



WHITE PAPER

The Climb Is the Cost

Remote physical maintenance for
telecommunications towers

This document states what we believe and how we intend to find out whether it is true. It should be tested against real tower operators before capital is committed, and revised from what they say rather than from further writing.

STEEPLEJACK ROBOTICS

WHITE PAPER V1, FOUNDER HYPOTHESIS

Summary

Every antenna azimuth change, every mechanical downtilt adjustment, every bolt torque check, every aviation obstruction light replacement on a telecommunications tower requires a certified rigger to climb it.

The industry has spent a decade making the *diagnosis* remote. Drone inspection is now routine: operators can survey a tower, verify alignment, assess mount condition and document work without anyone leaving the ground. This was a genuine advance and it is essentially complete.

But it did not remove the climb. It removed the reason to guess.

If a drone reports that an antenna is three degrees off azimuth, a crew still has to go up, loosen the bracket, re-aim the antenna, torque the bolts and come down. The survey cost perhaps a few hundred pounds. The remediation costs a day, a crew, permits, a method statement, traffic management where relevant, and exposure to the highest-risk activity in the industry.

The climb is the cost. Inspection moved the cheap half.

Steeplejack Robotics exists to move the expensive half: a teleoperated, and eventually semi-autonomous, system that performs physical maintenance tasks at height so that routine work no longer requires a human on the structure.

Four propositions determine whether this business exists. All four are testable within twelve months at modest cost, and the programme is designed to test them before significant capital is spent:

THE FOUR PROPOSITIONS

01 VALUE

Tower operators will pay materially more for remediation-without-a-climb than they pay for inspection-without-a-climb.

02 ACCESS

We can obtain real towers to develop and prove on.

03 SAFETY CASE

A robot operating on live infrastructure can be made acceptable to an operator's risk function and its insurers.

04 TASK VIABILITY

The specific manipulations — bracket adjustment, measured bolt torque, component replacement — are achievable under field conditions by a machine of deployable size and weight.

Proposition 3 is the one most likely to kill the business, and it is not a robotics problem.

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The problem

1.1 What the work is

A telecommunications tower requires recurring physical intervention:

- **Azimuth adjustment.** Rotating an antenna to change its horizontal bearing. Driven by network optimisation, new site builds nearby, and coverage complaints.
- **Mechanical downtilt.** Adjusting the physical angle of an antenna. Note that *electrical* downtilt is already remotely adjustable on modern antennas through established industry protocols — which is precisely the point. The industry has already automated the part that could be automated electronically. What remains is what requires hands.
- **Mount and bracket work.** Bolt torque verification, re-tensioning, bracket repositioning, corrosion remediation.

- **Component replacement.** Aviation obstruction lights, remote radio units, feeder connections, ancillary hardware.
- **Post-work verification.** Confirming and evidencing that the intervention achieved specification.

Every one of these currently requires a certified climber on the structure.

1.2 What a climb actually costs

The direct cost of sending a crew up a tower is only part of it. The full cost includes crew time (rarely fewer than two, for rescue capability), travel to often remote sites, method statements and risk assessments, permits and landlord access arrangements, specialist insurance, and where the tower is roadside or rooftop, traffic management or building access.

Beyond direct cost sit three structural pressures:

Risk.

Work at height on telecommunications structures is among the most hazardous routine industrial activity performed anywhere. Every avoided climb is an avoided exposure, and operators carry the liability.

Scarcity.

Certified riggers are in chronic short supply and the workforce is ageing. Capacity, not budget, is frequently the constraint on how much optimisation work an operator can execute in a season.

Frequency.

Network densification has increased the number of antennas per site and the frequency with which they need adjusting. The volume of physical work is rising while the workforce available to do it is not.

1.3 Why inspection did not solve it

Drone inspection is now standard practice for pre-climb assessment, alignment verification, mount condition analysis and post-work documentation. High-resolution imaging, LiDAR and automated defect recognition mean operators can identify problems before dispatching anyone.

This is genuinely valuable and it is a solved, competitive, commoditising market. We do not intend to enter it.

Its limitation is structural. Inspection converts an unknown into a known. It does not convert a known into a completed work order. The economic weight of tower maintenance sits in remediation, and remediation still means a climb.

Academic review of the field reaches the same conclusion: despite sustained research interest, telecommunications towers continue to be maintained manually by certified climbers worldwide.

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The thesis

Claim one — the value is in remediation, not diagnosis.

An operator's spend, risk exposure and capacity constraint all concentrate on the physical intervention. A technology that removes the climb captures a far larger share of the economics than one that merely informs it.

Claim two — teleoperation is deployable years before autonomy.

A human operator on the ground, controlling a machine on the structure, removes the climb today. It requires no breakthrough in autonomous manipulation. Autonomy is a later efficiency gain, not a precondition for the product.

Claim three — every teleoperated hour is training data.

Recorded operator demonstrations of real tasks on real structures constitute exactly the dataset required to make those tasks progressively autonomous. The service funds the research and produces its input.

Claim four — the product is verified completed work, not a robot.

An operator does not want to own a machine. They want a work order closed, to specification, with evidence sufficient for their own compliance and their client's acceptance. What we sell is a completed and evidenced intervention.

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What we build

3.1 The machine

A climbing platform carrying a manipulator, capable of ascending a tower structure, positioning itself at a work location, and performing bounded physical tasks under remote control.

Design constraints, in priority order:

1. **Failure containment.** The machine must not fall, and must not drop what it carries. This dominates every other consideration and shapes the mechanism from the first sketch.
2. **Non-modification of the structure.** It must work on towers as they are. Any requirement to fit rails, tracks or fixtures first reintroduces a climb and destroys the value proposition.
3. **Reaction force management.** Applying meaningful torque to a bolt puts equal torque into the platform. Grip and stiffness of the climbing system determine achievable torque accuracy. Locomotion and manipulation are one engineering problem, not two.
4. **Deployable weight.** Two people should be able to transport, rig and recover it. A machine requiring a crane has replaced one logistics problem with a worse one.

The capability ladder — motor control, encoder feedback, closed-loop positioning, vision, gripping, force sensing, measured torque, two-axis manipulation, structure detection, controlled vertical climbing, obstacle crossing, teleoperation, antenna detection, azimuth and downtilt measurement, bolt engagement, torque application, bracket manipulation, component replacement — is the development path, in dependency order.

3.2 The ground system

The commercial product. A teleoperation console plus a work record:

- Operator control interface with force and visual feedback
- Full session recording — every command, every sensor reading, every measurement
- Before-and-after measurement of the parameter being changed
- Torque values applied, recorded against specification
- Evidence package suitable for an operator's compliance file and their client's acceptance

The evidence layer is not documentation. It is the deliverable. An operator's willingness to accept remote work depends entirely on being able to prove what was done — particularly for aviation obstruction lighting, where replacement is a regulatory obligation and evidence is mandatory.

3.3 The autonomy layer

Recorded teleoperation sessions become demonstration data. Individual tasks graduate from fully manual to assisted to supervised-autonomous as data accumulates, task by task, beginning with the most repetitive and least variable.

This layer generates the intellectual property and, over time, the margin. It is not required for the first revenue.

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Competitive position

Drone inspection is a solved and crowded market.

We are not entering it, and we should be explicit about that in every conversation, because buyers will otherwise assume we are.

Robotic climbing platforms exist for inspection tasks

— monopole scanning, guy-wire assessment, corrosion checks. These are sensing payloads on climbing bases. They confirm that climbing is tractable and that operators will accept machines on their structures. They do not perform work.

Remote antenna alignment is being actively attempted.

A pilot deployment in the Philippines using an optical compass and robot arm to remotely fine-tune antenna alignment demonstrates both that the problem is recognised and that we are not alone in it. Pilots are not products, but this narrows our claim: we should not present remote alignment as unattempted.

The open ground is contact-rich manipulation:

engaging fasteners, applying calibrated torque, repositioning hardware, replacing components. This is the part that resists automation for the same reason all contact-rich manipulation does, and it is the part carrying the economic weight.

Our claim to novelty must therefore be narrow and specific:

teleoperated physical remediation with evidenced work verification, on unmodified structures. Not "robots for towers."

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The safety case problem

This is the most likely cause of failure, and it is not an engineering problem.

A machine operating at height on live infrastructure introduces risks an operator's risk function must accept and an insurer must price: dropped objects, structural loading, electromagnetic exposure near live antennas, control link loss, and recovery of a failed machine from height.

No amount of mechanical elegance substitutes for a safety case an operator's HSE department will sign. Three implications:

Design for the safety case from the first prototype, not after it.

Independent secondary retention, fail-safe grip on power loss, tethered tooling, defined loss-of-link behaviour, and a specified recovery procedure for a disabled machine. These are not features to add later; they determine the architecture.

Engage a work-at-height and structural competence early.

This expertise is specialist, purchasable, and cheap relative to discovering the requirements in year three.

Establish the insurance position before scaling.

If the risk is uninsurable at any reasonable premium, the business does not exist regardless of technical success. This should be tested in year one with a broker, not assumed.

We should expect the first deployments to be permitted only on decommissioned structures, then low-criticality live sites, then general use — and plan on that sequence rather than hoping to skip it.

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Route to revenue

Stage 1 — Prove on real steel (months 1–12)

No external revenue. Objective: a teleoperated bolt-torque or bracket adjustment performed at height on an actual tower, recorded and evidenced, witnessed by an operator.

Stage 2 — Teleoperated service (year 2)

Sell completed work, not equipment. Priced per intervention against the operator's fully-loaded cost of a crew visit. Begin with the narrowest task set that removes a whole climb — most likely azimuth and mechanical tilt adjustment with verified torque, since these are high-frequency and specification-bounded.

Revenue funds development. Every job produces demonstration data.

Stage 3 — Assisted and supervised autonomy (year 3+)

Individual tasks move from manual to assisted operation, raising the number of interventions per operator per day. This is where margin appears and where the defensible position accumulates.

Stage 4 — Licensing and equipment sale

Only once the safety case is established, the task library is proven, and operators are asking. Selling machines earlier transfers the risk to a customer who is not equipped to carry it.

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Open economics

The following must be established in year one and are stated as questions rather than assumptions:

- **What does a tower operator's fully-loaded cost of a single crew visit actually come to**, including permits, travel, method statements and traffic management — not just crew day rate?
- **How many such visits per site per year** are attributable to tasks in our target set?
- **What proportion of the avoided cost** will an operator pay for a remote intervention?
- **What does an intervention cost us to deliver** at steady state, including transport, rigging, operator time, machine amortisation and insurance?
- **What is the insurance premium** for this activity, and is it obtainable at all?

If a remote intervention cannot be delivered for materially less than the fully-loaded cost of a crew visit, the business does not work at that task and we should move to a task where it does.

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Why the United Kingdom

Market structure.

The UK and European tower estate is consolidated into a small number of large infrastructure owners. A short list of sophisticated buyers is far easier to sell to than a fragmented market, and one reference customer carries disproportionate weight.

Regulatory environment.

UK work-at-height and lifting regulation is strict and well-defined. A safety case accepted in the UK is portable to almost any other market; the reverse is not true. Building to the harder standard first is a durability advantage.

Capability.

Robotics engineering, control systems and safety-critical assurance expertise are available here.

Insurance.

The London market underwrites unusual and novel risk. The insurance question that determines this business is best answered where the specialty capacity sits.

Export.

Tower operators across Africa, Asia and Latin America face the same problem with worse rigger scarcity and more remote sites. Several are London-listed.

The proving ground

Development access to Southern African tower infrastructure, through established telecommunications relationships, provides what almost no competing venture can obtain: real structures to develop on, at low cost, without the regulatory overhead of a mature market, and with operators for whom rigger scarcity is acute enough to justify trying something unproven.

The intellectual property, the safety case and the commercial entity sit in the UK. The steel is where it is cheapest to learn on.

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Twelve-month programme

Sequencing principle: access and economics before capital.

Months 1–3 — Access, economics, safety

Secure written development access to at least one real tower — decommissioned or low-priority is ideal. Without this the programme cannot proceed and everything else is premature.

Interview tower operators, tower service contractors and rigging companies. Establish the fully-loaded cost of a crew visit and the annual frequency of target tasks. Ask directly what would have to be true for them to accept a machine doing this work.

Obtain a preliminary insurance and safety-case opinion from a broker and a work-at-height specialist.

Stage gate:

proceed to build only with tower access secured and a credible indication that the avoided cost supports a price.

Months 4–9 — Capability to teleoperation

Work the ladder in dependency order to the point of teleoperated manipulation. Bench, then ground-level mock structure, then real steel at low height. Design retention, fail-safe and recovery behaviour in from the start.

File for intellectual property protection on whatever proves genuinely novel in the climbing-plus-manipulation mechanism. Take a patent attorney's opinion early on what is protectable.

Months 10–12 — Witnessed demonstration

A teleoperated measured-torque or bracket-adjustment operation at height on a real tower, fully recorded and evidenced, witnessed by a tower operator. Obtain written feedback on what would be required for a paid trial.

Deliverables

- Written tower access agreement
- Evidenced fully-loaded crew visit costs from operators, and target task frequency
- Preliminary insurance position and safety-case requirements
- Teleoperated manipulation demonstrated at height on a real structure
- Recorded evidence package in the form an operator would accept
- At least one written expression of interest in a paid trial
- Filed intellectual property application
- Three-year plan with evidenced pricing assumptions

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What this is not

- 🚫 **Not a drone inspection company.** That market is solved and commoditising.
- 🚫 **Not a tower survey business.** Diagnosis is not where the cost is.
- 🚫 **Not an autonomous robotics research project.** Teleoperation is the product; autonomy is an efficiency programme layered on top of a working service.
- 🚫 **Not a machine vendor, initially.** We sell completed and evidenced work until the safety case is mature enough to transfer.
- 🚫 **Not a replacement for riggers.** Skilled climbers remain essential for complex, novel and emergency work. We target the repetitive, specification-bounded interventions that consume their capacity and expose them unnecessarily.

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Risks

SAFETY CASE REJECTED

Operators or insurers refuse to accept machine intervention on live infrastructure. Highest-probability fatal risk. Tested in months 1–3.

ECONOMICS INVERT

Delivered cost of a remote intervention exceeds the avoided cost of a crew visit. Tested in months 1–3; response is to change target task, not to persist.

COMPETITOR REACHES DEPLOYMENT FIRST

Remote alignment is being attempted. Mitigation is task focus — the contact-rich manipulation nobody has deployed — and the evidence layer, not speed alone.

FOUNDER CONCENTRATION

A single technical founder is a single point of failure. Early hiring priority is a second engineer, and safety-case competence should be bought in rather than learned.

NO DEVELOPMENT ACCESS

Without real structures, the ladder stops at simulation. Tested first, and the programme does not proceed without it.

MANIPULATION PROVES INTRACTABLE IN FIELD CONDITIONS

Wind, weather, corroded and seized fasteners, non-standard mounts, decades of undocumented modification. This is the genuine engineering risk and it is why development must move to real steel early rather than perfecting bench work.

CAPITAL INTENSITY

Hardware iteration is slow and expensive, and mechanical cycle times cannot be compressed by working longer hours. Budget and schedule should assume this.

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Founder and capability plan

Technical founder.

Owens the machine end to end — mechanism, climbing, manipulation, control, and the teleoperation stack. Locomotion and manipulation are deliberately not split between people, because the reaction-force coupling between them is the hardest problem in the design and an organisational seam there would become an integration failure.

Capabilities to acquire in year one, by hire or contract rather than by learning:

- Work-at-height and structural competence for the safety case
 - A patent attorney with mechanical and robotics experience
 - Commercial access to tower operators
 - A second mechanical or controls engineer, as early as funding permits
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References and verification status

The following are load-bearing and require verification against primary sources before external circulation.

1. **Fully-loaded cost of a tower crew visit, and frequency of target maintenance tasks.** To be established from operator interviews. No figure in this document should be presented externally as evidence.
2. **Remote electrical tilt capability and its limits** — specifically that azimuth and mechanical tilt remain manual. Verify against AISG specifications and antenna manufacturer documentation.
3. **Competitive landscape**, including current status of remote alignment pilots and robotic climbing platforms. Sourced secondarily; verify before making novelty claims.
4. **Aviation obstruction lighting replacement and inspection obligations** under UK CAA and ICAO requirements. Potentially a strong regulatory driver; confirm before relying on it.
5. **Rigger workforce availability and demographics.** Widely asserted in industry commentary; support with published data before external use.

Founder hypothesis, frozen for testing. Technical, regulatory and insurance statements require professional verification before external circulation.