

Online Resource 1

25 kg Nozzle-Turret Feeder: Operating Requirements and Conditional Sizing

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Status: Preliminary calculations for the proposed aircraft, silo and service system. These are not measured performance results or fabrication specifications.

1 Recalculation for a 25 kg nozzle-turret aircraft

1.1 Design basis and retained mechanism

This calculation updates the proposed farm-scale operating point to 25 kg of feed per sortie, two sorties per session, five sessions per day, and 500 kg storage per feed grade. These are design requirements, not outcomes of the 0.5 kg prototype trials. The tested two-nozzle turret is retained. The original farm-scale specification has three adjustable nozzles; both outlet counts are evaluated below without replacing the turret with a disc. The hexacopter configuration in that specification is retained for sizing. The four-rotor, 280 mm disc concept in the later CAD README is not adopted.

The reported trial data and historical 10.25 kg example are unchanged. The new 25 kg target supersedes the earlier 15 kg proposal for future aircraft sizing. Bulk densities, fill fractions, power, thrust margins and discharge times below are explicitly assumed scenarios. They must be replaced by measured feed properties and component performance before manufacture.

Table 1: New operating requirements and direct arithmetic.

Quantity	Requirement or calculation
Nominal loaded feed per sortie	25 kg
Sorties per session	2
Nominal loaded feed per session	50 kg
Sessions per day per pond	5
Nominal loaded feed per day per pond	250 kg
Sorties per day per pond	10
Prototype loads for a 50 kg session at 0.5 kg/load	100
Mean dose for 12 equal-dose waypoints per session	4.167 kg

A 12-waypoint session could assign six equal-dose points to each sortie, but this is only an allocation example; coverage must be checked from measured footprints. Loaded feed must be distinguished from delivered feed. At an illustrative 98% discharge fraction, a 25 kg load delivers 24.5 kg, and delivering 25 kg would require 25.51 kg loaded. That extra mass cannot be added to

an aircraft rated for only 25 kg of feed. Residual mass, hopper tare and dispenser mass must be included in the mission and aircraft budgets.

1.2 Hopper volume and silo capacity

For feed mass m , measured bulk density ρ_b , and allowable fill fraction ϕ ,

$$V_{\text{gross}} = \frac{m}{\rho_b \phi}. \quad (1)$$

Here $\phi_h = 0.80$ for the aircraft hopper and $\phi_s = 0.85$ for the silo are planning assumptions. The aircraft volume must be clear internal volume after subtracting the pusher, shaft and other intrusions; a CAD external envelope is not usable capacity.

Table 2: Sensitivity to assumed bulk density; none of these densities is a measured feed property.

Bulk density (kg m ⁻³)	25 kg hopper gross volume (L)	500 kg silo gross volume (m ³)
450	69.4	1.307
550	56.8	1.070
650	48.1	0.905

A preliminary **75 L clear internal hopper** provides geometric allowance across this density scenario, subject to weighed loading and flow tests. It replaces the unsupported 55 L assumption. At 80% filling, 55 L contains only 19.8 kg at 450 kg m⁻³ and 24.2 kg at 550 kg m⁻³.

For a silo with internal diameter D , cylindrical height h_c , tapered-bottom height h_f , and outlet diameter d_o , treating the taper as a conical frustum gives

$$V_s = \frac{\pi D^2 h_c}{4} + \frac{\pi h_f}{12} (D^2 + D d_o + d_o^2). \quad (2)$$

The README dimensions $D = 1.00$ m, $h_c = 1.20$ m, $h_f = 0.65$ m and $d_o = 0.12$ m give 1.136 m³. At 85% filling and the lowest assumed density, this holds only 434.3 kg. A geometrical candidate with $h_c = 1.45$ m and the other dimensions unchanged gives 1.332 m³, or 509.4 kg at that same density and fill fraction. Its internal vessel height is 2.10 m, excluding legs, actuators and upper fittings. The 120 mm outlet and taper are retained geometric assumptions, not a validated anti-bridging or mass-flow design. Control should limit loaded mass to the structural rating even when denser feed occupies less volume.

Five 500 kg silos contain 2500 kg; the seven-module source architecture contains 3500 kg. These correspond to 10 and 14 aggregate pond-days only when the grade-demand mix matches the inventory. A single grade supplying all 250 kg/day lasts two days. Per-grade depletion must be tracked separately. This calculation does not replace the original rotating-silo arrangement with the README's stationary-silo concept. If the full array rotates, its bearing load, inertia, drive torque, alignment and support structure must be designed for feed plus vessel mass. Tonne-scale mass does not prohibit rotation, but a small indexing actuator cannot be selected from capacity alone.

1.3 Feed-transfer and outlet requirements

Required total mass flow is $\dot{m} = m/t_d$, where t_d is active discharge time. Equal flow division gives $\dot{m}_n = \dot{m}/N_n$ for N_n nozzles. Equal division is an assumption to verify, particularly under tilt and changing hopper level.

A three-minute discharge is a useful test case, requiring 8.33 kg/min total. This is a target for pusher/gate calibration, not a demonstrated capacity. Nozzle bore cannot be obtained from payload alone. A mean-flow identity is $\dot{m}_n = \rho_{\text{eff}} A_n v_a$, where ρ_{eff} is the effective moving-stream density and v_a the axial velocity. Neither is established by bulk density alone. Outlet area, pellet clearance, wall friction, bridging and feed splitting require bench measurements.

Table 3: Flow needed to discharge a nominal 25 kg load.

Discharge time (min)	Total (kg min ⁻¹)	Each of 2 nozzles (g s ⁻¹)	Each of 3 nozzles (g s ⁻¹)
2	12.50	104.2	69.4
3	8.33	69.4	46.3
4	6.25	52.1	34.7

For continuous turret rotation, the proposed variable-speed motor should provide rotation with encoder feedback; position servos can actuate gates or nozzle elevation. The original record lists both a turret servo and a DC drive. Their roles and coupling must be resolved in the implementation drawing. No listed hobby servo is assumed capable of a particular continuous speed or loaded torque.

1.4 Turret speed: an idealized calculation only

The intended nozzles can change inclination relative to the rotating turret. The following table treats only a horizontal-release reference case; it does not constrain the mechanism to horizontal or fixed nozzles. For horizontal launch at height H , with zero initial vertical velocity and no air drag, wind or rotor flow,

$$t_f = \sqrt{\frac{2H}{g}}, \quad v_t = \frac{R}{t_f}, \quad n_{\text{ideal}} = \frac{60R}{2\pi r_e t_f}. \quad (3)$$

Here R is horizontal travel from the release location, r_e is the axis-to-exit radius, and the last equality assumes the pellet’s tangential velocity equals the local turret speed. Radius r_e is not the nozzle bore. Radial exit velocity, slip, pellet contact and aircraft motion are omitted.

Table 4: Idealized rpm at an assumed 2.5 m release height. These are neither calibrated set-points nor a validated operating band.

Exit radius (m)	4 m travel	6 m travel	8 m travel
0.15	357	535	713
0.20	268	401	535
0.25	214	321	428

Thus a 0.20 m exit radius and 6 m travel produce an idealized 401 rpm, not the disc README’s nominal 750 rpm. Actual settings require measured exit velocity and a deposition map. A simple angular-momentum estimate for pellet reaction torque is $\tau_p = \dot{m}r_e v_t$, assuming negligible inlet angular momentum. The three-minute, 6 m, 0.20 m example gives approximately 0.233 N m. Motor torque must additionally cover rotor acceleration $J\dot{\omega}$, bearing/friction loads, granular resistance and transients; 0.233 N m is not a motor rating. The servo/motor supply must be sized from measured continuous and startup current.

For an inclined outlet, let v_{z0} be the pellet’s initial vertical velocity, positive upwards, and $\mathbf{v}_{h0}$ its horizontal velocity in the ground frame. For release height $H > 0$ above a level pond, neglecting air forces,

$$t_f = \frac{v_{z0} + \sqrt{v_{z0}^2 + 2gH}}{g}, \quad \Delta \mathbf{x}_h = \mathbf{v}_{h0} t_f. \quad (4)$$

These follow from $0 = H + v_{z0}t_f - gt_f^2/2$. Nozzle inclination, turret phase and speed, pellet motion within the outlet, and aircraft velocity determine the release-velocity components. The nozzle-axis angle alone is not the pellet launch angle because turret motion contributes a tangential component. The release height and axis-to-exit radius can also change when a nozzle pivots. Accordingly, the rpm table cannot be converted into inclined-nozzle set-points by applying a single angle correction. Exit velocities, nozzle travel and deposition must first be measured. No numerical angle range is inferred from a static CAD view.

1.5 Aircraft mass, thrust and geometry

The required mass budget is

$$M_{\text{TO}} = 25 + m_{\text{airframe/propulsion}} + m_{\text{battery}} + m_{\text{hopper/turret}} + m_{\text{avionics/gear}} \quad \text{kg.} \quad (5)$$

No actual take-off mass has been established for the scaled aircraft. For a regular six-rotor layout, each rotor supports $M_{\text{TO}}/6$ kgf in symmetric hover. Using a total maximum-thrust-to-weight ratio of 2.0 as a preliminary design assumption gives the following requirements. This ratio is not a certification criterion or proof of motor-out recovery.

Table 5: Thrust requirements for assumed total take-off masses.

Assumed take-off mass (kg)	Hover per rotor (kgf)	Maximum per rotor at ratio 2.0 (kgf)
60	10.0	20.0
70	11.7	23.3
80	13.3	26.7

Propeller thrust and electrical power must be checked together using motor–propeller–ESC test data at the actual voltage, air density and temperature. Ideal propeller theory excludes losses and does not determine a qualified component combination (NASA Glenn Research Center, 2021). The earlier listed motor and propeller models are source design candidates, not validated selections for 25 kg of feed.

For six coplanar, non-overlapping rotors on a regular hexagon, propeller diameter D_p and an assumed 0.10 m tip clearance require opposite-motor spacing $L \geq 2(D_p + 0.10)$. The maximum rotor envelope is $L + D_p$. This gives 2.232 m motor spacing and 3.248 m envelope for 40-inch propellers; for 50-inch propellers, the values are 2.740 and 4.010 m. These are clearance calculations, not propeller selections. The README’s 1.925 m four-rotor wheelbase cannot simply be reused for the hexacopter.

The landing pad is sized to the gear footprint and positioning tolerance, while masts, silo supports and nearby obstacles must clear the complete rotor envelope. The README’s 3.4 m pad therefore cannot be accepted or rejected from propeller span alone.

1.6 Battery and flight-time sensitivity

At the README’s nominal 52.2 V, a 20 Ah battery stores 1.044 kWh. Assuming 80% mission-usable energy, its budget is 0.835 kWh. With mean total electrical power $\bar{P}$,

$$t_{\text{mission}} = \frac{60f_E V_b C_{\text{Ah}}}{1000\bar{P}_{\text{kW}}}, \quad C_{\text{Ah}} = \frac{1000\bar{P}_{\text{kW}} t_{\text{mission}}}{60f_E V_b}. \quad (6)$$

The assumed $f_E = 0.80$ is an energy allowance, not a validated return threshold. Power scenarios below include propulsion and auxiliary loads but are not predictions from a measured thrust map.

Table 6: Conditional endurance and capacity at 52.2 V and 80% usable energy.

Mean power (kW)	20 Ah duration (min)	40 Ah duration (min)	Capacity for 8 min (Ah)
8	6.26	12.53	25.5
10	5.01	10.02	31.9
12	4.18	8.35	38.3

A **40 Ah candidate** would cover an eight-minute mission within this assumed 8–12 kW range on nominal energy alone. Its mass can increase power demand, so this is an iterative sizing candidate, not a confirmed battery selection. The corresponding nominal currents are approximately 153–230 A; peak demand and low-voltage current will differ. Cell discharge capability, wiring, connectors, protection and thermal behaviour must be checked against the selected pack.

As a scheduling example, a 500 m one-way transit at 5 m/s takes 3.33 min for the round trip. Adding three minutes of active dispensing and one minute for other manoeuvres gives 7.33 min. This assumes the dispensing interval includes motion during dispensing; any additional between-waypoint travel or hold time must be added. Dock distance, wind, route and loaded/unloaded power determine the actual mission. Two sorties require a recharge or battery exchange if one pack does not have enough energy for both.

1.7 Dock energy and turnaround

A sortie lasting eight minutes at a mean power of 10 kW consumes 1.333 kWh. For ten sorties, the daily aircraft energy is 13.33 kWh per pond. At an assumed 90% input-to-battery charging efficiency, daily replenishment requires approximately 14.81 kWh, excluding the silo, controls and standby loads.

For charger input power P_c and efficiency η_c ,

$$t_c = \frac{60E_{\text{replenish}}}{\eta_c P_c}. \quad (7)$$

With the same 1.333 kWh replenishment, 5 and 6 kW input give idealized energy-transfer times of 17.8 and 14.8 min, respectively. These exclude charge taper, battery cooling, alignment, refilling and interruptions. Approximate battery-side current at 52.2 V would be 86–103 A; contact design cannot be based on the number of pogo pads alone.

These calculations do not select conductive charging over the wireless concept. Wireless and conductive interfaces need separate measured efficiency, alignment, temperature and battery-compatible charging control. The 90% efficiency is an assumption for arithmetic, not demonstrated inductive performance. The existing 3.4 m dock dimensions remain a layout candidate pending gear geometry and clearances. Continuous service requires a sortie/refill/recharge schedule; battery exchange or additional packs may be needed if two sorties must follow immediately.

1.8 Status of the recalculated design

The usable outputs are the 50 kg/session and 250 kg/day schedule, a 75 L preliminary clear-volume hopper, the per-nozzle flow requirements, and the conditional silo, rotor-clearance, thrust and energy calculations. The preliminary silo geometry is 1.0 m internal diameter, 1.45 m cylindrical section and 0.65 m tapered section, subject to actual density and flow behaviour. The motor, propeller, nozzle bore, rotational set-point, actuator torque, battery pack and charging hardware remain unselected. Raw calculations and all assumptions are supplied in `calculations/recalculate.py` and `calculations/results.json`. No CAD geometry, trial result or software-study feeding schedule is changed by these sizing calculations.

References

NASA Glenn Research Center. Propeller thrust, 2021. URL <https://www.grc.nasa.gov/www/k-12/airplane/propth.html>. Beginner’s Guide to Aeronautics. Accessed 21 September 2026.