SWOVEE / A02 + OFFWORLD FIELD CELL

BUILD A SYSTEM. NOT A DEMO.

Engineering dossier for the mobile rovalizer: Earth construction, Swovee Scoop, autonomous Moon and Mars material loops, safety, verification and delivery.

REVISION 1.0 | CONTROLLED PUBLIC BASIS | 13 AUGUST 2026

Earth baseline: A02 | Lunar field cell: L01 | Mars branch: M01

CHAPTER 00 / READING MAP

DECISIONS FIRST. DETAIL ON DEMAND.

The website carries the thesis. This dossier carries the engineering basis. Each chapter begins with a decision, then exposes the interfaces, budgets and evidence required to make it.

STATUS

Concept architecture

No integrated Swovee machine has been built or field-tested. Dimensions and performance values are design targets—not test results, product certification, structural approval or a promise of commercial availability.

01

System architecture

Boundary, operating states, interfaces, target specification and seven coupled budgets.

02

Materials and process

Physical inputs, dry-to-wet plant, feed modes, media envelope, process instruments and cleanout.

03

Offworld field cell

Swovee Scoop, Moon and Mars material loops, waterless modes and delayed autonomy.

04

Safety and validation

Authority stack, Earth gates, environmental evidence and offworld precursors.

05

Team and delivery

Core seats, planetary specialists, partner map and dual-track development path.

R

Reference basis

Standards bodies and research programs that frame the current concept.

READING RULE

Decision makers can read the chapter openings and yellow decision boxes. Discipline engineers should follow interfaces, energy and mass budgets, and acceptance evidence. Reviewers should begin with Chapter 04 and the stated reasons to

stop.

CHAPTER 01 / SYSTEM ARCHITECTURE

ONE MACHINE. SEVEN COUPLED BUDGETS.

Swovee is one controlled construction system. Mobility, stabilization, material behavior, arm motion, geometry, safety and acceptance must close together.

CHAPTER DECISION

Freeze the system boundary

The A02 boundary includes the rover, stabilization, arm, tool, perception, dry and liquid storage, dosing, mixer, wet buffer, pump, hoses, cleaning capture, power, compute, safety controls and job records.

1.1 / OPERATING STATES

01 / TRAVEL

Material secured

Arm stowed, outriggers retracted, terrain speed and grade limited.

02 / STABILIZE

Create a local datum

Ground contact checked, work envelope leveled and pose uncertainty bounded.

03 / PLACE

Run coupled loops

Motion and material remain inside signed process and safety limits.

04 / VERIFY

Accept, correct or stop

Scan and process signature decide whether the next layer may begin.

1.2 / SYSTEM INTERFACES

ID	INTERFACE	WHAT MUST BE CONTROLLED
M01	Chassis to ground	Bearing, slope, slip, settlement and outrigger reactions.
M02	Chassis to arm	Base deflection, vibration, reach, torque and safe pose limits.
P01	Mixer to pump	Buffer level, residence time, suction condition and restart state.
P02	Pump to nozzle	Pressure loss, hose movement, blockage detection and bead control.
D01	Plan to controller	Signed job package, bounded parameters and deterministic state machine.

ID	INTERFACE	WHAT MUST BE CONTROLLED
Q01	Process to acceptance	Batch genealogy, settings, scan, coupon and exception record.

CHAPTER 01 / TARGET SPECIFICATION

A02 BASELINE. TARGETS, NOT CLAIMS.

The first platform is sized to leave the laboratory while remaining transportable and serviceable. Values frame trades and verification plans.

PARAMETER	TARGET	ENGINEERING NOTE
Travel envelope	4.6 x 2.3 x 2.7 m	Transport and worksite access target
Dry / operating mass	4,700 / 6,250 kg	Includes full day-bin and liquid states
Arm reach	3.2 m radius	From stabilized local datum
Vertical print reach	2.7 m per setup	Advance and re-register for longer work
Nominal bead	35-120 mm	Variable-width tool target
Qualified output	0.20-0.80 m3/h	Depends on validated material and geometry
Placement target	+/- 8 mm local frame	Combined machine and process target
Climb / side slope	28 / 18 degrees	Travel target; placement requires stabilization
Onboard material	650 kg dry + 240 L water	Day-bin configuration
Wet buffer	220 L agitated	Residence time remains recipe-limited
Onboard energy	118 kWh LFP	Mixed mobility, arm and process duty
Endurance	5-8 hours	Job and ambient dependent
Environmental	IP65 / -10 to 48 C	Earth A02 target only
Transport	20 ft flat rack concept	Final tie-down and lifting analysis required

CHAPTER 01 / CONTROL BUDGETS

SEVEN LEDGERS. ONE REVIEW.

Each budget crosses disciplines. A change to water capacity changes mass, center of gravity, duty cycle, cleanout capacity and transport.

NO.	BUDGET	REVIEW QUESTION
01	Mass + CG	Track dry, full, partially depleted and sloshing states; prove wheel and outrigger reactions.
02	Energy + heat	Drive, arm, mixing, pumping and compute share peak power, duty-cycle energy and cooling.
03	Pressure	Every hopper, mixer, pump, bend, hose, valve and nozzle consumes margin.
04	Time	Mix age, open time, interlayer interval, refill, pause recovery and cleaning deadline.
05	Accuracy	Survey, localization, base deflection, arm error, tool offset and bead deformation.
06	Confidence	Terrain, localization and material estimates must carry uncertainty into state decisions.
07	Waste	Prime, purge, failed coupons, wash water and rejects need capacity and custody.

MINIMUM SYSTEM WORK PRODUCTS

SYSTEMS

Control the whole

ConOps, requirements, block diagram, interfaces, budgets, verification matrix and configuration plan.

MECHANICAL

Carry the reactions

General arrangement, load cases, stability, FEA, arm mount, hose routing and service access.

ELECTRICAL

Close power and heat

Single-line, load list, battery protection, grounding, EMC, ingress and thermal strategy.

SOFTWARE

Bound behavior

State machine, interfaces, calibration, signed plans, logs and cyber threat model.

PROCESS

Prove the wet path

PFD, P&ID;, mass balance, dosing tolerance, pressure model, cleaning validation and passport.

CIVIL

Accept the work

Design basis, substrate, reinforcement, durability, coupons, inspection and project acceptance.

CHAPTER 00A / REVISION CONTROL

WHAT CHANGED. WHAT REMAINS OPEN.

Revision 1.0 turns the public dossier into a bounded decision record. It adds the site-suitability method, first commercial offer, evidence ledger, trust perimeter and controlled-CAD decision without pretending those controls are test evidence.

ID	CHANGE	CONTROLLED POSITION
R1	Status truth	States explicitly that no integrated Swovee machine has been built or field-tested.
R2	Site suitability	Separates onboard visible-surface observations, imported records and professionally verified evidence.
R3	Commercial offer	Defines the launch hypothesis as a paid assessment followed by a bounded, engineer-supervised civil pilot.
R4	Evidence ledger	Reports zero paid assessments, signed pilots and independent Swovee tests unless a controlled record exists.
R5	Trust perimeter	Adds safety, environmental, structural-approval, cyber, privacy and AI-authority boundaries.
R6	CAD control	Public package is now imagery-only; detailed editable CAD is held for controlled counsel and engineering review.

CAD DISCLOSURE

Containment is not retraction

Editable CAD was previously published. Replacing the download cannot undo that disclosure, identify prior downloaders or control copies already obtained. Preserve the dated archive and disclosure inventory for patent, export, licensing and freedom-to-operate counsel.

CHAPTER 00B / PRODUCT STATUS

ONE FAMILY. CLEAR RELEASE STATES.

Names identify architecture branches and modules—not products available for purchase. A status label travels with every claim and configuration.

ID	CONFIGURATION	CURRENT STATE	RELEASE BOUNDARY
A02	Earth rovalizer	Concept / target architecture	No integrated machine; not certified; not for sale
S01	Swovee Scoop	Concept packaging model	No built Swovee prototype; not flight qualified
P01	Prep Dock	Concept module	Interfaces and processing thresholds open
F01	Forge	Concept module	Thermal process and environmental evidence open
R01	Offworld rovalizer	Concept branch	Mission-specific redesign required
U01	Utility Pallet	Concept module	Power, storage, thermal and mission interfaces open

CHAPTER 02 / MATERIALS + PROCESS

CONCRETE IS NOT A REFILL. IT IS A CONTROLLED PROCESS.

A02 is designed to mix qualified printable mortar onboard, receive qualified wet material or condition characterized soil. Each route has explicit entry conditions; none is an integrated test result.

CHAPTER DECISION

Build the material loop first

If Swovee cannot repeatedly dose, mix, pump, stop, restart and clean a qualified material, mobility adds cost without creating a construction product.

2.1 / REQUIRED INPUTS

INPUT	PHYSICAL ENTRY	RELEASE DATA
Binder	Sealed pod or supersack adapter	Lot ID, chemistry, fineness, age, storage history
Fine aggregate	Dry, graded 0-4 mm baseline	Gradation, moisture, density, contaminants
Process water	Baffled tank or metered connection	Quality, temperature, conductivity
Admixtures	Keyed cartridges to metering pumps	Product, lot, density, temperature, dose limits
Microfibers	Optional conditioned microfeeder	Length, aspect ratio, compatibility, dispersion evidence
Recipe	Signed digital material passport	Ratios, temperature window, open time, acceptance method

No dry gate or liquid valve opens until the physical lot, measured state and signed recipe agree. Raw excavation, anonymous ready-mix and untracked admixture are rejected at the system boundary.

CHAPTER 02 / ONBOARD PLANT

DRY IN.
VERIFIED WET OUT.

The baseline keeps binder and sand dry until demand. This limits wet residence time, enables lot tracking and makes the process recoverable.

01 / RECEIVE

Keyed dry transfer

Binder and graded sand enter sealed day bins through dust-controlled connections.

02 / VERIFY

Release the lots

Mass, moisture, lot IDs and recipe authorization must agree.

03 / DOSE

Meter each stream

Loss-in-weight screws handle solids; pumps meter water and admixtures.

04 / MIX

Condition continuously

Paddle or twin-shaft mixing is observed through torque and temperature.

05 / BUFFER

Decouple demand

A small agitated hopper smooths flow without hiding material age.

06 / PUMP

Keep the path short

A reversible progressive-cavity pump feeds the instrumented arm hose.

2.2 / BASELINE INSTRUMENTATION

MEASURE	INSTRUMENT	CONTROL PURPOSE
Mass	Load cells on dry bins and liquids	Close the recipe and job mass balance
Flow	Metering feedback on water and admixture	Compare command and delivery continuously
Pressure	Pump outlet and distributed hose taps	Find restriction; protect pump and hose
State	Mixer torque, wet temperature, buffer level	Expose rheology drift and residence time
Geometry	Nozzle pose plus layer scan	Link process signature to placed bead

CHAPTER 02 / FEED MODES

THREE ROUTES. NO UNQUALIFIED MATERIAL.

The baseline hardware supports three deliberately different logistics patterns. Changing feed mode does not waive the material passport or acceptance tests.

DRY KIT

Metered dry-in / mixed onboard

Binder and sand remain dry. Water and admixtures are dosed into the continuous mixer. Best control of open time and genealogy.

WET BYPASS

Qualified printable mortar

A keyed 50 mm inlet receives a prequalified printable mix. The rover buffers, instruments and pumps it. Ordinary ready-mix is not accepted by default.

TERRA KIT

Processed earth / point stabilization

Local material is sampled, corrected, crushed and screened before entry. Raw soil is never scooped directly into the baseline mixer.

2.3 / MEDIA ENVELOPE

STATUS	MEDIUM	PATH	LIMIT
Qualified	Printable fine-aggregate mortar	A02 baseline	0-4 mm aggregate; pumpability, buildability, open time and interlayer behavior verified.
By source	Low-carbon blended cement mortar	A02 baseline	Every binder or SCM source change reopens the process window.
Pilot	Short-fiber mortar	Conditional	Fiber length and dose limited by feeder, hose and nozzle evidence.
Pilot	Stabilized screened earth	Terra Kit	Characterized, moisture-corrected and screened before entry.
R&D;	Alkali-activated material	Separate wet path	Chemical compatibility, handling and qualification are distinct.
Rejected	Coarse-aggregate concrete	Not A02	Aggregate above 4 mm requires a new mixer, pump, hose and nozzle architecture.
Rejected	Conventional ready-mix	Not automatic	Ordinary slump concrete is not inherently printable or compatible.
Other tool	Resin, foam, thermoplastic	Not A02	Thermal or chemical isolation, fume control and separate safety case required.

CHAPTER 02 / CLEANOUT + RECOVERY

WET MATERIAL NEEDS A DESIGNED EXIT.

A construction robot that cannot recover from pauses, restrictions and cured residue is not field equipment. Cleanout is part of the production cycle.

NORMAL CLOSE

Finish inside the material window

Stop dry feed, chase the mixer into the buffer, purge into capture, reverse the pump, remove the short hose cassette and wash within a contained circuit.

BLOCKED PATH

Isolate stored pressure

Use pressure taps to bound the segment. Follow approved reversible-pump or mechanical recovery. Replace the cassette when time exceeds the safe window.

WASTE CUSTODY

Measure every exit

Record prime, purge, failed coupon, wash water, filter solids and hardened waste against onboard and site capacity.

SERVICE DESIGN

Assume wear and cure

Make mixers, rotors, stators, hoses, seals and nozzle parts visible, accessible and replaceable without dismantling the arm.

FIRST MATERIAL RIG

90-DAY ITEM	DESCRIPTION
Hardware	Two dry mini-hoppers; water and admixture dosing; 100-200 L/h continuous mixer; 80 L buffer; progressive-cavity pump; 10 m instrumented hose; representative nozzle.
Tests	Eight-hour dosing drift; thermal window; interruption and restart; pressure map; blockage recovery; batch genealogy; captured cleanout; twenty wall coupons.
Exit	Three qualified mix families and a process window that predicts bead quality from measured inputs. If not achieved, do not build the rover.

CHAPTER 03 / OFFWORLD FIELD CELL

DO NOT SHIP CEMENT. SHIP A MATERIAL FACTORY.

Swovee uses local regolith as bulk mass, then applies compaction, heat or a tightly rationed binder only where structure and durability require it. The opening product is a coordinated field cell, not one overloaded rover.

ARCHITECTURE DECISION

Minimum-binder construction

Use screened and compacted local soil for volume. Fuse or bind only load paths, joints, faces and wear surfaces. Delivered pressure liners and tension systems remain outside the regolith claim.

3.1 / SYSTEM OF MACHINES

ID	PRODUCT	SYSTEM ROLE
S01	Swovee Scoop	Excavate, assay and haul traceable quarry lots
P01	Prep Dock	Scalp, screen, weigh, classify and release feed
F01	Forge	Compact, heat, hot-press or condition the approved lot
R01	Rovalizer	Grade, form, place, assemble and inspect
U01	Utility Pallet	Mission power, storage, thermal rejection and communications

Scoop can keep mining while Rovalizer builds. The most abrasive classification work stays at a serviceable dock rather than beside precision placement mechanisms.

3.2 / MATERIAL LADDER

MODE	FEEDSTOCK	WATER	LOCAL	FIRST USE	STATUS
R00 RAW	Screened + compacted regolith	No	Near-100%	Berms, shielding, subbase, trench fill	Baseline
F01 FUSE	Microwave/laser-vitrified regolith	No	Near-100%	Pads, roads, pavers, hard skins	Baseline R&D;

MODE	FEEDSTOCK	WATER	LOCAL	FIRST USE	STATUS
P02 POLY	Regolith + recycled/imported polymer	No	Up to 90% target	Blocks, joints, repair	Contingency
S03 SULFUR	Regolith + elemental sulfur	No	Site-dependent	Mars pavers, unpressurized works	Resource-gated
G04 GEO	Alkali-activated regolith	Yes	Site-dependent	Sealed-cure research	Later R&D;
C05 CEMENT	Portland-type mix	Yes	Low initially	Earth A02 until refinery exists	Not offworld v1

CHAPTER 03A / SWOVEE SCOOP S01

A QUARRY ROVER. WITH A DRILL - NOT AS A DRILL.

Opposed bucket drums move bulk loose material with balanced reaction. A removable rotary-percussive BorePod is reserved for hardpan, buried ice, samples and geotechnical holes.

MECHANICAL DECISION

Do not make boring the bulk miner

At an assumed bulk density of 1,600 kg/m3, a 100 mm diameter by 1 m bore contains only about 12.6 kg. One tonne takes roughly 80 full-depth holes before losses.

PRODUCT VISUALIZATION / S01-ET EARTH DEMONSTRATOR - DESIGN TARGETS, NOT FLIGHT-PROVEN SPECIFICATIONS

01 / HARVESTER	02 / BOREPOD	03 / PREP DOCK
Opposed bucket drums Two articulated hollow drums make shallow 10-20 mm skim cuts, lift the captured load and reverse to unload. Internal baffles retain material during haul.	**Rotary-percussive cassette** A centerline 60-100 mm tool advances in instrumented 100 mm bites to a 1 m target depth. Both drum arms plant as reaction feet.	**Classify before release** A compliant hopper, load cells, scalping grate and recipe screen separate released feed, fines and oversize. A crusher is not in the first baseline.

CHAPTER 03A / SCOOP TARGET SPECIFICATION

SIZED TO BE ENGINEERED. NOT IMAGINED.

NASA excavation and drilling heritage makes these ranges plausible; Swovee must earn every number in representative simulant, dust, thermal-vacuum and reduced gravity.

PARAMETER	A0 TARGET	BOUNDARY
Stowed envelope	2.0-2.4 x 1.2-1.5 x 0.8-1.1 m	Lander and Earth demonstrator trade
Dry rover mass	145-235 kg incl. BorePod	Mission-selected battery and avionics
Drum diameter / width	300-430 mm / 0.65-0.90 m	Opposed articulated drums
Controlled skim cut	10-20 mm/pass	30 mm abort target
Carried per cycle	75-100 kg	Target inferred from arm loads
Loose-simulant collection	100-170 kg/h	Earth target, not lunar guarantee
Released screened feed	60-120 kg/h	Recipe and reject fraction dependent
Bore cartridge	60-100 mm dia / 1.0 m	Ten instrumented 100 mm increments
Average / peak power	1-2 kW / 3-5 kW	Excavation, mobility and prep trade
Energy target	<=20 Wh/kg over 50 m haul	Integrated screened-feed gate
Battery target	6-12 kWh usable	Power pallet and campaign dependent
Durability gate	>=20 t handled	Before flight architecture freeze

Freedom to operate: NASA's opposing counter-rotating bucket-drum architecture is patented and offered for licensing. Complete an IP review and technology-transfer discussion before freezing production geometry.

CHAPTER 03A / SCOOP OPERATIONS

FROM QUARRY CELL TO MATERIAL PASSPORT.

The machine releases mass, grading and provenance - not anonymous dirt. Jams, rocks and dust are normal operating cases.

01 **Assay** Bore selected cells; classify loose, hardpan, volatile-sensitive, obstacle or prohibited ground.	02 **Harvest** Servo shallow passes while fore and aft drum torque remain balanced.	03 **Weigh** Infer payload from arm loads and calibrated lift current; stop at ordered batch mass.
04 **Haul** Raise drums, verify clearance and travel along the approved energy-safe route.	05 **Dock** Use LiDAR, fiducials and compliant mechanics; reverse both drums into P01.	06 **Release** Accept only material inside mass, grading, composition and contamination rules.

3A.1 / FAULT RECOVERY

FAULT	DETECTION	AUTONOMOUS RESPONSE
Uneven bite	Torque imbalance + chassis pitch	Lift overloaded arm; reduce advance; re-enter shallow
Hidden boulder	Current spike + arm load + stereo	Stop, reverse, map keep-out; route oversize to fill
Blind screen	Rising torque + missing output mass	Pause feed; reverse, tap or brush; do not force
Seized BorePod	Torque rise + no depth progress	Pulse percussion; reverse; withdraw in stages
Lost localization	LiDAR, VO and wheel state disagree	Stow, stop, relocalize against beacon
Low power / heat	Forecast reserve or limit breached	Abort cut; raise tools; return to utility pallet

CHAPTER 03B / LUNAR MATERIAL LOOP

TURN LUNAR SOIL INTO STONE. NO BULK WATER. NO CEMENT KILN.

The lunar baseline is dry, binderless and compression-first: excavate whole regolith, screen only what the process needs, compact it, fuse selected regions and inspect every lot.

LUNAR DECISION

Microwave fusion is the controlled baseline

Concentrated solar and laser heads remain compatible options. The first objective is a site-specific heating window that limits gas evolution, pores and thermal cracking.

3B.1 / CLOSED LOOP

01 / QUARRY

Whole regolith first

Scoop skims a qualified cell; oversize is retained for civil fill or mapped as obstacle.

02 / PREP

Screen only as required

Prep Dock weighs and meters recipe-selected grading into a sealed hopper.

03 / FORM

Compact thin lifts

Rovalizer grades a horizontal bed, fills a reusable mold or compacts a keyed unit.

04 / FUSE

Heat under feedback

A 2.45 GHz microwave or qualified laser head scans under reflected-power and thermal control.

05 / PROVE

Cool and inspect

Geometry, cracks, NDE and witness coupons decide whether the lot may continue.

3B.2 / FORMING LADDER

LEVEL	PROCESS	FIRST PRODUCTS	LIMIT
Tier 0	Raw civil works	Grading, compaction, trenches, backfill and shielding	Lowest energy; not airtight
Tier 1	Fused horizontal skin	Dust lanes, pavers, foundations and pad coupons	Compression-first; inspect cracks
Tier 2	Keyed masonry	Step-heated blocks assembled as arches, vaults and shells	Imported liner and tension system
Tier 3	Cast / melted units	Abrasion tiles and high-load bases	Higher power, refractory and shrinkage risk

CHAPTER 03B / LUNAR PROCESS CONTROL

VACUUM CHANGES THE HEAT PROBLEM.

Heating and cooling become material recipe variables. Laboratory coupon strength is not a full-scale structural guarantee.

HEAT **Measure coupling** Reflected microwave power and thermal imaging close scan speed and power.	**GAS** **Stage the cycle** Heat, degas, cool and reheat as required to reduce pores and runaway.
COOL **Bound gradients** Vacuum removes convection; conduction paths and cooldown schedule matter.	**PROVE** **Inspect each lot** Geometry, crack mapping, ultrasound/mm-wave NDE and witness coupons.

A 2024 vacuum study reported about 65 MPa compression in 5 g pressed simulant coupons after staged heating. That supports process experiments, not flight-scale throughput, flexure, fracture toughness or durability claims.

3B.3 / FIRST BUILD ENVELOPE

STATUS	PRODUCT	BOUNDARY
Yes / first	Grade, trenches and berms	Screened or raw regolith; compact and scan
Yes / first	Shielding and overburden	Local mass around delivered pressure vessel
Target	Roads, hardstands and pavers	Compacted lifts with fused wear surface
Target	Foundations and unpressurized shells	Keyed units after structural qualification
Not yet	Operational landing pad	Plume, thermal shock, erosion and fracture gates
No v1	Printed airtight habitat	Delivered liner, doors, windows and tension system

Rejected as v1 baselines: sulfur in exposed lunar service; geopolymers without a sealed heated water-recovery cure; imported polymer except for rationed joints and repair.

CHAPTER 03C / MARS MATERIAL LOOP

BUILD WITH THE DIRT. DO NOT SPEND THE WATER.

Mars v1 compacts regolith for bulk mass, vitrifies selected hard surfaces and hot-presses rationed recycled polymer for precision units. Sulfur and water-based binders are resource-gated upgrades.

MARS DECISION

No cement plant in v1

Water, activators, calcination and controlled curing make terrestrial cement a poor opening move. New process cartridges activate only after local resource and energy loops are demonstrated.

3C.1 / MATERIAL STACK

MODE	PROCESS	FEED	WINDOW	FIRST USE	STATUS
R00	Compact	Screened regolith	Mechanical	Shielding, berms, subbase, infill	First
F01	Vitrify	Regolith only	High thermal/electrical	Hard skins, pavers, ribs, pads	First R&D;
P02	Hot-press	Regolith + recycled HDPE	~220 C + high pressure in lab	Blocks, bases, repairs	Contingency
S03	Sulfur	Regolith + elemental sulfur	~120-148 C	Pavers, unpressurized works	Resource-gated
M04	Mineral binder	Mg/Si + water + chemicals	Refinery + controlled cure	Later settlement construction	Future

NASA has demonstrated a binderless laser-regolith subsystem at TRL 5 on Earth with lunar and Mars simulants. That is subsystem evidence; an autonomous Mars quarry-to-structure system has not been demonstrated.

CHAPTER 03C / WATER + SULFUR

POSSIBLE IS NOT THE SAME AS AVAILABLE.

The Mars plan treats each resource as a quantified production loop. Orbital indications and mineral names do not release construction feedstock.

3C.2 / WATER LEDGER

BASIS	VALUE	ENGINEERING CONSEQUENCE
Curiosity soil example	~2 wt% water	Even at impossible 100% recovery, 1 t water requires ~50 t of that feed
NASA larger reference	~700 t regolith/month	~3.4 t water; ~3,300 kg rig; ~55 kWe peak reference
Swovee policy	Construction last	Crew, agriculture, oxygen and propellant have priority

If landed ground truth confirms shallow ice, Scoop delivers icy cuttings to a separate sealed auger dryer, vapor compressor, condenser, purifier and storage plant. That plant is not hidden inside the printer.

3C.3 / SULFUR TRUTH

ATTRACTIVE

Waterless thermoplastic

Elemental sulfur melts near 120 C, is reheatable and has produced useful laboratory sulfur-regolith strength.

RESOURCE GAP

Sulfate is not binder

Most known Martian sulfur is chemically bound. A mine, reduction refinery, reagents and power must exist.

PROPERTY GAP

Coupon results diverge

One study reported >50 MPa; a later CO2-rich study reported only 3.66 MPa maximum compression.

Release S03 only after a landed survey confirms usable elemental sulfur or a separate refinery demonstrates closed production. First uses remain pavers, linings and unpressurized works.

CHAPTER 03C / POLYMER + CONTAMINATION

RECYCLE IMPORTS. ISOLATE THE DUST.

A stationary hot press is a credible precision-material contingency. Perchlorate and dust controls are part of the process boundary.

01

Recover

Shred retired packaging, containers and approved habitat polymer streams.

02

Clear

Do not combine polymer with untreated regolith until compatibility and off-gas tests release the lot.

03

Blend

Meter classified regolith and a rationed polymer fraction under recorded heat and mass.

04

Press

Form keyed tiles and blocks in a compact press rather than an Earth concrete nozzle.

A 2026 laboratory study reported 61 MPa compression for a hot-pressed 90% Mars-simulant / 10% HDPE composite processed near 220 C and 100-350 MPa. That supports a block-press experiment, not freeform field extrusion.

3C.4 / PERCHLORATE + DUST CONTROLS

CONTROL	REQUIRED DESIGN RESPONSE
Sealed handoff	Enclose excavation-to-processing transfer; use replaceable filters and wear liners
Thermal off-gas	Monitor oxygen and chlorine species around the ~300-500 C treatment regime
Material classes	Separate external shielding feed from any crew-contact or polymer-compatible feed
Service	Dust-cleared optics/radiators, isolated bearings, replaceable seals and decontamination
Power	Accept mission grid power; schedule heat; batteries cover mobility, peaks and safe shutdown

CHAPTER 03 / AUTONOMOUS CAMPAIGN

EARTH SENDS GOALS. THE FIELD CELL RUNS THE CYCLE.

Mars light time is roughly 4-22 minutes one way; Moon latency is about 1.3 seconds. Both require onboard recovery for throughput and protection.

01 / LAND + WAKE

Self-test before motion

Deploy, verify tools, power, thermal control and communications; hold safe on failure.

02 / MAP + FENCE

Accept a signed polygon

Build the terrain twin and keep-out zones; Earth approves goals and reserves.

03 / ASSAY + COUPON

Earn the recipe

Scoop opens cells and Forge creates coupons before structural production.

04 / QUALIFY

Downgrade unknown feed

Only released lots enter structure; uncertain material becomes fill or reject.

05 / BUILD + PROVE

Close every pass

Schedule quarry, haul, thermal processing, metrology, recharge and repair.

06 / RECOVER

Exceptions, not joysticks

Deterministic routines handle jams, occlusion, link loss and low power.

AI may estimate diggability, clogging, wear, routes, recipes and schedules. Independent protection and deterministic control own motor limits, cut depth, thermal limits, collision avoidance, geofences and safe shutdown.

CHAPTER 04 / SAFETY ARCHITECTURE

AI MAY PROPOSE. SAFETY MUST DECIDE.

The machine safety boundary remains deterministic. AI planning cannot bypass limits on state, speed, force, pressure, heat, geography or recovery.

CHAPTER DECISION

Separate planning from protection

AI can interpret terrain, propose geometry and optimize sequencing. A deterministic supervisor owns allowed state transitions and independent safety functions own the final stop.

LAYER 01

Human authority

Mission, exclusion zones, structural basis, recipe and release conditions.

LAYER 02

AI planning

Terrain interpretation, sequencing and paths with confidence bounds.

LAYER 03

Deterministic supervisor

Signed limits, allowed states, bounded commands and approved recovery.

LAYER 04

Safety functions

Emergency stop, protective stop, limited speed and force, energy isolation.

4.1 / REQUIRED SAFETY WORK

PACKAGE	MINIMUM CONTENT
Hazards	Crush, collision, instability, hose energy, pressure release, dust, chemicals, noise, electricity and wet-material contact
Functions	Emergency stop, protective stop, safe speed, safe pose, work-zone intrusion, overpressure, loss of stability and safe restart
Validation	Trace hazard to safety requirement, implementation, achieved performance and witnessed test evidence
Operations	Isolation, lockout, rescue, spill response, blocked-path procedure, cleaning, training and site control

CHAPTER 04 / DEVELOPMENT GATES

EVIDENCE TO CONTINUE. REASONS TO STOP.

A gate is not a calendar milestone. It is a decision backed by named evidence, an owner and an explicit consequence when evidence is missing.

GATE	DECISION	WORK PACKAGE	EXIT EVIDENCE
G0	Architecture freeze	ConOps, requirements, hazards, boundary, budgets, P&ID; and interfaces	No unowned critical interface; models close with margin
G1	Bench material loop	Complete dosing, mixing, buffer, pump, hose, nozzle and cleaning path	Repeatability, pressure margin, restart and captured cleaning
G2	Motion mule	Rover, stabilization, arm, perception and work-zone controls	Stable poses, bounded registration error and safe fault response
G3	Coupled Alpha	Material and motion linked to batch, settings, toolpath and scan	Geometry and process stay inside window across relocations
G4	Pilot release	Integrated safety, crew, service, structural basis and field method	Released site, trained crew, spares and signed acceptance

4.2 / EARLY KILL TESTS

K01 / MATERIAL

Eight-hour drift

Vary lots, moisture and ambient temperature. Stop if ratio error, pressure or geometry cannot be predicted and recovered.

K02 / MOBILITY

Ten relocations

Place across uneven ground. Stop if seam error accumulates or surveying dominates the job.

K03 / AUTONOMY

Delayed supervision

Inject blockage, occlusion, network loss and actuator faults. Stop if routine recovery needs real-time teleoperation.

CHAPTER 04 / OFFWORLD GATES

HERITAGE IS NOT SYSTEM READINESS.

Bucket drums, drills and regolith heating have relevant subsystem evidence. The combined Swovee field cell remains a TRL 2 concept until the integrated loop earns higher readiness.

GATE	DECISION	TEST ENVELOPE	REQUIRED EVIDENCE
O1	Simulant process	Three relevant simulants	Specific energy, grading, strength distribution, porosity, flexure, fracture and wear
O2	Ten-tonne feed loop	Scoop + Prep Dock + Forge	Mass/energy closure, reject fraction, tool wear, jams and every intervention
O3	Environmental coupon	Vacuum or Mars CO2 + temperature + dust	1 m2 horizontal work and 1 m compression element with NDE
O4	Thirty-day autonomy	Delayed communications + injected faults	No hidden teleoperation; complete material and inspection ledger
O5	Flight precursor	Uncrewed 100-1,000 kg construction coupon	Create, inspect and proof-load before habitat-scale claim

INTEGRATED KILL RULE

Revise Scoop if it cannot close the feed ledger

Target <=20 Wh/kg recipe-compliant screened feed over a 50 m haul, with no more than one unplanned human intervention per eight operating hours in sustained Earth testing.

CHAPTER 04 / DESIGN BASIS

START HERE. VERIFY APPLICABILITY.

The following sources frame the concept. The applicable jurisdiction, intended use and final risk assessment determine the actual compliance path.

SOURCE	TOPIC	USE IN SWOVEE BASIS
ISO/ASTM 52939:2023	Additive construction process and quality principles	Process qualification, feedstock, build and acceptance basis
ACI Committee 564	3-D printing with cementitious materials	Industry guidance, structural and material methods
ISO 12100	Machinery risk assessment and reduction	Hazard identification and protective measures
ISO 13849-1:2023	Safety-related control systems	Required performance level remains application-specific
ISO 10218	Industrial robot safety	Arm and integration principles
ISO 3691-4	Driverless industrial trucks	Evaluate relevant autonomous mobility principles
OSHA silica guidance	Respirable crystalline silica	Dry loading, cleanup and field controls in the United States
Local law and code	Machinery, electrical, environmental, concrete and building	Project and jurisdiction-specific approval

This list is not a conformity declaration. A competent safety and certification team must confirm scope, current editions, regional adoption, exclusions and the complete set of applicable requirements.

CHAPTER 05 / TEAM + DELIVERY

TWELVE SEATS. ONE TECHNICAL AUTHORITY.

The initial team is organized around interface ownership. Materials, field operations and safety hold authority from day one, not after the robot is assembled.

CHAPTER DECISION

Name one chief systems engineer

One technical authority owns requirements, interfaces, budgets, design reviews and final trade decisions. Discipline leads retain authority within their domains; no critical interface remains ownerless.

01 **Chief systems engineer** Mission, requirements, interfaces, configuration and trade authority.	02 **Robotics lead** Mobile manipulation, planning, calibration and recovery.	03 **Materials lead** Wet, granular, thermal and composite process qualification.
04 **Process engineer** Bulk solids, screening, dosing, mixing, heating and cleanout.	05 **Mechanical lead** Chassis, Scoop, arms, structures, tools and serviceability.	06 **Controls engineer** Real-time motion, machine state and actuator integration.
07 **Perception engineer** Terrain fusion, localization and as-built metrology.	08 **Safety + autonomy** Hazards, deterministic limits, fault recovery and validation.	09 **Structural engineer** Design basis, reinforcement, durability and acceptance.
10 **Field operations** Crew methods, logistics, recovery and pilot delivery.	11 **Electrical / power** Battery, distribution, EMC, thermal and ingress.	12 **Test + quality** Verification, supplier quality and evidence configuration.

CHAPTER 05 / PARTNERS + PLAN

CAPABILITIES THAT SHOULD NOT BE IMPROVISED.

A small core team needs laboratories, planetary specialists, equipment integrators, contractors and assurance experts with authority to expose problems.

LAB

Printable-material laboratory

Rheology, fresh-state methods, interlayer bond, durability and structural specimens.

PLANT

Mixer + pump integrator

Continuous dosing, progressive-cavity pumping, wear and hardened-material recovery.

FIELD

Contractor pilot partner

Sites, operators, logistics, temporary works, productivity data and failure feedback.

ASSURANCE

Code + certification advisors

Machinery conformity, functional safety, environmental controls and building approval.

5.1 / OFFWORLD SPECIALISTS

SPECIALTY	REQUIRED AUTHORITY
Planetary geotechnics	Regolith mechanics, excavation energy, simulants and landed ground truth
Mining process	Scalping, screening, mass balance, wear and quarry operations
Rotary-percussive drilling	BorePod bits, reaction, withdrawal, ice/hardpan and jam recovery
High-temperature process	Microwave, laser, refractories, gas evolution and thermal stress
Tribology + dust	Vacuum lubrication, labyrinth seals, wear, optics and radiators
Flight assurance	Radiation, thermal-vacuum, shock, planetary protection and precursor release

5.2 / DUAL-TRACK DEVELOPMENT PATH

WINDOW	MILESTONE	PRIMARY OUTPUT
0-3 mo	Define	ConOps, hazards, IP review, material modes, partner RFQs and closed models
3-9 mo	Bench loops	A02 wet path plus Scoop drums, BorePod, Prep Dock and fused coupons
9-18 mo	Earth mobility	Excavation/haul and mobile placement with traceable material lots
18-30 mo	Analog campaign	Ten- then twenty-tonne handling, vacuum/CO2 coupons and delayed autonomy
30-48 mo	Precursor decision	Freeze one lunar demonstrator only after integrated gates close

Timing is a planning range. Financing, supplier lead times, test results, material qualification, regulatory review and site availability can change the sequence.

CHAPTER A / READINESS + CLAIM BOUNDARY

LOOKS LIKE A PRODUCT. READS LIKE ENGINEERING.

The dossier may be complete enough to support reviews and partner outreach. The integrated offworld system is not available for purchase, certified for construction or flight-qualified.

A.1 / TECHNOLOGY READINESS TRUTH

ELEMENT	EVIDENCE LEVEL	WHAT IT DOES NOT PROVE
Swovee Scoop integrated system	TRL 2 concept	No built Swovee prototype; Earth breadboard is the next evidence
Opposing bucket drums	Relevant TRL 4-5 heritage	NASA RASSOR/IPEx prototypes; not Swovee production performance
Rotary-percussive sampling	Relevant TRL 6 heritage	Lunar hardware operation exists; planned 1 m recovery was not completed
Electrodynamic dust clearing	Relevant TRL 7 heritage	Lunar dust removal demonstrated; integration still required
Binderless regolith heating	Subsystem/lab evidence	Coupon and subscale demonstrations; no full Swovee field loop
Sulfur/polymer/Mg/geopolymer	Laboratory pathways	Resource, energy, scale and environmental qualification unresolved

A.2 / CLAIM BOUNDARY

CATEGORY	BOUNDARY
Can target	Clearing, grading, trenches, berms, compacted shielding, roads, pavers, foundation coupons and protective shells around delivered habitats
Cannot claim	Flight-proven lunar concrete, a pressure-tight printed habitat, guaranteed strength or throughput, years unattended, or local production of all binders and reinforcement
Commercial first	S01-ET Earth analog demonstrator for simulant yards, mining research and closed material-flow pilots
Space status	Mission-specific research configuration; not for sale until environmental, endurance, autonomy, assurance and flight gates close

CHAPTER 06 / SITE SUITABILITY

AUDIT THE TERRAIN. DO NOT CERTIFY WHAT THE SENSORS CANNOT SEE.

The proposed audit ranks build, access, staging, refill and exclusion zones inside an authorized search area. It is pre-design decision support, not a boundary survey, utility locate, geotechnical report, environmental determination, permit or structural release.

6.1 / EVIDENCE CHANNELS

CLASS	INPUT	BOUNDARY
O / OBSERVED	LiDAR, stereo vision, RTK/GNSS, IMU, odometry and work-zone sensing	Visible surface geometry, slope, roughness, obstacles, access and machine reach—with uncertainty
A / IMPORTED	Survey, parcel, utility, flood, soil, geology, zoning, wetland and hazard records	Publisher, version, date, CRS, accuracy, license and conflicts remain attached
V / VERIFIED	Licensed survey, utility locate/potholing, borings/CPT/DCP, laboratory and professional review	Overrides conflicting screen-level inference and supplies release evidence

6.2 / AUDIT SEQUENCE

01

Authorize

Define the project, jurisdiction, machine/material configuration and lawful search area.

02

Register

Fuse visible-surface observations and imported layers to surveyed control; expose gaps and uncertainty.

03

Gate

Classify constraints as exclude, mitigate, prefer or unknown/hold. Missing mandatory evidence never passes.

04

Generate

Test rotated candidate envelopes including work offsets, rover stations, refill, washout and emergency access.

05

Compare

Return Pareto options for cost, schedule, disturbance and resilience—not one unexplained score.

06

Verify

Order the survey, utility, geotechnical, environmental and civil work needed for the finalists.

07

Release

Licensed professionals and the authority having jurisdiction approve the signed build package.

HARD HOLD

Unknown is not acceptable

Outside the authorized/buildable envelope, unresolved setbacks/easements, unlocated utilities, unsafe access or support, prohibited environmental zones and missing mandatory evidence remain disqualified or not assessable until documented mitigation and professional approval exist.

CHAPTER 07 / COMMERCIALIZATION

SELL THE DECISION FIRST. EARN THE MACHINE LATER.

The launch hypothesis is not a hardware preorder or a finished-house sale. Swovee first proposes a paid suitability and constructability assessment, then—only after evidence and approvals—a bounded, engineer-supervised non-occupied civil pilot.

7.1 / FIRST OFFER

STEP	DECISION	DELIVERABLE	BOUNDARY
1 / DISCOVERY	Qualification	Site authority, use case, budget, jurisdiction and evidence availability	No charge proposed until scope is understood
2 / ASSESSMENT	Paid professional work package	Candidate zones, constraints, unknowns, field-test plan and cost/schedule range	Pricing follows real scope; no published universal fee
3 / PILOT BASIS	Design + acceptance	Engineer-of-record, material/process qualification, permits, insurance, crew and acceptance metrics	May stop without a field build
4 / BOUNDED PILOT	Supervised civil work	Drainage, erosion, barrier, equipment or utility-protection scope	No occupied-house or autonomous-unattended promise
5 / HANDOFF	As-built + service record	Geometry, genealogy, process data, exceptions, inspection, waste and maintenance	Named acceptance authority signs completion

The proposed first buyer is a private industrial, quarry or remote civil-site owner or contractor with a bounded drainage, erosion-control, barrier, equipment-work or utility-protection problem. This is a customer-discovery hypothesis and must change if evidence disagrees.

7.2 / EVIDENCE + TRACTION LEDGER

ITEM	CURRENT	EVIDENCE BOUNDARY
Integrated A02 hardware	0	No integrated machine built
Swovee-owned material-loop test datasets	0	No controlled bench record yet
Independent witnessed Swovee tests	0	No third-party verification yet
Controlled customer-discovery interviews	0	No interview ledger supplied
Paid site assessments	0	Seeking first qualified partner

ITEM	CURRENT	EVIDENCE BOUNDARY
Signed pilot sites or LOIs	0	No signed record supplied
Supplier quotations in controlled register	0	Concept BOMs are not quotes
Site-suitability method	Documented	Public method; not customer-validated
CAD packaging artifacts	Concept	Geometry validated; not fabrication release

EVIDENCE RULE

Zero is a valid number

Every future result should be dated and classified as planned, building, tested, failed or independently verified. Publish failures, raw measurement context and protocol changes alongside successful artifacts.

CHAPTER 08 / TRUST + RELEASE

DESIGN THE PERIMETER. THEN EARN THE RELEASE.

A mobile concrete-processing robot combines outdoor autonomy, heavy machinery, pressure, dust, caustic material, geospatial data and structural work. No one standard or disclaimer closes that case.

DOMAIN	MINIMUM CONTROL	RELEASE BASIS
Operational safety	ODD, work-zone protection, stopping maps, stabilization, safe restart and recovery	ISO 17757 / ISO 13849 / applicable mobile-robot and machinery rules
People + material	Trained roles, competent-person duties, LOTO, silica, wet cement, pressure and noise	OSHA and project industrial-hygiene plan
Environment	Contained washout, runoff/stormwater controls, spill response and waste custody	EPA plus jurisdiction-specific permits
Structure	Survey/geotech, licensed design, recipe/process qualification, special inspection and AHJ approval	ISO/ASTM 52939 is useful but not a complete building approval
AI + cyber	Advisory AI, deterministic safety, signed plans/updates, segmentation, logs, rollback and SBOM	NIST AI RMF, NIST OT guidance and secure-by-design review
Data + privacy	Authorized capture, minimization, provenance, retention, deletion, sharing and ML-reuse decisions	Applicable privacy/data law and site agreements
Commercial release	Entity, contracts, insurance, warranties, service, spares and named acceptance authority	Qualified counsel, broker and professional team

CURRENT GATE

No paid field pilot is released

The public architecture is reviewable, but the hazard log, operational design domain, functional-safety allocation, structural system, power/thermal closure, quantified verification thresholds, reliability case and commercial responsibility matrix remain open.

CHAPTER R / REFERENCE BASIS

DESIGN FROM EVIDENCE. PUBLISH THE FAILURES.

These sources frame the current architecture. They do not replace project-specific engineering, certification, testing or approval.

SOURCE	TOPIC	LINK
NIST	Cement-based additive manufacturing	https://www.nist.gov/programs-projects/additive-manufacturing-cement-based-materials
ISO	ISO/ASTM 52939:2023	https://www.iso.org/standard/81177.html
ACI	Committee 564 - 3-D Printing with Cementitious Materials	https://www.concrete.org/getinvolved/committees/directoryofcommittees/acommitteehome.aspx?committee_code=C0056400
NASA	Construction technology for Moon and Mars exploration	https://www.nasa.gov/directorates/stmd/nasa-enables-construction-technology-for-moon-and-mars-exploration/
NASA TechPort	MMPACT	https://techport.nasa.gov/projects/116319
ISO	ISO 13849-1:2023	https://www.iso.org/standard/73481.html
OSHA	Respirable crystalline silica in construction	https://www.osha.gov/silica-crystalline/construction
NASA	Space communications latency	https://www.nasa.gov/missions/tech-demonstration/space-communications-7-things-you-need-to-know/
NASA	Lunar Surface Technology / IPEx	https://www.nasa.gov/lunar-surface-technology/
NASA NTRS	RASSOR 2.0 design and targets	https://ntrs.nasa.gov/citations/20210011366
NASA NTRS	Autonomous lunar excavation	https://ntrs.nasa.gov/citations/20210022218
NASA Tech Transfer	RASSOR patent and licensing	https://technology.nasa.gov/patent/KSC-TOPS-7
NASA	Dust mitigation / EDS	https://www.nasa.gov/dust-mitigation/
NASA NTRS	Microwave lunar construction	https://ntrs.nasa.gov/citations/20205010871
Scientific Reports	Staged microwave vacuum coupons	https://www.nature.com/articles/s41598-024-79504-x

SOURCE	TOPIC	LINK
ESA	Binderless concentrated-solar sintering	https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/3D_printing_of_a_model_building_block_for_a_lunar_base_outer_shell
NASA NTRS	Binderless laser-regolith process	https://ntrs.nasa.gov/citations/20250010749
NASA NTRS	Mars water extraction architecture	https://ntrs.nasa.gov/citations/20230018562
Icarus	Sulfur-regolith under CO2-rich conditions	https://doi.org/10.1016/j.icarus.2024.116134
Communications Materials	Mars simulant / HDPE hot-pressed composite	https://doi.org/10.1038/s44334-026-00103-x
NASA	Mars surface power decision	https://www.nasa.gov/wp-content/uploads/2024/12/acr24-mars-surface-power-decision.pdf

EDITORIAL RULE

Failure is a deliverable

Publish mass ledgers, failed coupons, pressure traces, registration drift, intervention counts, reject rates and cleanout time alongside finished structures. Swovee is an independent concept; no third-party affiliation or endorsement is claimed or implied.