# A Realistic Design Concept for a Transformable Air-to-Ground Combat Vehicle: Engineering the *StarCraft II* "Viking"

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**Abstract**

The *StarCraft II* Viking is a fictional vehicle that transitions between a fixed-wing air-to-air interceptor and a bipedal ground-assault platform. Although it is a product of game design, the concept raises a genuinely instructive engineering question: how close can current aerospace and robotics technology bring us to a vehicle that is both a capable fighter and a walking ground unit? This paper develops a conceptual engineering design for such a transformable fighter–walker and evaluates its feasibility. Drawing on morphing-aircraft research, variable-sweep wings, vertical and short takeoff and landing (V/STOL) propulsion, and humanoid robotics, we propose a twin-engine, variable-sweep, tailless delta configuration with articulated legs that fold beneath the fuselage. We derive mission requirements from the in-game role, analyze aerodynamics, structures, actuation, power, locomotion, control, and human factors, and construct first-order mass and power budgets. The analysis shows that the defining transformation mechanism is technically realizable at laboratory scale but imposes severe penalties in mass, cost, reliability, and pilot survivability at combat scale. We therefore argue that a practical near-term realization is not a crewed fighter but an unmanned, mission-optimized morphing demonstrator.

## 1 Introduction

Fictional military hardware has a long record of anticipating, and sometimes inspiring, real engineering. Orbital bombardment, powered exoskeletons, and unmanned combat vehicles all appeared in fiction long before becoming programs of record. The *StarCraft II* Viking belongs to a particularly demanding category: a crewed vehicle that must serve both as a high-performance air-to-air interceptor and, after a mid-mission transformation, as a walking ground-assault platform. In the game this dual role is a balance decision; in reality it would be among the most difficult integration problems in aerospace engineering.

This paper treats the Viking not as a game unit but as a set of design requirements. Its objective is to translate the fictional capability into a defensible near-term engineering concept and to assess, subsystem by subsystem, how far that concept is from feasibility. We do not attempt to reproduce the game's exact geometry or performance; instead we ask what configuration a designer would choose today if the twin requirements of a fast fighter and a walking ground unit were imposed together.

The study proceeds as follows. Section 2 derives a concept of operations and quantitative requirements from the Viking's in-game role. Section 3 proposes an overall configuration and transformation architecture. Sections 4–9 analyze aerodynamics, structures and materials, propulsion and power, ground locomotion, control, and human factors. Section 10 assembles first-order mass and power budgets and discusses feasibility, cost, and scaling. Section 11 concludes.

The central finding is that the two capabilities are individually mature but fundamentally in tension. Flight performance rewards minimum structural mass and high specific power, while walking locomotion rewards massive actuators, load-bearing joints, and low ground pressure. The transformation mechanism sits exactly at this tension and converts a hard problem into a very expensive one. We argue that the concept is aerodynamically plausible and mechanistically realizable at reduced scale, but that a full-scale crewed Viking is unlikely to be cost-effective; the most credible near-term descendant is an unmanned morphing demonstrator.

## 2 Concept of Operations and Requirements

In *StarCraft II* the Viking fills two roles. In fighter mode it is a long-range air-to-air unit used to intercept heavy enemy aircraft; in assault mode it is a short-range ground attacker. This role duality translates into a demanding concept of operations (CONOPS): the vehicle must transit rapidly to a battle area at fighter speeds, loiter or engage airborne targets, convert to a ground vehicle, operate in close terrain, and ideally convert back again.

We decompose the mission into three phases: air superiority and transit, transformation and transition flight, and ground assault and extraction. From these phases we derive the top-level requirements in Table 1. The air phase borrows targets from a fourth-generation fighter: a dash speed of at least Mach 1.6, a combat radius of about 700 km with internal fuel, and a service ceiling above 12,000 m (Anderson, 2011; Raymer, 2018). The ground phase borrows targets from mobile ground systems: a traverse of several hundred kilometers, off-road mobility, and the ability to cross obstacles. The transformation phase is the most unusual and is bounded by a target of ten seconds or less at a transition airspeed near 150 knots. This decomposition of a concept of operations into traceable quantitative requirements follows the practice recommended in introductory aircraft design texts (Jenkinson and Marchman, 2003).

Two requirements dominate all downstream design decisions. The first is ground contact pressure, because a vehicle heavy enough to be a fighter will sink into soft terrain if its feet are small. The second is transformation mass overhead: every kilogram spent on joints and actuators is a kilogram subtracted from fuel, weapons, or structural margin. These two requirements are stated explicitly because they drive the feasibility discussion in Section 10.

**Table 1:** Top-level design requirements derived from the Viking's dual role.

| ID | Requirement | Target |
|---|---|---|
| R1 | Fighter-mode dash speed | ≥ Mach 1.6 |
| R2 | Combat radius (internal fuel) | ≥ 700 km |
| R3 | Service ceiling | ≥ 12,000 m |
| R4 | Transformation time | ≤ 10 s (30 s acceptable) |
| R5 | Ground traverse distance | ≥ 300 km |
| R6 | Ground cruise speed | ≥ 25 km/h |
| R7 | Internal payload | ≥ 1,500 kg |
| R8 | Ground contact pressure | ≤ 100 kPa |
| R9 | Crew | 1 (optionally unmanned) |

# 3 Overall Configuration and Transformation Architecture

We select a tailless delta configuration with variable-sweep outboard wings, twin afterburning turbofans, and two articulated legs that fold into ventral bays. The delta planform gives good supersonic area distribution and high low-speed lift at high angle of attack, while variable sweep reconciles efficient subsonic cruise with low wave drag (Anderson, 2011; Loftin, 1985; Raymer, 2018). The engines are mounted inboard with three-dimensional thrust vectoring, which provides pitch and roll authority during slow transition flight and, in principle, short or vertical takeoff and landing support.

The transformation is chosen to be a discrete reconfiguration rather than a continuous smooth morph. Morphing-aircraft research distinguishes small, continuous shape changes such as variable camber from large, discrete changes of topology such as folding wings or rotating engine nacelles (Barbarino et al., 2011; Weisshaar, 2013). Continuous skin morphing offers aerodynamic benefits but demands compliant skins that must simultaneously carry aerodynamic load and change shape, a materials problem that remains only partially solved (Kota et al., 2003). Discrete reconfiguration with rigid load-bearing segments and well-defined hinges is lower risk, easier to certify, and compatible with locking joints that carry both flight and ground loads. We therefore adopt folding and rotating segments with a minimal morphing skin at the joints only.

The transformation sequence is: (i) slow to transition speed and level the aircraft; (ii) unlock and extend the legs downward; (iii) rotate the outer wing panels aft and lock them as the fuselage pitches up; and (iv) place the feet on the ground and shift load from aerodynamic lift to the legs. The reverse sequence restores flight, as illustrated in Figure 1. Each step is mechanically analogous to existing systems: variable sweep uses the same wing-pivot technology as the F-14 and Tornado (Frawley, 2002; Loftin, 1985); the tilting of the lifting and propulsion system resembles the XV-15 and V-22 tiltrotor programs (Gertler, 2012; Maisel et al., 2000); and the ground mode is a legged robot of the kind demonstrated by ASIMO, BigDog, and Atlas (Hirai et al., 1998; Kuindersma et al., 2016; Raibert et al., 2008). The novelty is not any single mechanism but their integration into one airframe.

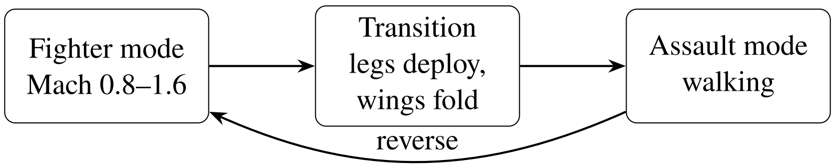


**Figure 1:** Conceptual transformation sequence between the fighter and assault modes.

**Table 2:** Comparison of the proposed concept with representative enabling platforms.

| Platform | Mass (kg) | Max speed | Enabling feature |
|---|---|---|---|
| Viking concept | ~20,000 MTOW | Mach 1.6 / 40 km/h | Transformable |
| F-14 Tomcat | ~33,700 MTOW | Mach 2.34 | Variable sweep (Loftin, 1985) |
| V-22 Osprey | ~23,900 VTOL | 509 km/h | Tiltrotor (Gertler, 2012; Maisel et al., 2000) |
| AV-8B Harrier | ~14,100 MTOW | Mach 0.97 | STOVL (Frawley, 2002) |
| Atlas humanoid | ~85 | 1.5 m/s | Bipedal walking (Kuindersma et al., 2016) |

# 4 Aerodynamics and Flight Performance

In fighter mode the vehicle behaves as a supersonic delta-wing aircraft. Lift is governed by the familiar relation

$$L = \frac{1}{2}\rho V^2 S C_L, \tag{4.1}$$

where $L$ is lift, $\rho$ is air density, $V$ is true airspeed, $S$ is the reference wing area, and $C_L$ is the lift coefficient. Selecting a reference wing area of about 35 $m^2$ and a maximum lift coefficient near 1.6 in the landing configuration gives a clean-wing stall speed of roughly 65 m/s at a landing mass of 18,000 kg. That stall speed is high but manageable with thrust vectoring and high-lift devices.

Variable sweep is retained because it directly addresses the fundamental conflict between supersonic cruise and low-speed handling. At high sweep the wave drag falls and the transonic area distribution improves; at low sweep the effective aspect ratio rises and improves the lift-to-drag ratio for loiter and approach (Anderson, 2011; Loftin, 1985). In the Viking this mechanism gains a second function: folding the outer panels inward reduces planform span so that the vehicle can operate in the constrained airspace of a ground battle, and it reduces the moment of inertia that must be controlled during transformation.

The most serious aerodynamic challenge is the transition itself. As the vehicle pitches up and the legs deploy, the center of pressure shifts and the control surfaces become partially blanked by the changing geometry. Low-speed, high-angle-of-attack flight is already a regime of separated flow and reduced control power; adding large moving masses makes the problem explicitly time-varying. A Breguet range estimate confirms that the air-phase requirement is achievable in principle, but only if the transformation mass overhead is kept small:

$$R = \frac{V}{c}\left(\frac{L}{D}\right)\ln\left(\frac{W_i}{W_f}\right), \tag{4.2}$$

where $c$ is the thrust-specific fuel consumption and $W_i$, $W_f$ are the initial and final weights. For a cruise lift-to-drag ratio near 10, a specific fuel consumption of about 0.8 lb/lbf-h (roughly 22.7 mg/N-s), and a fuel fraction near 0.35, the cruise range is on the order of 900–1,200 km, so the 700 km combat radius is feasible on paper. The caveat is that every kilogram of transformation hardware reduces the fuel fraction and erodes this margin.

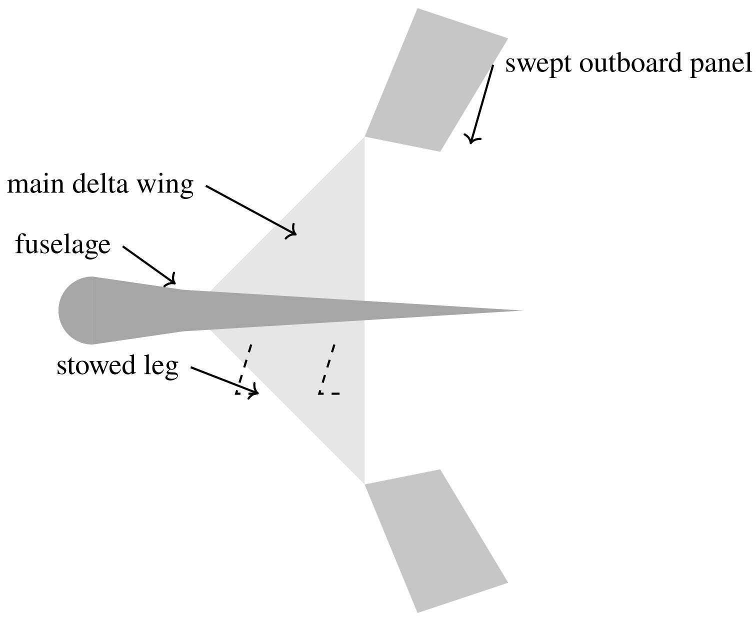


**Figure 2:** Simplified top-view schematic of the proposed fighter-mode configuration (not to scale).

# 5 Structures, Materials, and Morphing Joints

The airframe must satisfy two load cases that are normally never combined: supersonic maneuvering loads and the concentrated ground-reaction loads of walking. The wing box and fuselage are sized by flight loads, but the leg attachment points and the transformation joints see loads on the order of half the vehicle weight during touchdown and walking, with impact factors of two to three during landing. These joints must lock rigidly enough to carry flight loads, yet unlock and move quickly enough to meet the transformation-time requirement.

A first-order structural assessment points to a conventional metallic–composite hybrid rather than an exotic all-morphing structure. Titanium and high-strength steel are retained for the leg joints and wing pivots, where fatigue and bearing loads dominate, while carbon-fiber-reinforced polymer is used for the wing skins and fuselage to save mass (Corke, 2003; Raymer, 2018). Shape-memory alloys and other smart materials are attractive for small conformal actuators, but their bandwidth and energy efficiency are generally too low for the large, fast, high-authority motions required here (Barbarino et al., 2011; Lagoudas, 2008). The transformation should therefore be powered by conventional hydraulic or electromechanical actuators, with smart materials confined to secondary tasks such as gap seals.

The cost of the mechanism is substantial. Historical variable-sweep aircraft carried a structural penalty of roughly 10–20 percent of empty weight relative to a comparable fixed wing (Loftin, 1985); adding legs, feet, and their retraction systems raises this penalty toward 30 percent or more. Fatigue and battle-damage tolerance at the moving joints become critical life-limiting factors, because a single jammed hinge strands the vehicle in one mode.

# 6 Propulsion and Power

Fighter-mode performance is supplied by two afterburning turbofans of roughly 90 kN thrust each, giving a thrust-to-weight ratio near unity at combat weight, consistent with a supersonic multirole fighter (Boyce, 2012; Mattingly, 2006). Three-dimensional thrust vectoring contributes to low-speed control during transformation and offers the option of short takeoff and vertical landing, following the approach demonstrated on the Harrier and F-35B families (Bevilaqua, 2014; Frawley, 2002).

The distinctive power problem is the ground mode. A walking vehicle does not use the main engines; it needs hundreds of kilowatts of mechanical power at the legs. If this power were drawn from onboard batteries, the energy-density gap would be crippling: jet fuel stores roughly 40–45 MJ/kg, whereas state-of-the-art lithium-ion cells store on the order of 0.7–1.0 MJ/kg (crc, 2004; Nitta et al., 2015). Battery power for a multi-hour ground mission would add thousands of kilograms. The practical answer is a small auxiliary power unit, a turboshaft of about 400 kW, that drives a hydraulic or high-voltage electric actuation system while the main engines are shut down or idling. This mirrors the trend toward more-electric-aircraft architectures, in which a common electric power bus supplies many formerly hydraulic or pneumatic loads (Rosero et al., 2007).

Table 3 summarizes the estimated ground-mode power demand. The dominant term is locomotion: a 14,500 kg vehicle walking at about 7 m/s with a cost of transport of 1.5–2.0 requires roughly 200–300 kW of mechanical output, and the actuator and thermal losses raise the input requirement to about 350–400 kW. This is feasible with a compact turboshaft, but it reinforces the observation that walking is an energy-intensive and heat-intensive mode of locomotion.

**Table 3:** Estimated ground-mode power demand during walking.

| Load | Power (kW) | Basis |
|---|---|---|
| Locomotion (mechanical) | 200–300 | CoT $\cdot$ $mgv$ |
| Actuator and thermal losses | 100–150 | ~70% efficiency |
| Avionics and cooling | 40 | electrical bus |
| Sensors and communications | 10 | payload |
| **Total input** | **350–500** | APU-sized source |

# 7 Ground Locomotion

The ground mode is the least mature part of the concept and the place where the fictional Viking is most forgiving. Bipedal locomotion is now well understood in principle. The zero-moment point (ZMP) criterion, introduced by Vukobratovic, provides a tractable stability condition for walking, and modern humanoids such as ASIMO and Atlas demonstrate dynamic walking, running, and manipulation using optimization-based control (Hirai et al., 1998; Kuindersma et al., 2016; Raibert et al., 2008; Siciliano and Khatib, 2016; Vukobratović and Borovac, 2004). The intellectual challenge is therefore not whether a biped can walk, but whether it can walk while weighing fifteen tonnes.

The numbers are unforgiving. A 14,500 kg vehicle supported on two feet must keep ground contact pressure below about 100 kPa on firm soil. With a total foot contact area $A_f$ this requires

$$\sigma = \frac{W}{A_f} \leq \sigma_{\max}, \tag{7.1}$$

and solving with a weight near 142 kN gives a required total foot area close to 1.4 m$^2$. That implies very large feet, lower-leg tracks, or a four-legged stance. Each leg and its actuators must also lift, accelerate, and absorb the impact of a multi-tonne mass, driving leg mass into the range of thousands of kilograms and competing directly with fuel and weapons. Walking speed and endurance are correspondingly limited: a realistic bipedal cruise of 20–40 km/h is achievable only with careful gait optimization, while a wheeled or tracked auxiliary mode would be far more efficient over open ground.

We therefore keep bipedal locomotion as the design aspiration but recommend, for any realistic implementation, a hybrid that carries wheels or tracks on the legs or that substantially reduces ground-mode mass. The ground mode also creates a recoil problem: firing a cannon from a standing biped destabilizes the platform, so the design must fire from a braced stance or use recoil management far more sophisticated than a tracked vehicle requires.

## 8 Control, Avionics, and Flight Dynamics

The Viking is a time-varying, multi-body system. During transformation its inertia, center of mass, and aerodynamic properties change by tens of percent in a few seconds, so no single trim condition describes the vehicle. A practical controller therefore uses gain scheduling across the transformation envelope and, where possible, model predictive control that optimizes a trajectory for the entire maneuver rather than reacting step by step (Siciliano and Khatib, 2016). The same optimization-based philosophy that controls Atlas locomotion transfers naturally to the transition-flight problem, and this cross-domain reuse is one of the concept's genuine engineering attractions.

The control architecture is heavily automated even though the vehicle is nominally crewed. Walking is delegated to the motion computer, because a human pilot cannot continuously balance a multi-tonne biped while also managing the battle; the pilot issues high-level movement goals and supervises, much as in advanced driver-assistance systems. Sensor fusion combines inertial, air-data, and ground-contact sensing so that the controller can switch control laws at the moment the feet touch down (Kuindersma et al., 2016).

Electrically, the vehicle follows the more-electric-aircraft trend: electro-hydrostatic and electromechanical actuators offer the high bandwidth, modularity, and reconfigurability that a morphing platform needs, and they simplify the fluid plumbing that would otherwise cross the moving joints (Rosero et al., 2007). The cost is a substantial electrical and thermal load, which is already included in the power budget of Section 6.

## 9 Human Factors and Survivability

A crewed Viking confronts several human-factors problems that no operational aircraft has solved together. The cockpit must function in two orientations: near-horizontal in fighter mode and near-vertical when the vehicle stands, which complicates displays, ejection, and the pilot's vestibular and visual references (Davis et al., 2008). The ejection seat must be qualified for both attitudes and for the presence of large moving appendages immediately around the cockpit. Sustained high-g air combat and the low-speed, high-workload transition impose very different physiological demands, and the transformation itself would be disorienting without strong automation.

Survivability is equally compromised. The transformation joints, leg actuators, and external feet are difficult to armor and become single-point failures that can strand the vehicle or cause loss of control; a hit to a hip joint is effectively a mission kill. Armoring the legs raises mass and ground pressure, while stealth shaping is degraded by the same moving surfaces and appendages that enable the dual role. These penalties are cumulative and are among the strongest arguments for an unmanned derivative, in which life support, ejection, and cockpit-orientation constraints disappear and the risk tolerance for battle damage improves.

## 10 Feasibility, Cost, and Scaling

Assembling the preceding analyses into a first-order mass and power budget makes the central trade concrete. Table 4 gives a notional breakdown for a 14,500 kg empty vehicle. The transformation and locomotion systems together account for roughly one-third of empty mass, a penalty comparable to the empty weight of a small combat aircraft, and the ground-mode power demand approaches the output of a helicopter auxiliary power unit. These are not impossibility results, but they are severe.

**Table 4:** First-order empty-mass budget for the proposed concept.

| Item | Mass (kg) | Fraction (%) |
|---|---|---|
| Wing and fuselage structure | 3,200 | 22 |
| Propulsion (two engines, inlets, nozzles) | 2,700 | 19 |
| Legs and feet | 3,000 | 21 |
| Transformation actuators and joints | 1,400 | 10 |
| Avionics, electrical, and cooling | 950 | 6 |
| Fuel system | 450 | 3 |
| Crew and life support | 300 | 2 |
| Armament integration | 700 | 5 |
| Morphing skins and fairings | 1,000 | 7 |
| Margin | 800 | 5 |
| **Total empty mass** | **14,500** | **100** |

The comparison in Table 2 is instructive. Every element of the Viking exists separately: variable sweep matured on the F-14 and Tornado, tiltrotor flight on the XV-15 and V-22, STOVL on the Harrier and F-35B, and bipedal walking on ASIMO and Atlas (Bevilaqua, 2014; Frawley, 2002; Gertler, 2012; Hirai et al., 1998; Kuindersma et al., 2016; Loftin, 1985; Maisel et al., 2000). Integrating them compounds their individual penalties. Historical V/STOL and variable-geometry programs repeatedly showed that the flexibility is purchased with weight, complexity, cost, and maintenance burden, and several were abandoned or heavily constrained for exactly those reasons (Bevilaqua, 2014; Loftin, 1985; Maisel et al., 2000).

Cost scales badly as well. Development of a clean-sheet combat aircraft now runs to tens of billions of dollars, and a vehicle that must additionally be certified as a ground robot multiplies the test and safety burden. Reliability is a further concern: a mechanism with dozens of large actuated joints will struggle to match the availability of a conventional fixed-wing aircraft, and the maintenance burden measured in hours per flight hour would likely be dominated by the transformation hardware. We therefore argue that the credible path is not a full-scale crewed fighter but a spiral of increasingly capable unmanned demonstrators: first a sub-scale morphing air vehicle to retire the transformation aerodynamics, then a transition-capable unmanned vehicle, and finally an optionally-piloted design if the mission value justifies it.

This conclusion does not dismiss the Viking; it locates the concept where fiction is most useful, as a forcing function for asking which capabilities are worth their true cost.

## 11 Conclusion

This paper has translated the *StarCraft II* Viking from a game unit into an engineering design problem and assessed its feasibility with near-term technology. The air phase is plausible: a variable-sweep delta fighter with thrust vectoring can meet the stated speed, range, and altitude requirements. The transformation is mechanistically realizable as a discrete reconfiguration built from existing variable-geometry, tiltrotor, and legged-robot hardware. The ground mode is the weak link: a fifteen-tonne biped faces severe ground-pressure, actuator-mass, and energy penalties that make walking locomotion marginal and expensive.

The binding constraints are mass and power. Transformation and locomotion hardware consume about a third of empty mass and dominate the auxiliary power budget, eroding exactly the fuel, payload, and performance margins that a fighter needs. The concept is therefore feasible at reduced scale and in unmanned form, but a full-scale crewed Viking is unlikely to be a rational procurement choice. More broadly, the exercise demonstrates the value of treating speculative fiction as a requirements generator: the Viking does not reveal the future of combat aviation, but it exposes, with unusual clarity, the physical cost of versatility.

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