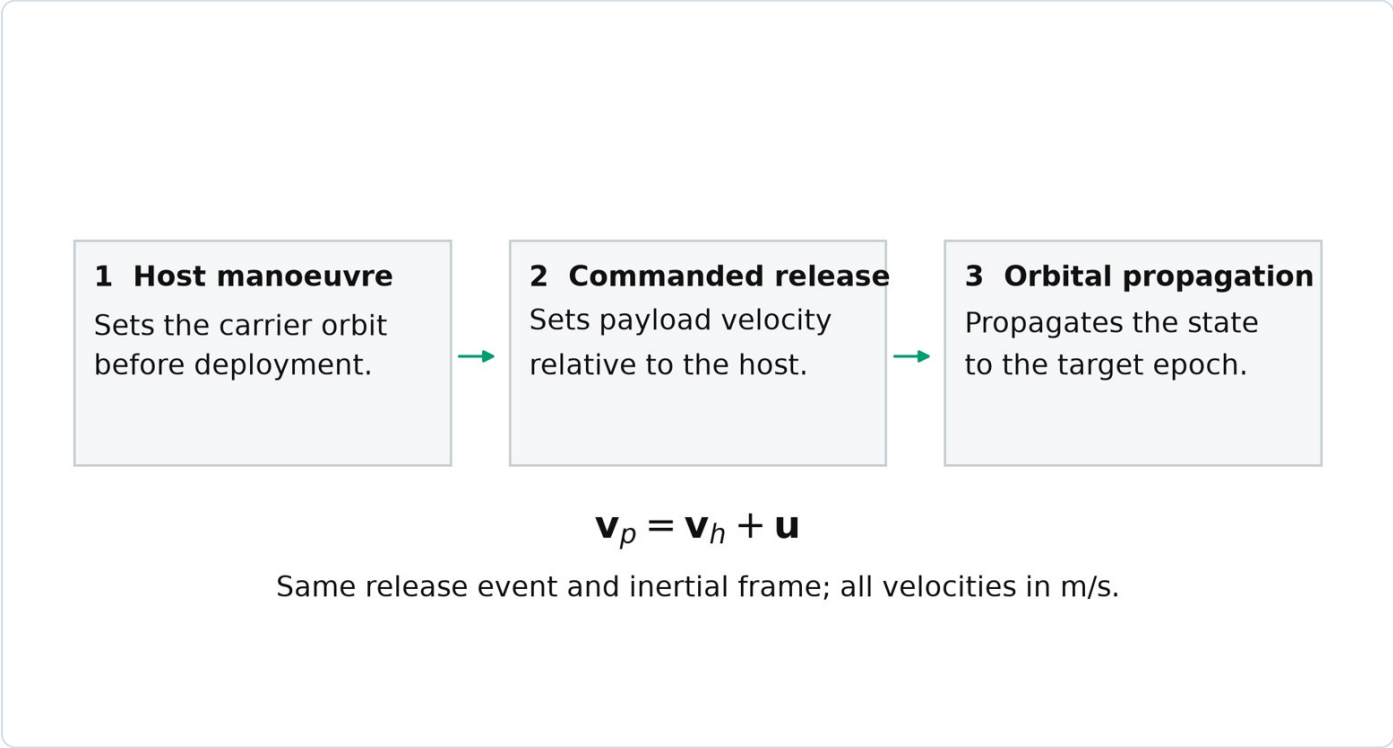
Research programme

- Development history, research ecosystem and next hardware stage

One connected argument: mission, machine, evidence and development.

The host moves the orbit. VOLLEY commands departure.

- Initial integration audience: orbital-transfer and rideshare host operators
- POEM inspires reuse of an orbital platform; Electron Kick Stage inspires host manoeuvres
- Individual departure velocity is an additional mission variable



Explanatory schematic. Release velocity and host velocity refer to the same event and frame.

Add a controllable relative release state to a manoeuvring host.

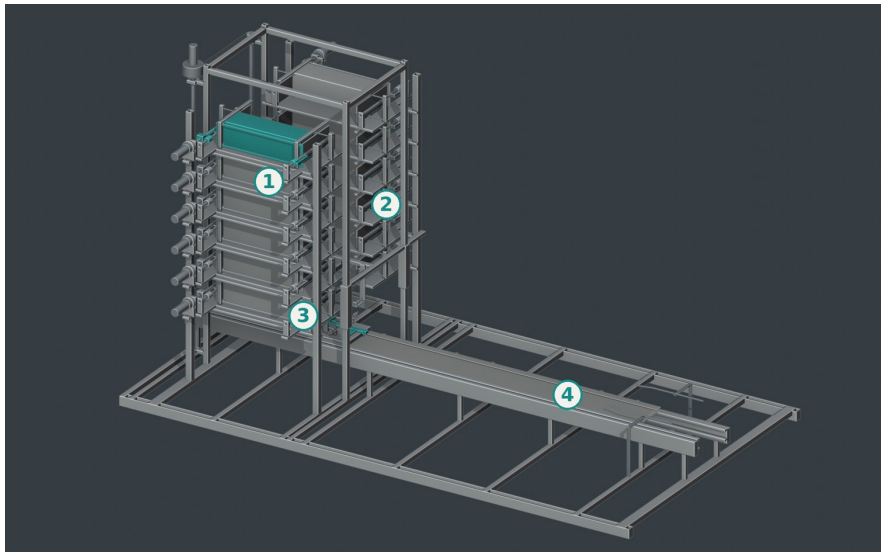
The contribution is the integrated retained-carrier cycle

Prior work / study	Engineering focus
Zhao et al. (2022)	Stacked electromagnetic deployment
Zhao et al. (2025)	Storage and transport interfaces
Feng et al. (2025)	Reachable-domain study
VOLLEY	Integrated custody, finite motor/source, arrest and mission burden

Connect custody, finite motor force, source response, arrest and mission burden.

A complete reference for twelve retained payloads

- Two fixed six-cell banks; one indexed captive pallet
- Guided lead-screw feed; positive carrier capture
- Reusable moving-magnet carrier; fixed three-phase stator



CAD-derived assembly view. The represented payload is a 3U envelope surrogate.

12 × 4 kg
3U envelope surrogates

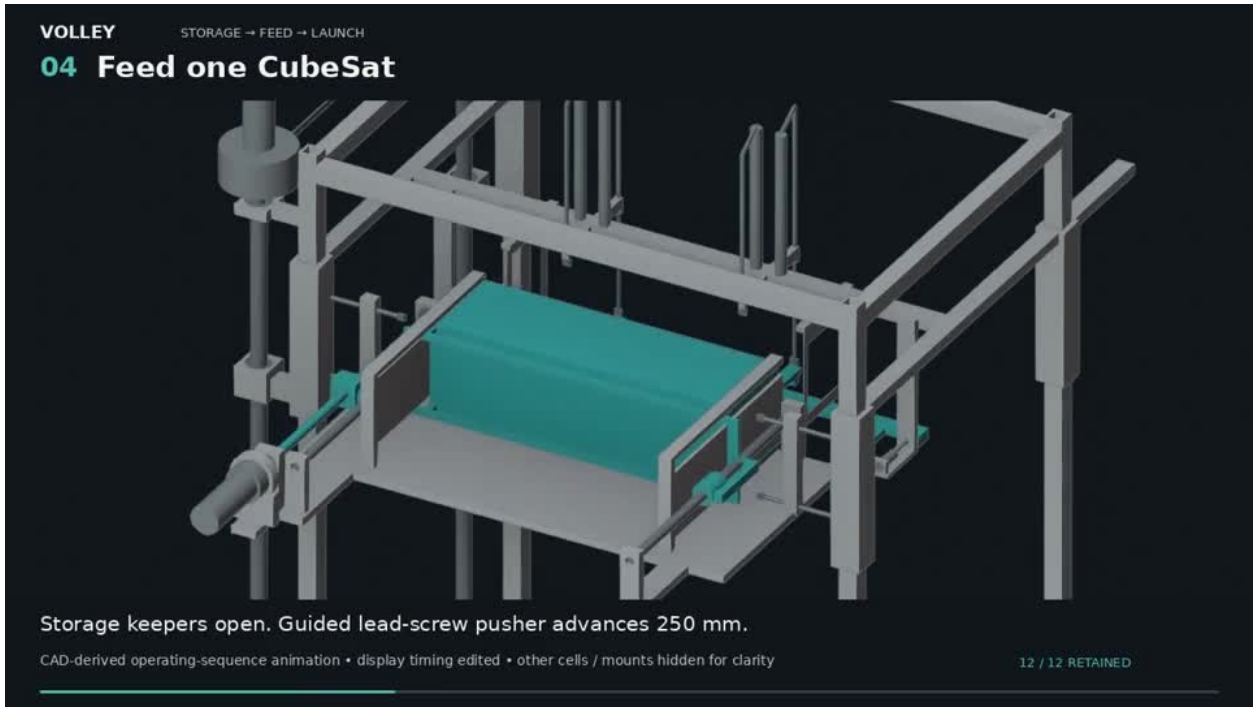
1–3 m/s
Analysed command cases

2250 mm
Guide-rail allocation

Define a repeatable path from storage to free departure.

Feed one cell into a supported receiver

- Index the receiver to the selected cell
- Open the permitted restraint; advance the guided pusher
- Establish receiving containment; retract the pusher and close the cell

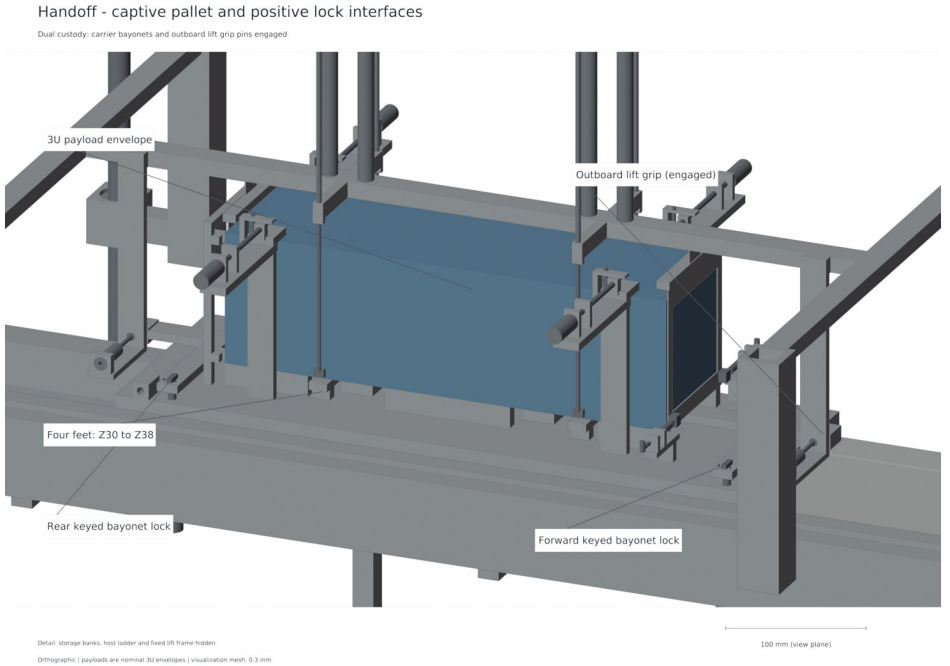


CAD-derived operating sequence; display timing edited. Static fallback shown.

The selected guided lead screw transfers the payload into the lift-held pallet.

Transfer custody before withdrawing support

- Carrier capture caps and independent pins engage
- Keyed pallet shafts insert 12 mm and rotate 90°
- Only then do lift grips retract and the lift clear the launch path



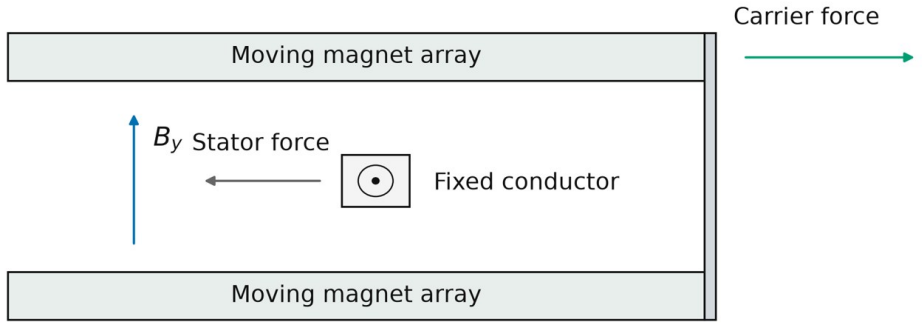
CAD-derived docking state. Modelled capture sequence; not a photographed hardware test.

One captive pallet stays with the reusable carrier through launch and recovery.

Finite geometry sets the motor force

- Integrate current density over the represented copper
- Finite magnet blocks, active conductors and returns enter the calculation
- Launch and arrest use their corresponding position-dependent maps

$$F_x = \int_{Cu} (J \times B)_x \, dV$$



Local force/reaction schematic. The numerical model integrates the represented finite geometry.

≈1.328 N/A
Active-conductor coefficient

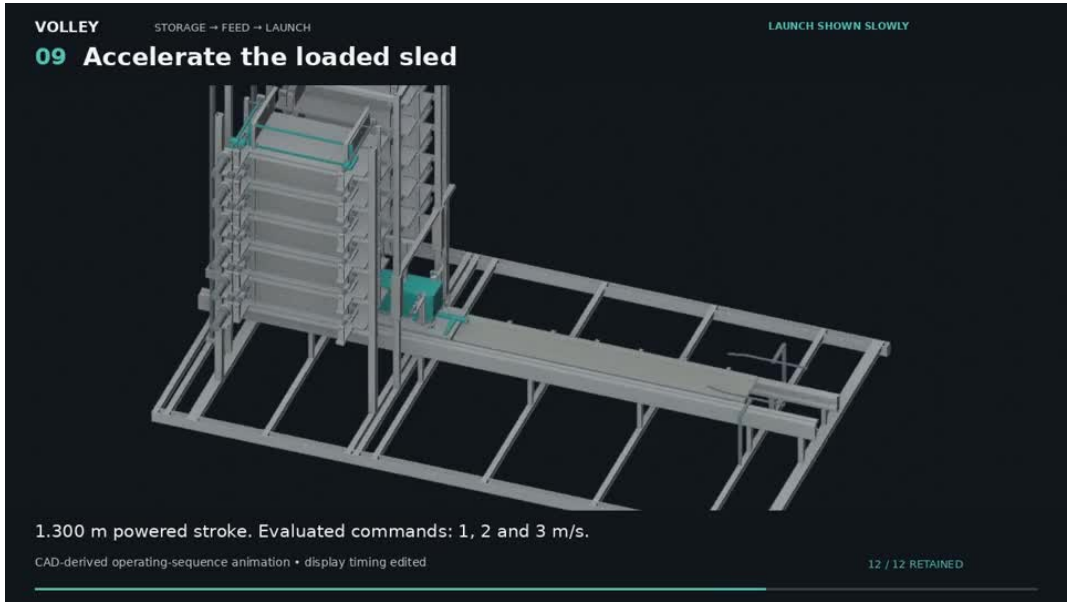
≈1.399 N/A
Including represented returns

Opposed permanent-magnet arrays exchange force with a fixed three-phase winding.

Solve source, current and motion together

- Phase voltage, current and back-emf
- Finite capacitance and ESR constrain available terminal power
- Rear contact reaches zero; the retained carrier then arrests

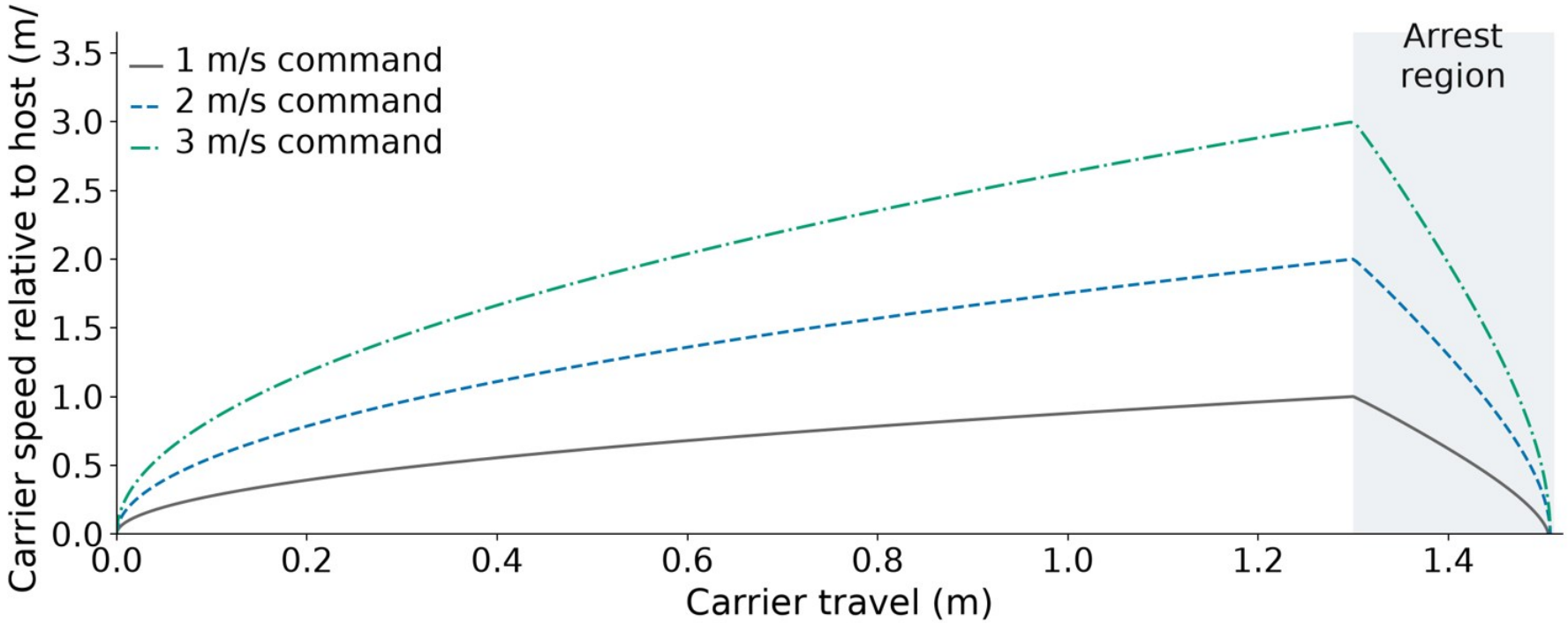
$$V_q = R\, I_q + L\, dI_q/dt + K_e(x)\, v$$



CAD-derived operating sequence; display timing edited. Static fallback shown.

The release event changes the mechanical connectivity of the model.

The principal 3 m/s case completes release and arrest

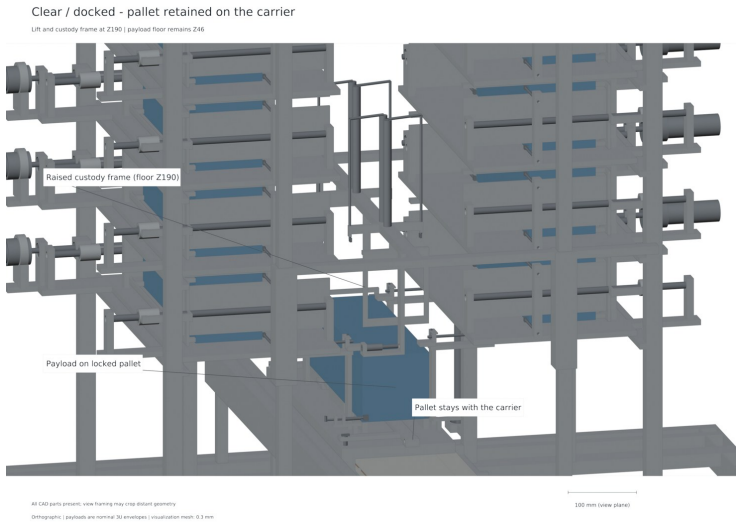


Computed histories. Principal case: 3 m/s command, nominal source, 20 µH; source and case-specific checks apply.

3 m/s command → 2.999864 m/s release · carrier stop position 1.507289 m

Check solids, states and the represented motion path

- Eight native and STEP states retain part identities and pallet counts
- 154 accepted sampled-motion and refinement checks
- Named solid-volume mass ledger separates CAD material and allowances



CAD-derived launch-ready state. Native solid and exchange-geometry records support the displayed arrangement.

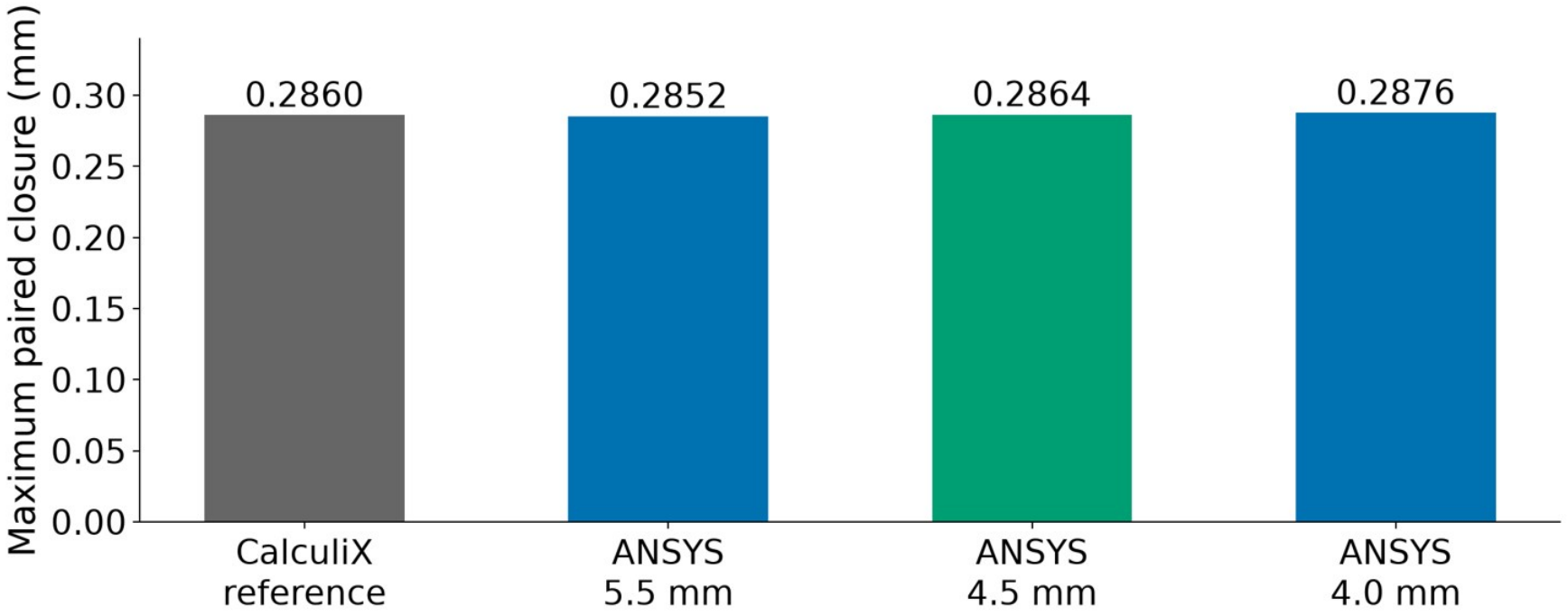
8
Native / STEP states

154
Motion / refinement checks

149.557 kg
Represented dry CAD mass

Geometry is checked beyond a single assembly rendering.

Independent static calculations reproduce paired closure

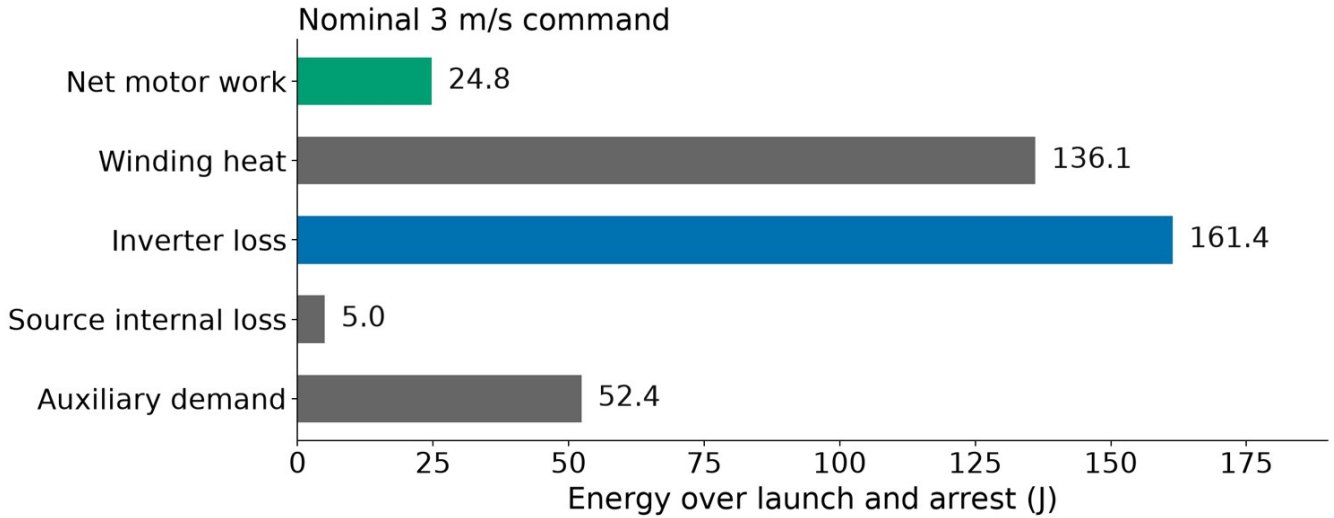


Computed bare-chassis comparison. ANSYS mesh refinement sensitivity is distinct from experimental accuracy.

Paired closure: 0.285983 mm (CalculiX) · 0.286392 mm (primary ANSYS sample)

Thermal budgets and interlocks complete the operating boundary

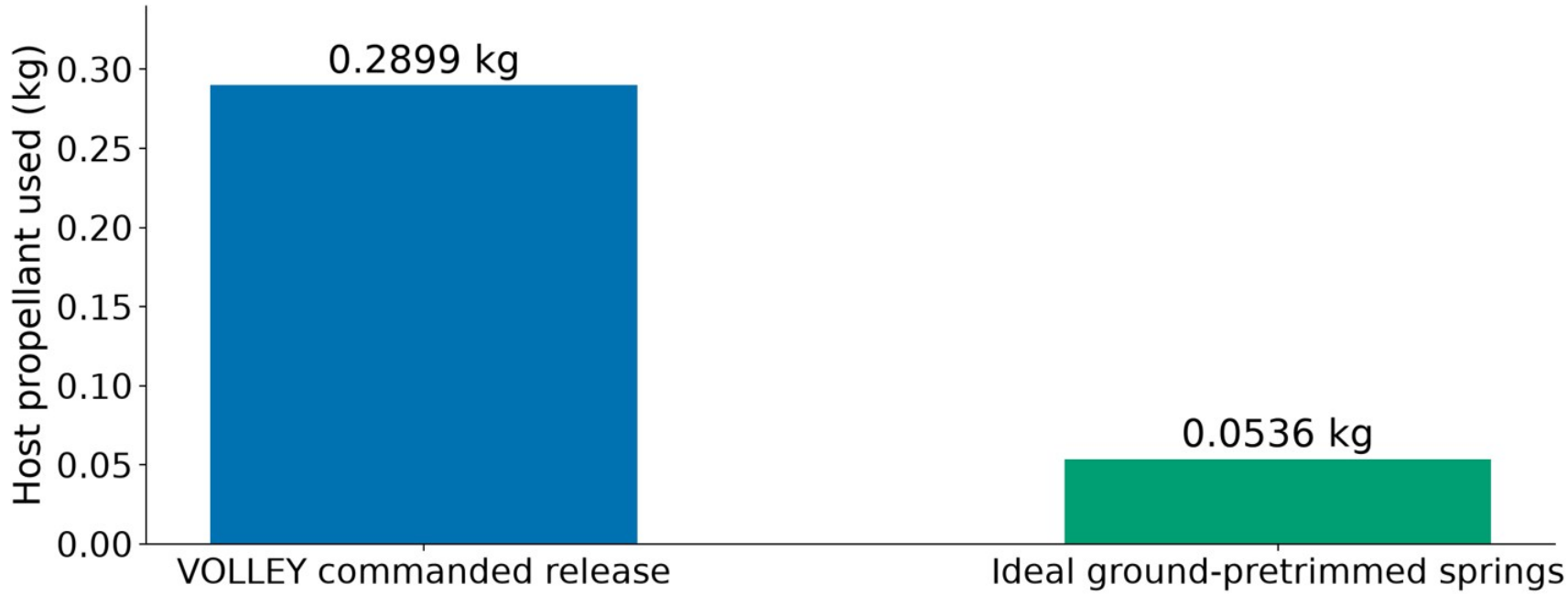
- Copper heating uses the current history and represented conductor field
- Repeated-shot estimates distinguish bulk rise, local rise and cooling assumptions
- 24 nominal commands; 166 passing interlock-model tests



Computed principal-case energy account. Numerical residuals check conservation; they are not efficiency or reliability measurements.

Electrical losses, contact assumptions and sequencing stay explicit.

Compare equal delivery targets and count retained resources



Selected feasible tested policies in the alternating target family with a 5 N host ceiling; device masses and burn guards retain their declared differences.

Host propellant: 0.2899 kg (VOLLEY) · 0.0536 kg (ideal ground-pretrim spring)

A complete computational reference connects the machine to the mission

Operating cycle

- Storage, feed, capture, departure, arrest and return are defined

Coupled model

- Finite force, source response and retained mass are evaluated together

Engineering checks

- Geometry, structure, thermal budgets and mission resources share an evidence chain

The study delivers a defined operating cycle and configuration-specific engineering results.

Development follows linked engineering questions

01

Concept and architecture

Concept and host architecture → feeder, carrier and finite motor models

02

Integrated evaluation

Integrated computational reference → independent numerical comparisons

03

Prototype requirements

Reusable tools and Labs investigations → physical-development requirements

Five-plus years of VOLLEY development produced a connected engineering record.

An engineering ecosystem grew around the deployment problem

VOLLEY Labs

- VOLLEY Labs: feeder alternatives, force benchmarking and new speed configurations

Reusable tools

- Reusable tools: motor design, separation/orbits, CAD automation and source traceability

Future interfaces

- GatewayCX: proposed cislunar network relationship; technical paper draft for future peer review

Each related project addresses a specific part of the development chain.

VOLLEY Labs research catalogue; engineering tool repositories; GatewayCX architecture

Gen6 turns the reference into an instrumented hardware programme

01

Gen6 prototype

Gen6: instrumented feed/lock and motor/source articles, then a mixed 1U/3U prototype

02

Higher-speed study

Higher-speed programme: separate ~10 m/s computational design; 1 km/s stretch research objective

03

Long-term architecture

Future host: a POEM-inspired free-flying carrier, replenishable constellations and Artemis-era lunar science/communications

Long-term cislunar delivery: 3.5 km/s departure research, with targeting and capture designed separately.

Blackbook §11.2; Labs high-speed and lunar architecture studies; NASA lunar infrastructure programme

Commanded deployment, evaluated as a complete system

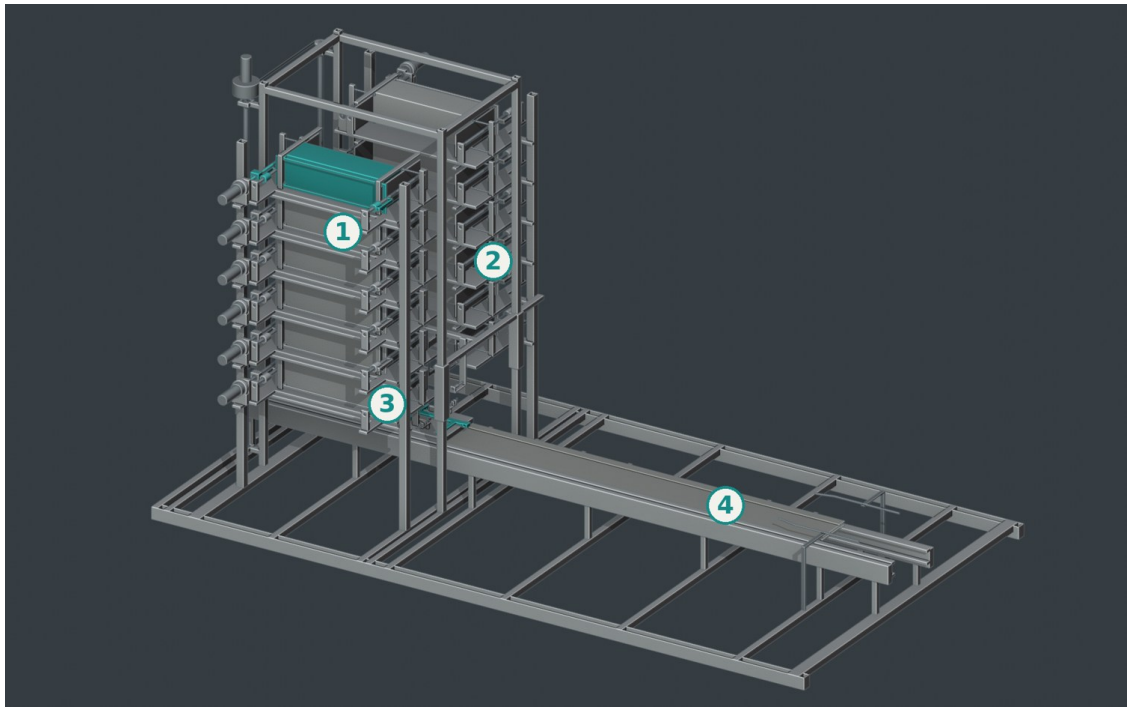
A defined machine. Coupled engineering. A measured route to hardware.

Questions

- CubeSat interface sources; Zhao 2022/2025; Feng 2025; Halbach and finite-motor literature
- Native CAD, finite-element, circuit and orbital source records accompany the study
- VOLLEY technical record: github.com/aaaaaaaaaaaavm/VOLLEY

Reference quantities and mass boundaries

- Payloads: 12 × 4 kg; each 340.5 × 100 × 100 mm
- Dry CAD 149.557 kg; power/control allowance 7 kg; loaded device 204.557 kg
- Retained moving carrier plus pallet: 13.127806 kg

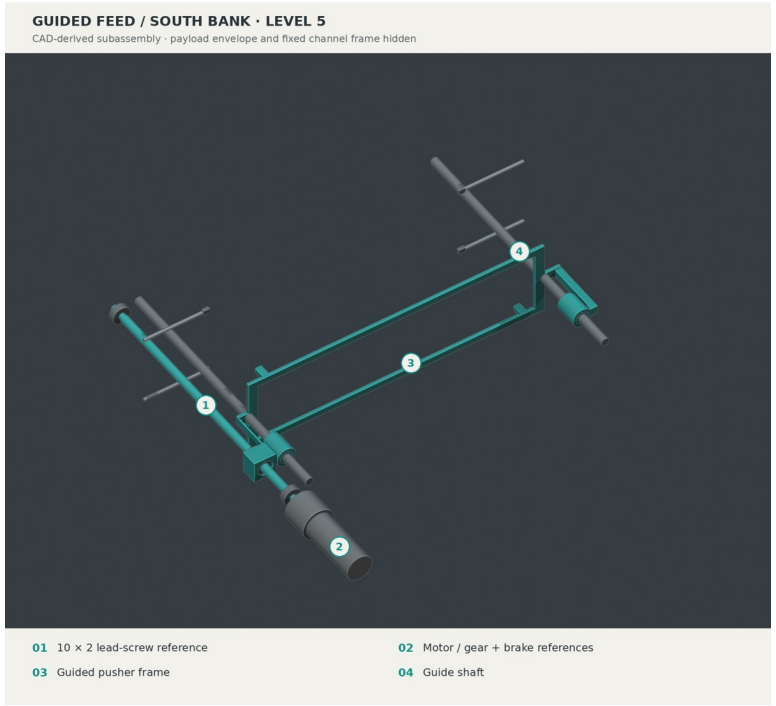


CAD-derived assembly; mass values are modelled/allocated, not scale measurements.

Keep represented CAD material, system allowances and payloads separate.

Why a guided lead screw?

- Lead screw selected; rack-and-pawl retained as runner-up
- Seven candidates preserve pantograph, telescope, belt, drum and spring/gate concepts
- Weighted scores are declared judgments; measured reliability remains a hardware question

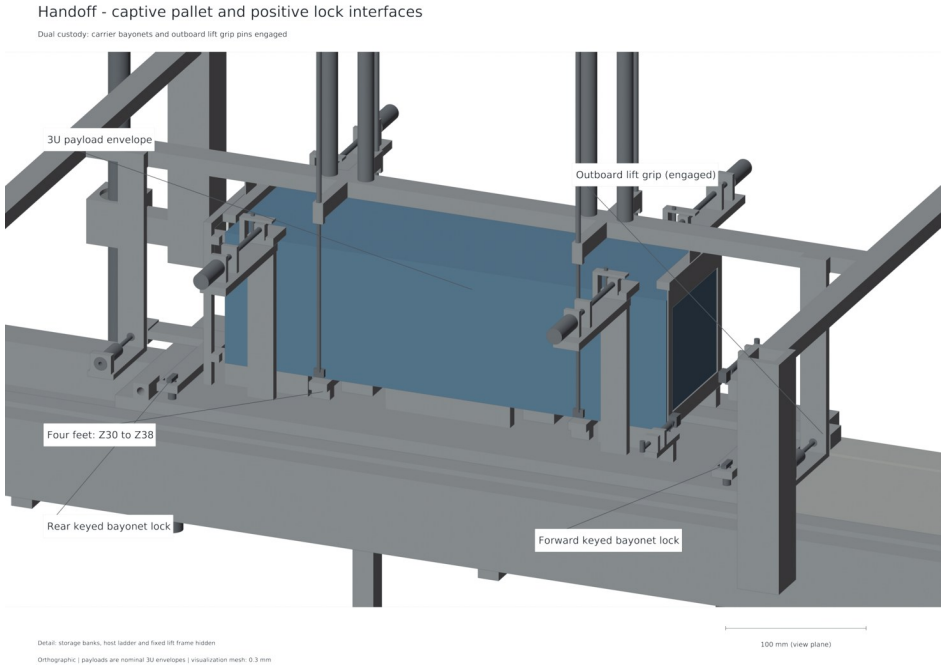


CAD-derived feeder detail. Detailed comparison remains in Labs.

Selection balances restraint, controlled travel, packaging and failure behaviour.

Capture before lift release

- 12 mm lock insertion; keyed heads rotate 90°
- Lift grips retract 26 mm only after permitted carrier capture
- Same pallet remains through launch, arrest and return



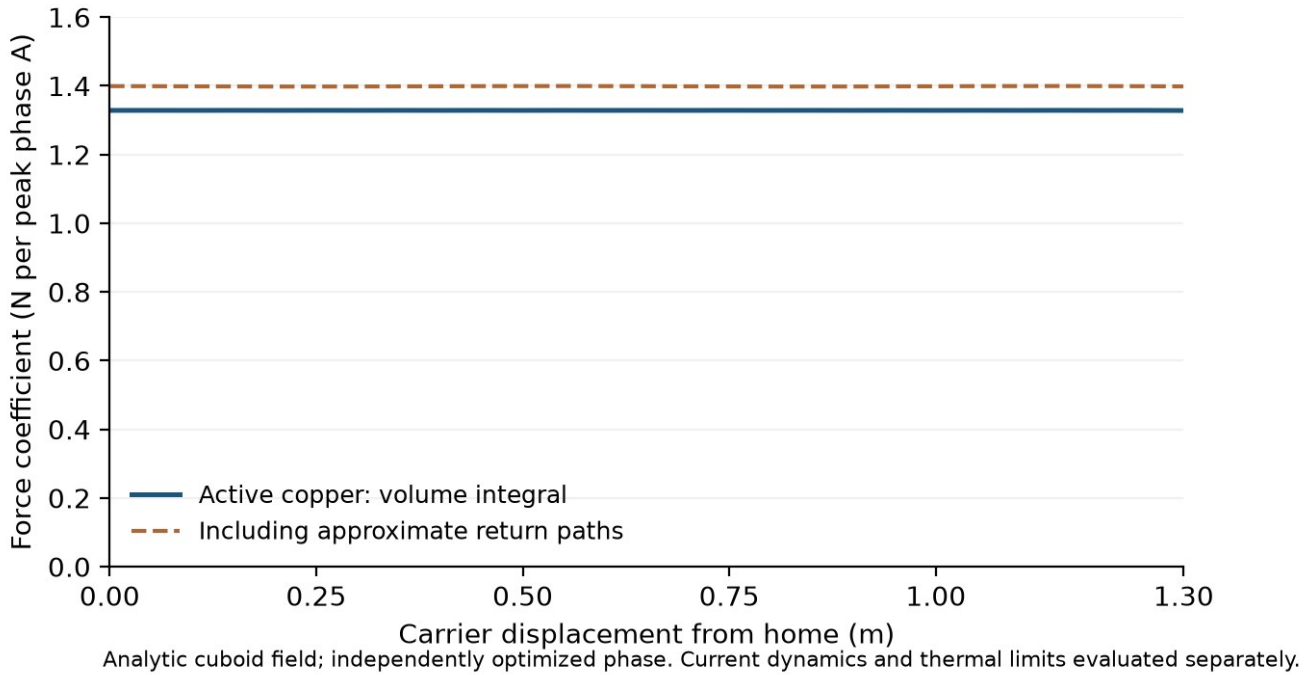
CAD-derived state; interlock logic and geometric checks have separate scopes.

Carrier capture and independent locking precede lift withdrawal.

Finite-field and current-path comparisons

- Finite source-face comparison checks the active field/force formulation
- Conduction FEM at 0.65 m: 1.396651 N per peak phase ampere
- Uniform bars plus approximate returns: 1.399055 N/A; local difference −0.1718%

$$F_x = \int (J \times B)_x \, dV$$



Numerical comparison at stated stations; not a physical accuracy specification.

Alternative calculations test different aspects of the represented model.

Source and switching allocations

Nominal source

- 32S2P, 64 cells; nominal 6.25 F and 0.176 Ω

Adverse source

- Adverse 3.9375 F and 0.352 Ω; 2.9 V/cell regeneration terminal cap

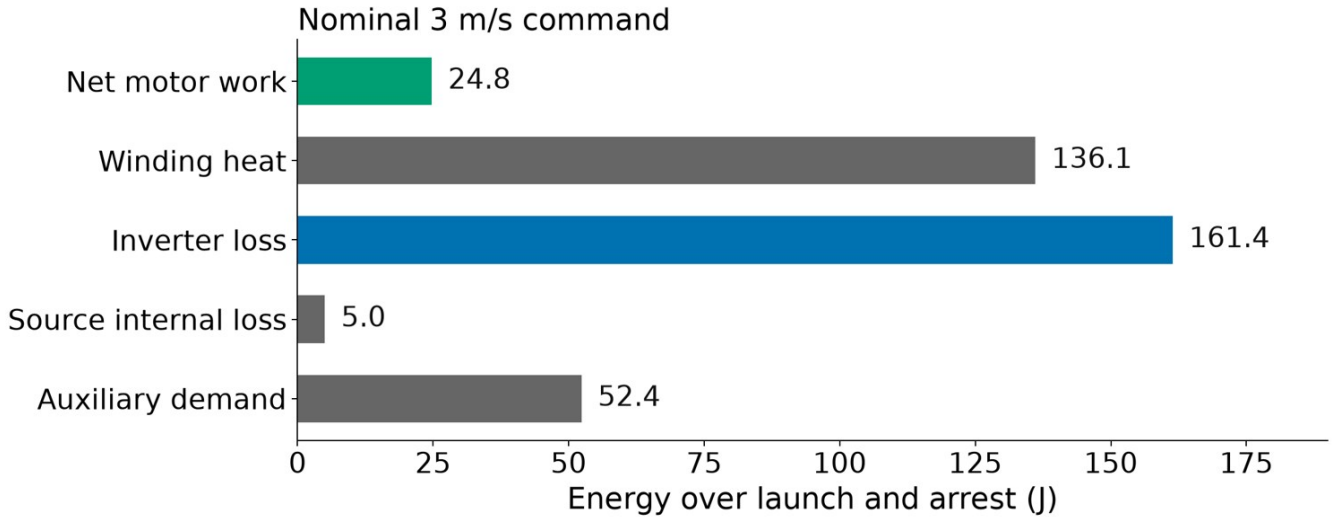
Power stage

- Three half bridges, 10 devices per switch position, 60 MOSFETs; 40 kHz reference PWM

Ratings enter the model with finite impedance and declared switching assumptions.

Principal nominal energy account

- Capacitor draw: 379.682 J in the 20 µs principal nominal replay
- Copper 136.066 J; inverter 161.429 J; bank 5.039 J; auxiliaries 52.389 J
- Full-cycle mechanical term 24.768 J; do not equate it with peak moving-body kinetic energy

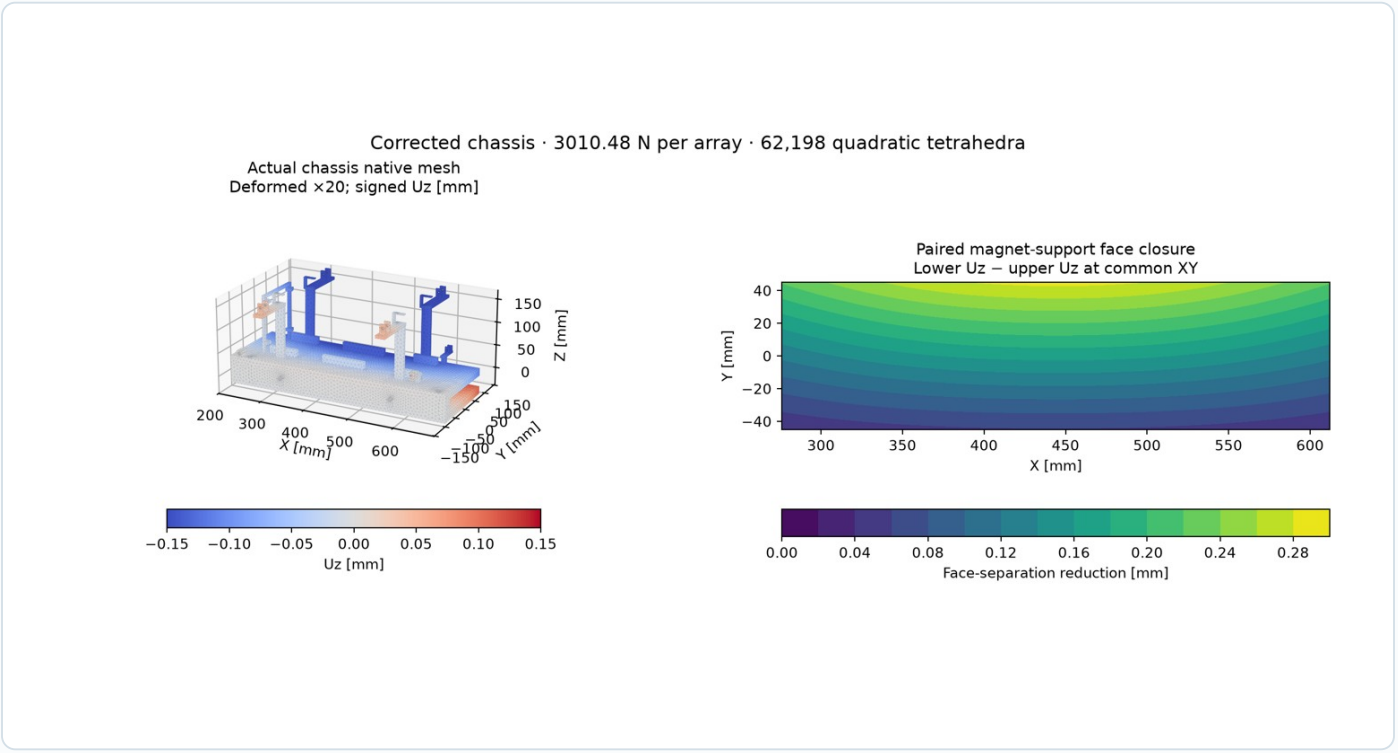


Numerical ledger for one specified case; regenerative braking and event boundaries matter.

Signed energy terms include source and auxiliary losses.

Gap closure and individual-face budgets

- CalculiX nominal paired closure 0.285983 mm; 1.3-load closure 0.371778 mm
- Conditional centring split, plus alignment/flatness/assembly/thermal allowances
- Individual-face reference design budget 0.264111 mm



Native bare-chassis mesh and paired closure. Deformation ×20; assembled allowances are separate.

A paired closure is not an individual assembled clearance.

Thermal and fault interpretation

Temperature and time

- 3.295053 K is a temperature rise; 450 s is the inter-shot interval

Thermal measures

- Bulk, volume-99 and sharp-corner mesh observations have different meanings

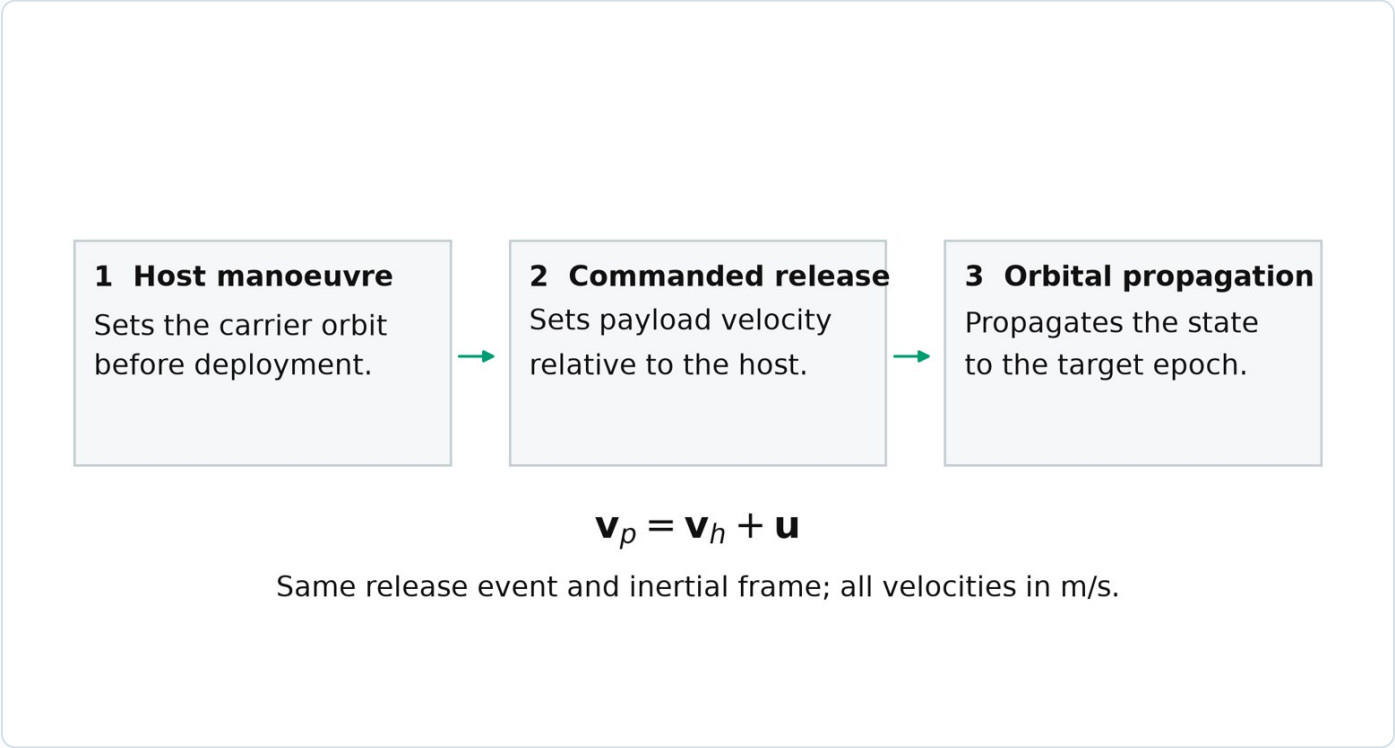
Encoded logic

- 166 interlock tests verify encoded logic, not a measured reliability probability

Keep quantities and test meanings distinct.

Host reaction and the common terminal epoch

- Principal 3 m/s nominal relative release gives about 2.927 m/s payload inertial increment
- Count carrier acceleration, subsequent carrier arrest and changing retained mass
- Compare all payload position/velocity targets at a common epoch



Explanatory mission schematic; complete comparison includes host manoeuvres and device mass.

A commanded relative release differs from the payload inertial increment.

Higher-speed work already in Labs

New configuration

- Longer powered travel, revised finite winding and source accounting

Model checks

- Retained-carrier nominal/adverse cases pass their declared circuit/motion checks

Alternative design

- Attached-shoe alternative and its adverse speed miss remain separately recorded

The approximately 10 m/s study is a separately specified computational design.

Lunar departure and capture are separate operations

Parking-orbit screen

- Ideal 500 km parking-orbit screen: approximately 3.058 km/s departure increment

Departure energy

- A prograde 3.5 km/s increment from that reference is Earth-escape energy

Capture design

- Lunar targeting, host recoil and lunar capture require their own complete mission design

Departure speed alone does not establish lunar-orbit delivery.

Selected bibliography and research record

Y. Zhao et al. (2022). “Design and analysis of a new deployer for the in-orbit release of multiple stacked CubeSats.” Remote Sensing 14(17), 4205.
doi:10.3390/rs14174205

Y. Zhao et al. (2025). “Simulation analysis and experimental verification of the transport characteristics of a high-volume CubeSat storage device.” Aerospace 12(6), 466.
doi:10.3390/aerospace12060466

H. Feng, Y. Yang and Y. Wu (2025). “Design and reachable domain analysis of on-orbit electromagnetic launcher for CubeSats.” International Journal of Aerospace Engineering, 3000765.
doi:10.1155/ijae/3000765

Architectural and mission context

ISRO · POEM-3 mission account

Rocket Lab · Electron guide v7.0

NASA · Lunar surface technology

Planned IEEE-formatted paper · venue unselected · manuscript unsubmitted

The paper documents the checked study; tools retain their own contribution boundaries.