WHEN A MINE LEARNS TO FLY

The Periodic Table of Air Power Vs the Licensing Office That Grounds It

> ***The miner believes he holds the leverage.***
> ***The refiner knows better.***
> ***The licensing clerk simply signs, or does not.***

IT STARTS IN A HOLE IN THE GROUND

We like our military power photogenic. Carriers slicing through swell. Stealth fighters at golden hour. Missiles drawing tidy white lines across a very expensive sky.

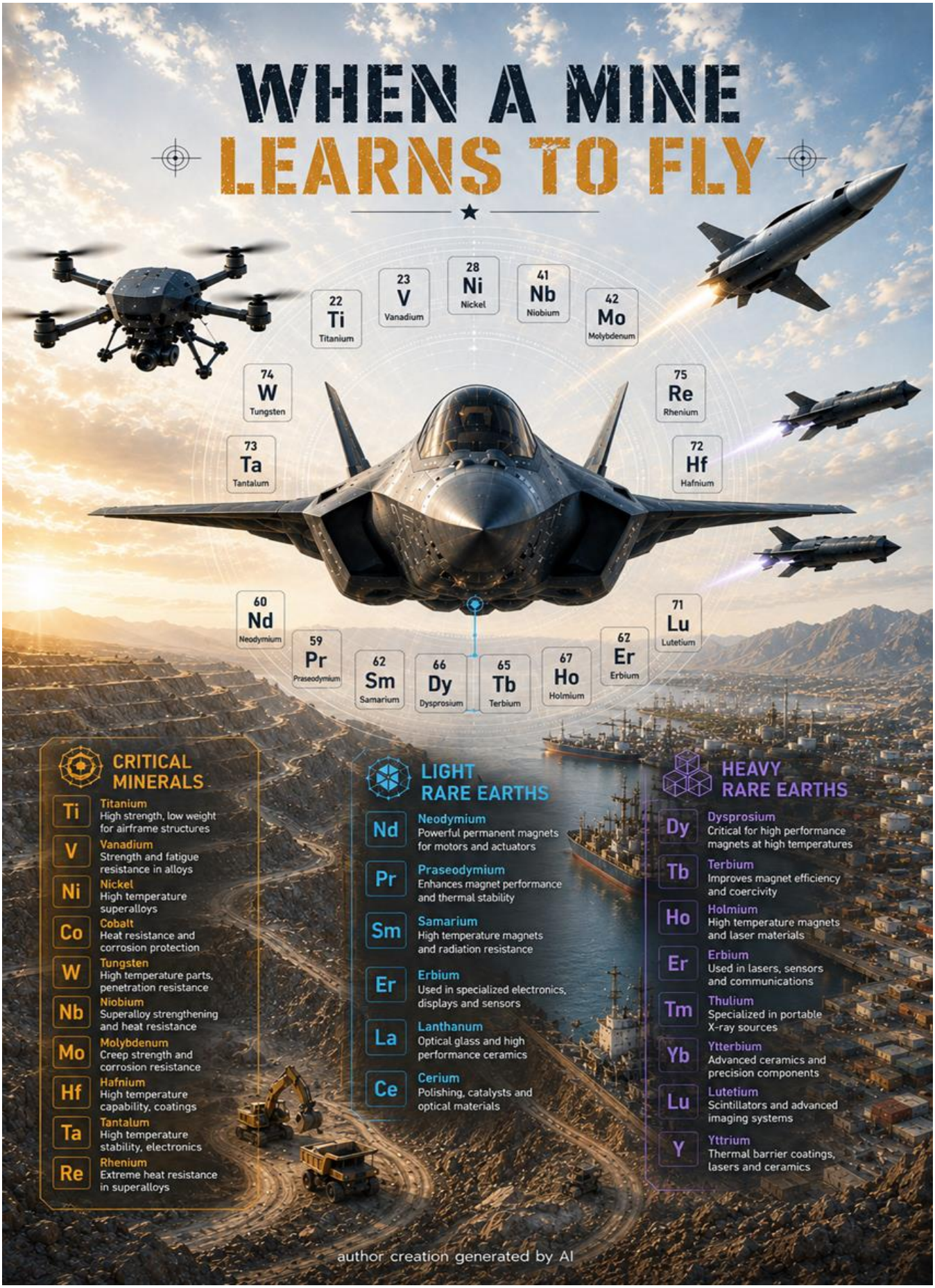
None of it starts in a hangar.

Before a fifth-generation fighter gets airborne, its ingredients have done more international travel than most diplomats.

Titanium from Australia. **Niobium** from Brazil. **Tungsten** from Chad and Vietnam. **Cobalt** from Congo DRC.

Hafnium scraped out of zircon. And **rare earths** refined almost invariably in China.

> ***That is the real map of air power.***
> ***It does not look like a fleet review.***
> ***It looks like a supply chain.***


WHEN A MINE
LEARNS TO FLY
22 Ti Titanium
23 V Vanadium
28 Ni Nickel
41 Nb Niobium
42 Mo Molybdenum
74 W Tungsten
75 Re Rhenium
73 Ta Tantalum
72 Hf Hafnium
60 Nd Neodymium
59 Pr Praseodymium
62 Sm Samarium
66 Dy Dysprosium
65 Tb Terbium
67 Ho Holmium
62 Er Erbium
71 Lu Lutetium
CRITICAL MINERALS
Ti Titanium High strength, low weight for airframe structures
V Vanadium Strength and fatigue resistance in alloys
Ni Nickel High temperature superalloys
Co Cobalt Heat resistance and corrosion protection
W Tungsten High temperature parts, penetration resistance
Nb Niobium Superalloy strengthening and heat resistance
Mo Molybdenum Creep strength and corrosion resistance
Hf Hafnium High temperature capability, coatings
Ta Tantalum High temperature stability, electronics
Re Rhenium Extreme heat resistance in superalloys
LIGHT RARE EARTHS
Nd Neodymium Powerful permanent magnets for motors and actuators
Pr Praseodymium Enhances magnet performance and thermal stability
Sm Samarium High temperature magnets and radiation resistance
Er Erbium Used in specialized electronics, displays and sensors
La Lanthanum Optical glass and high performance ceramics
Ce Cerium Polishing, catalysts and optical materials
HEAVY RARE EARTHS
Dy Dysprosium Critical for high performance magnets at high temperatures
Tb Terbium Improves magnet efficiency and coercivity
Ho Holmium High temperature magnets and laser materials
Er Erbium Used in lasers, sensors and communications
Tm Thulium Specialized in portable X-ray sources
Yb Ytterbium Advanced ceramics and precision components
Lu Lutetium Scintillators and advanced imaging systems
Y Yttrium Thermal barrier coatings, lasers and ceramics
author creation generated by AI

FIVE SYSTEMS, ONE LONG SHOPPING LIST

THE AIRFRAME. Titanium and vanadium: strong, light, refreshingly indifferent to corrosion and fatigue.

THE ENGINE. Where materials go to die. The hot section runs past the melting point of the metal it is made from, survivable only thanks to cooling channels and ceramic coatings.

Steel would simply sag. Instead: superalloys of nickel, cobalt, niobium, molybdenum, tantalum, tungsten, hafnium and at the top end rhenium, a metal so scarce it barely exists outside copper mining.

STRUCTURE AND HIGH-TEMPERATURE HARDWARE. Mounts, fittings, fasteners, everything holding the fire in place: nickel, cobalt, chromium, molybdenum, tungsten, rhenium again.

Nobody makes a documentary about a bracket. Nobody flies without one.

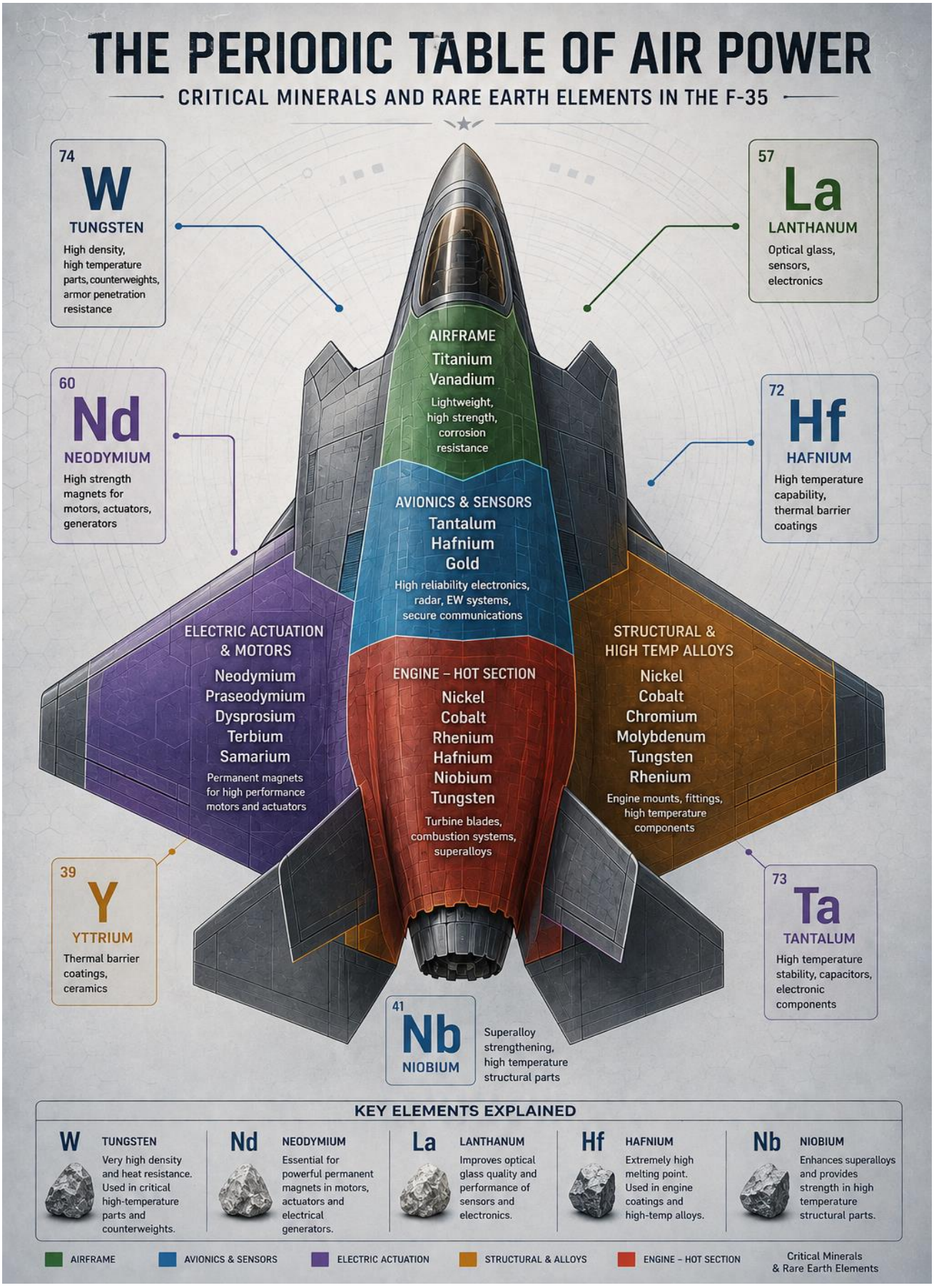
ELECTRIC ACTUATION. Hydraulic muscle has been replaced by compact motors and generators running on permanent magnets: neodymium, praseodymium, samarium, plus dysprosium and terbium to stop the magnet losing its nerve when things get hot.

Rare earths never made an aircraft faster. They made it precise.

SENSORS AND AVIONICS. Tantalum and hafnium keep their composure at temperature, lanthanum improves optical glass, yttrium goes into ceramics and thermal coatings.

Alone, none of it looks decisive. Together, it is the entire ecosystem.

> ***A fighter engine is metallurgy doing a very convincing impression of aerodynamics.***


THE PERIODIC TABLE OF AIR POWER
CRITICAL MINERALS AND RARE EARTH ELEMENTS IN THE F-35
74 W TUNGSTEN
High density, high temperature parts, counterweights, armor penetration resistance
57 La LANTHANUM
Optical glass, sensors, electronics
60 Nd NEODYMIUM
High strength magnets for motors, actuators, generators
72 Hf HAFNIUM
High temperature capability, thermal barrier coatings
AIRFRAME
Titanium
Vanadium
Lightweight, high strength, corrosion resistance
AVIONICS & SENSORS
Tantalum
Hafnium
Gold
High reliability electronics, radar, EW systems, secure communications
ELECTRIC ACTUATION & MOTORS
Neodymium
Praseodymium
Dysprosium
Terbium
Samarium
Permanent magnets for high performance motors and actuators
ENGINE – HOT SECTION
Nickel
Cobalt
Rhenium
Hafnium
Niobium
Tungsten
Turbine blades, combustion systems, superalloys
STRUCTURAL & HIGH TEMP ALLOYS
Nickel
Cobalt
Chromium
Molybdenum
Tungsten
Rhenium
Engine mounts, fittings, high temperature components
39 Y YTTRIUM
Thermal barrier coatings, ceramics
73 Ta TANTALUM
High temperature stability, capacitors, electronic components
41 Nb NIOBIUM
Superalloy strengthening, high temperature structural parts
KEY ELEMENTS EXPLAINED
W TUNGSTEN
Very high density and heat resistance. Used in critical high-temperature parts and counterweights.
Nd NEODYMIUM
Essential for powerful permanent magnets in motors, actuators and electrical generators.
La LANTHANUM
Improves optical glass quality and performance of sensors and electronics.
Hf HAFNIUM
Extremely high melting point. Used in engine coatings and high-temp alloys.
Nb NIOBIUM
Enhances superalloys and provides strength in high temperature structural parts.
AIRFRAME
AVIONICS & SENSORS
ELECTRIC ACTUATION
STRUCTURAL & ALLOYS
ENGINE – HOT SECTION
Critical Minerals & Rare Earth Elements

THE PART EVERYONE SKIPS

Public debate is obsessed with mining. A country announces a rare earth discovery and behaves as though it has been handed a seat at the table. Geology is the easy part.

Between rock and wing lie concentration, cracking and leaching, separation, purification, metal reduction, alloying, forging, magnet pressing and coating.

Then the brutal stage: aerospace qualification. Every alloy heat and every magnet vendor is written into a type certificate. Change the source and you requalify months at best, years at worst.

> ***Owning the ore is a press release.***
> ***Owning the process is leverage.***

YOU DO NOT NEED AN EMBARGO. YOU NEED A LICENSING OFFICE.

Embargoes are crude: headlines, retaliation, a trade case gift-wrapped for your opponent. Far more elegant to keep everything perfectly legal, perfectly available, and simply make the paperwork breathe.

April 2025: licensing lands on seven medium and heavy rare earths, aimed squarely at defence-adjacent users. **July**: partial easing, collective exhale. **October**: the largest expansion yet, reaching foreign products made with Chinese material or Chinese technology.

November: suspended for a year after a trade truce. **January 2026**: the catalogue quietly adds samarium, gadolinium and lutetium. **Early 2026**: fresh dual-use controls, this time pointed at Japan. **March 2026**:

A national supply-chain security framework folds the whole apparatus into one instrument.

> ***Open. Shut. Open, but differently. Shut again.***

It is a turnstile, not a wall. Whitelists run to a handful of approved firms per material **fifteen** for tungsten, **eleven** for antimony. Even those need shipment-by-shipment licence, with nominal **45-day** reviews that stretch into months, or into a polite silence.

Nothing is banned. Nothing is refused. Things simply take longer this quarter than last, and the forms have changed again. Weaponised bureaucracy: astonishingly effective, and almost impossible to litigate.

THE CERTIFICATE IS THE AIRCRAFT

Aerospace cannot improvise its way out. A carmaker requalifies a magnet supplier in a few months and moves on. A defence prime cannot: the part is on the certificate, the certificate is the aircraft, and no certificate means no delivery however finished the airframe on the ramp may look.

So the cycle runs. Window opens; manufacturers scramble, stockpile, requalify and congratulate themselves on their resilience. Window shuts. The whitelist changes, the documentation changes, the end-use declarations grow more inquisitive, and round two begins from a standing start. Repeat until every procurement department in the West is running on fumes.

The failure mode is often absurdly small. In **2022** the Pentagon parked **eighteen F-35s** because a samarium-cobalt magnet inside a Honeywell turbomachine pump was traced to a Chinese alloy from a **fifth-tier** supplier. Harmless, carrying no data, no safety risk. It merely broke a

specialty-metals rule. Deliveries resumed only after a national security waiver signed at the very top of the Department of Defense.

> ***The most expensive weapons program in history, stopped by a magnet the size of a coin,five layers down a chain nobody had fully mapped.***

The 2026 numbers are less amusing. Neodymium-praseodymium oxide has multiplied **sixfold** in six months, tungsten concentrate has **tripled**, antimony has **doubled**, and European licence approval rates have fallen below **25%**. This is control rather than scarcity, applied in reversible doses that preserve pricing power, extract concessions, and keep Western investors hesitant.

> ***Every time the window reopens, the business case for building your own refinery gets harder to sign.***
> ***That is not a side effect. That is the product.***

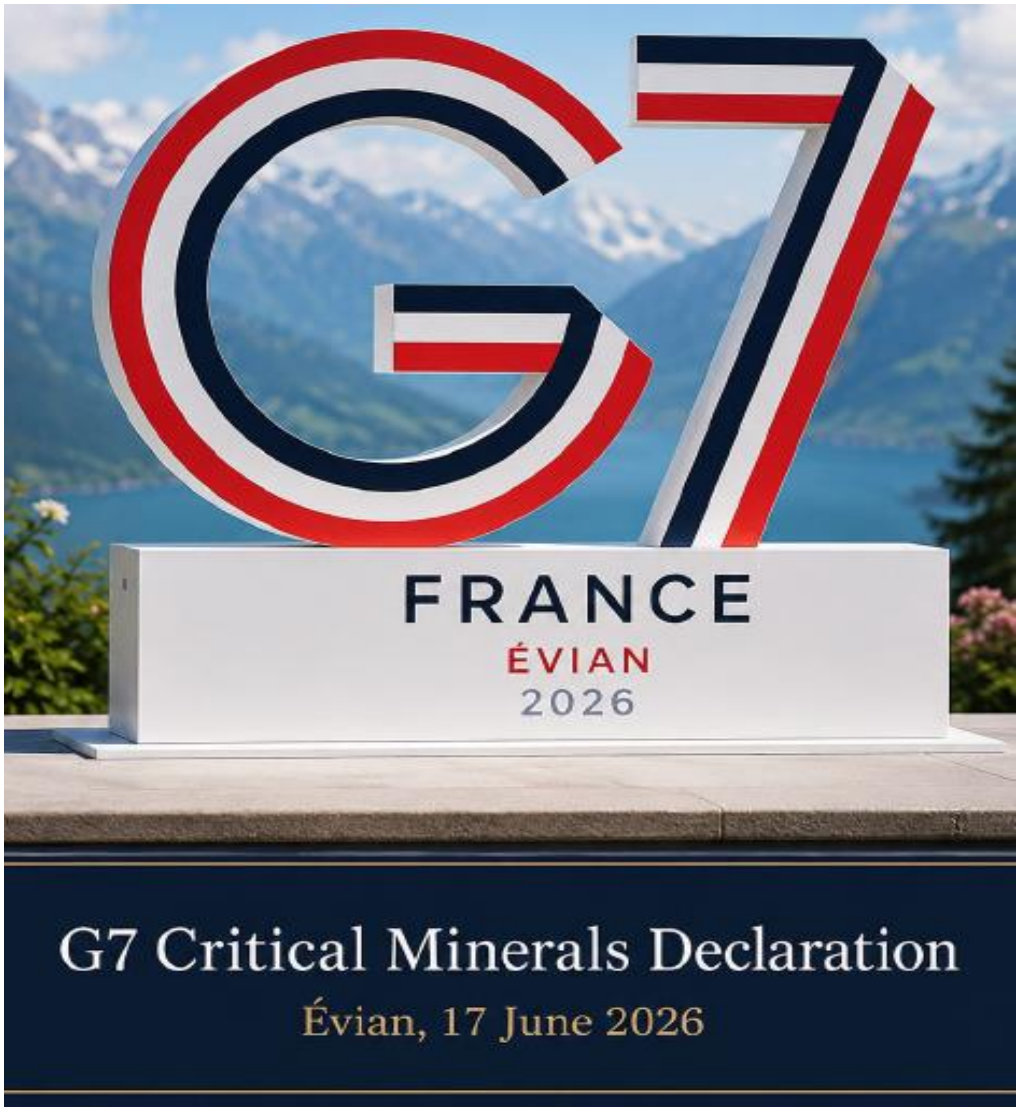
EVERYONE WANTS A REFINERY. NOBODY WANTS IT NEARBY.

The West and Japan have responded with the thing they do best: convening. The G7 Critical Minerals Action Plan. A ministerial in Washington drawing over fifty nations. Trade ministers in Paris in May 2026**. Then Evian in June, where leaders with Australia signing on committed to an actual number:** dependence on a single non-G7 supplier for rare earths and permanent magnets below **60% by 2030**, with an ambition of **50%**. Nearly two hundred projects, some **€64 billion**.Real money and real political alignment.

Also the easy half.A new mine takes ten to eighteen years. But the mine is not the bottleneck. Refining is and here is the sentence that never survives into a communique:

> ***Separating rare earths is a filthy business,***
> ***and no electorate wants it in their constituency.***

Solvent extraction at industrial scale, acid by the tanker, and residues carrying thorium and uranium that have to live somewhere for a very long time. China's **ninety-per-cent-plus** share of global refining is not geological luck. It is an outsourcing decision the West made across thirty years, banked the savings from, and then forgot it had made.



MALAYSIA: THE EXCEPTION, AND ITS PRICE

One substantial rare earth separation plant operates outside China: **LYNAS at Gebeng**, in Pahang, processing concentrate shipped from Mount Weld in Western Australia.

It has run since **2012**, and it has spent essentially its entire life in a fight.Court challenges. Stop Lynas umbrellas.

Licence conditions demanding that cracking and leaching leave the country, later lifted.

More than **a million tonnes** of residue accumulated on site. In **March 2026** it finally won a **ten-year** operating licence: no new waste facility, residue operations to cease by **2031**.

Weeks later it signed a multi-year rare earth supply agreement with the Pentagon, handing local opponents a second grievance.

> ***The question is no longer "why are we hosting the waste?". It is "why are we hosting it for someone else's air force?"***

That is the honest lesson of Gebeng. Non-Chinese processing is technically solved.

What it costs is not mainly capital it is a permanent, decade-long argument with environmentalists, opposition politicians and the neighbours. Malaysia has been paying that bill for fourteen years.

The G7 has signed the declaration and has not yet reached the part where someone explains a tailings pond to their own voters.

CONCLUSION:
THE GROUND, THE REFINERY, THE RUNWAY

Air superiority does not begin on the runway. It begins underground, passes through refineries and laboratories, waits for a certification stamp, and only then reaches the assembly line.

The twentieth century counted airframes.

The twenty-first counts separation circuits, magnet presses and licensing queues. None of it photographs well. All of it decides the outcome.

> ***Two races are running at once.***
> ***The first builds the aircraft.***
> ***The second decides whether anyone can.***
> ***The periodic table has become a map of geopolitical influence.***
> ***Awkwardly, the valuable territory is downstream and it is zoned residential.***

F R A N K
Geopolitician & Board Strategy Advisor
Author & Editor frank@frank.blue