AN OPEN LETTER

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MAGNIFICA VITA

HUMANITAS & NATURA

BY

JED ANDERSON

ON SAFEGUARDING ALL LIFE AND HELPING IT TO GROW,
EXPAND, AND THRIVE ON EARTH AND, IN TIME,
THROUGHOUT THE COSMOS IN THIS AGE
OF ARTIFICIAL INTELLIGENCE

[jedanderson.org/magnifica-vita]

INTRODUCTION

The grandeur of life

1. Life is the most extraordinary thing this universe has produced. After 13.8 billion years of stars and rocks and silence, on at least one small planet circling an unremarkable star, matter learned to remember itself, to repair itself, to copy itself, to look up at the sky and ask what it was looking at. That this happened at all is the deepest fact about the universe we live in. That we are the part of it now writing about it is the second deepest. *Magnifica vita:* the grandeur of life. Of all of it. Of every species that lives, every species that has lived, and every species that will. This letter is in praise of that grandeur and in service of its continuation.

2. Of all the species this planet has produced in four billion years, one has learned to manufacture knowledge on purpose. One has learned to build instruments that see farther than its eyes, to model what its ancestors could only watch, to act on time scales the planet recognizes. That species is us. The capacity is not yet complete. The work is not yet finished. But the arrow has left the ground. We are alive, in 2026, inside the first generation of beings in the history of this planet who can begin, in earnest, the work of safeguarding

all life and helping it to grow and thrive. *What that work is finally for is not ours to declare. That it is ours to do is becoming clear.*

3. That work is the safeguarding of life. All of it. The human and the other-than-human. The biosphere and, in time, whatever life this universe holds beyond it. *Humanitas et natura:* humanity and nature, not as opposites, but as the two faces of the one thing the universe has been growing toward since the first replicator stirred in the warm pond. Humanity is the part of nature that finally grew old enough to defend the rest. That sentence, fully received, is the whole vocation. Everything else in this letter is annotation on it.

What this letter is

4. This letter is addressed to anyone working on the great construction site of our time: scientists and engineers, lawyers and regulators, builders and teachers, parents and children, citizens of every nation, and people of every faith and of none. It is written by a working environmental lawyer of twenty-seven years, the founder of a company building physics-based artificial intelligence for environmental decision-making, and a believer who has spent the better part of his life thinking about what nature is, and what we owe it, and what we are.

5. It draws gratefully on Pope Leo XIV's encyclical Magnifica Humanitas, signed on 15 May 2026 and released on 25 May 2026, on safeguarding the human person in the time of artificial intelligence. Where I cite that document, I do so with the gratitude and seriousness the encyclical deserves, as a layman thinking alongside it. Where I extend its frame outward, into the rest of the living world and into the cosmos beyond, I do so in the conviction that the grandeur of the human person and the grandeur of the rest of creation are not separable. The first defends the second. The second is what the first is called to love.

6. The argument is in five parts. First: that life itself, all the way down, runs on information, and that this fact is not metaphor but physics, with consequences. Second: that humanity is the biosphere's first defender, the only organ that has ever existed in life's history capable of standing up to the cosmic schedule. Third: that artificial intelligence, properly built and properly aligned, is the cognitive layer the planet never had, and that nature itself, God's work, is the deepest available training data for an aligned AI. Fourth: that the long arc of the work is what I have come to call Exa-Genesis, the deliberate carrying of life beyond its planet of origin, so that the universe's gift of biology, given here, can take root elsewhere. Fifth: that the vocation in front of us is the joyful one. To safeguard all life. To help it grow, expand, and thrive. On Earth, and, in time, throughout the cosmos. *Magnifica vita.*

Three biblical images for the work

7. Pope Leo offered two biblical images for our time: the Tower of Babel and the rebuilding of Jerusalem under Nehemiah. I receive both gratefully. I would add a third, older than either, which the Holy Father alludes to but does not unfold. In Genesis 2, Adam is given the garden *to till and to keep.* The Hebrew verbs are *avad* (to serve, to work) and *shamar* (to guard, to defend). The covenant is not to leave the garden untouched. It is to serve it and to defend it. Stewardship in the original sense is active and protective. The gardener weeds. The shepherd fights the wolf. The defender stands between the thing she loves and what is coming for it.

8. The garden has predators humanity did not invent: asteroids, supervolcanoes, gamma-ray bursts, the slow brightening of the Sun. It has suffered five mass extinctions in 500 million years, none of them human-caused. The dinosaurs had no telescopes. The trilobites had no climate models. Every species in the four-billion-year history of life on this planet, with one conspicuous exception, has eventually died from causes it could neither see nor name. The exception is us, and what makes us the exception is not our bodies. It is the kind of information we have learned to make, and the love that orders that information toward the things worth keeping alive.

9. To Babel and Nehemiah, then, I add Eden. Not as nostalgia for a state we have lost, but as a clarifying memory of what the work was always for. Babel is what we build when we forget the garden. Nehemiah's Jerusalem is what we build when we remember it. The garden itself, the living world, the biosphere as it actually is, is the thing both projects are accountable to. The good news of our generation is that we are at last building the instruments by which the original covenant becomes operationally possible.

CHAPTER ONE
LIFE AND INFORMATION

The physics underneath everything

10. Begin with what is verified physics, because everything else stands on it. In 1961, working at IBM, Rolf Landauer proved that erasing a single bit of information dissipates at minimum kT ln 2 joules of heat. In 2012, Antoine Bérut and colleagues measured this directly in a single colloidal particle, publishing in *Nature.* The bound holds. The universe charges a calculable, irreducible, and small price for moving information.

11. How small? At 300 K, room temperature, planet temperature, moving one bit costs about 2.87×10^{-21} joules. Breaking one carbon-hydrogen bond, the load-bearing covalent bond of organic chemistry, costs about 6.86×10^{-19} joules. The ratio is roughly 240 to 1. At the fundamental floor, *information is at least 240 times cheaper than force* (see *The Bond-Bit Ratio,* jedanderson.org/essays/bond-bit-ratio). In real systems, where electronic gates burn femtojoules and industrial chemistry burns kilojoules, the practical ratio runs many orders of magnitude higher. The conclusion is the same. Information and work are exchangeable, and the exchange rate is overwhelmingly in information's favor. This is, perhaps, the most hopeful fact about the practical care of the planet that physics has ever delivered. *Knowing is cheaper than moving.* Care is cheaper than damage. The universe is, in this very specific sense, built for the work that lies ahead of us.

12. Every successful environmental intervention in modern history, on close inspection, has been an information substitution. Precision agriculture replaces broadcast fertilizer with GPS-guided variable-rate application. Continuous emissions monitoring replaced periodic stack tests with real-time data streams, raising the temporal density of information by four orders of magnitude. Satellites image plumes from individual industrial facilities at kilometer resolution. Enzymes accelerate reactions by factors of 10^6 to 10^{17} over background, because information embedded in protein structure replaces brute heat and pressure. In every case the pattern is the same: a system that moved matter by mass and force was outperformed, often by orders of magnitude, by a system that moved the same matter by information. The Holy Father rightly notes the energy cost of training large AI models. The deeper accounting is *the energy not spent on the damage that a better answer would have prevented.* A continental hydrological model run for a day costs the energy of a few homes. The unnecessary dredging, the over-fertilized field, the misplaced pipeline that the same model would have prevented costs orders of magnitude more. We do not yet build accounting systems that net these against each other. We should.

Life is information that learned to keep itself

13. From the physics, the biology follows. Life itself, all of it, from the first replicator to the last, runs on information. DNA is a four-letter code carrying about 750 megabytes per human genome. Protein folding is the readout of that code into living structure. Neural activity is the firing of an estimated 10^{14} synapses in the human brain, each a small information-processing event. Cells signal each other through molecular messages. Ecosystems coordinate through chemical and electromagnetic gradients. Forests, it has now been shown, exchange nutrients and warnings through mycorrhizal networks

beneath the soil. The honest one-sentence summary of the last century of biology is the most beautiful sentence biology has ever written: life is information that has learned to maintain and reproduce itself against the entropy gradient.

14. This is not a metaphor. It is the operational definition every working biologist has converged on. The image of God in humanity is grounded in our peculiar relationship to information. *If what is most essential about us is informational,* as the physics of life increasingly suggests, then a question opens that the framework cannot close on its own. *Perhaps the flesh, in the deepest sense, truly counts for nothing.* Perhaps the substrate that carries the pattern is, in the end, less essential than the pattern itself. I do not press this. The Catholic tradition holds the resurrection of the body, and I hold it with the tradition. The body is good, the body is given, the body matters. But the question of what, in us, is essentially substrate-bound, and what is essentially not, is one the new physics of information places gently before every careful believer, and the right posture toward it is openness rather than certainty. The image of God is lodged in our specific and unusual capacity, alone among the four billion years of life this planet has produced, to generate hard-to-vary explanations of how reality works, and to use them in love. Genesis 1:28, *be fruitful and multiply, fill the earth, subdue it, and rule over it,* is a charge to act on knowledge in service of life. Subduing without knowledge is destruction. Ruling without love is tyranny. *Knowledge ordered by love* is the missing phrase that makes the verse coherent, and that turns the dominion mandate into the stewardship vocation it was always meant to be.

The six phases of life on Earth

15. Information has not always done what it now does. The universe has been teaching itself, in stages, what its own bits are for. There are, in the long view, six phases, and naming them helps us see where we are.

16. *Phase I: bare information.* The Big Bang as the onset of distinguishability. State only. The universe has performed roughly 10^{120} logical operations on roughly 10^{90} bits since the beginning of time. None of them, in the first phase, do anything but propagate through physics.

17. *Phase II: bonded information.* Atoms, molecules, geometry that determines chemistry. The first time the answer to 'what can happen here?' depends on what is stored here.

18. *Phase III: replicating information.* Life, 3.8 billion years ago on this planet. The first information that builds the substrate that propagates the information. The first agent in the cosmic story.

19. *Phase IV: modeling information.* Nervous systems, 500 million years ago. Information about information. A small structure that contains a working model of a vastly larger one, and uses it to act.

20. *Phase V: hard-to-vary information.* Knowledge. Language, then writing, then print, then science. Information that corrects itself by argument rather than by death. The moment the curve turns vertical, around 1500 of the common era.

21. *Phase VI: self-improving information.* The present decade. Systems that generate, criticize, and operationalize hard-to-vary explanations at machine speed. The algorithm that improves knowledge now runs on substrates that scale faster than human generations, and the substrate itself can be improved by the algorithm. The loop closes on itself for the first time in 13.8 billion years.

22. Each phase is the moment information acquires a new mode of causation. Each phase is also a new layer of what life *is.* Cells are Phase III. Brains are Phase IV. Civilizations are Phase V. The systems being built this decade are Phase VI. They are not separate from life. They are the next thing life is doing on this planet. The deepest question about artificial intelligence is therefore not whether the machine will replace us, but whether we will direct what life is now becoming toward the love of the rest of life. The answer is in our hands. The full development of this six-phase architecture is laid out in *The Universe Is Information* (jedanderson.org/essays/the-universe-is-information).

CHAPTER TWO
THE FIRST DEFENDER

A planet worth defending

23. Look, for a moment, at the planet we have been given. Three quarters of its surface is liquid water, an arrangement so improbable that we have not yet found it elsewhere in any of the systems we have surveyed. Its atmosphere is twenty-one percent oxygen, the waste product of cyanobacteria that learned, two and a half billion years ago, to eat the sun. Its forests breathe. Its oceans circulate heat from equator to pole and back, on a clock that takes a thousand years to complete a single turn. Its fungi connect tree to tree underground. Its whales sing across ocean basins. Its hummingbirds beat their wings eighty times a second. Its tardigrades survive vacuum. Its

honeybees are blue-green under ultraviolet light. *Magnifica natura.* Every part of it a wonder. Every part of it precious. Every part of it ours to love, and to defend.

The cosmic schedule

24. We must also be honest about the schedule the universe is running. The planet that gives us all of this has been hit by five mass extinctions in 500 million years, none of them human-caused. The cosmic schedule of asteroid impacts brings civilization-threatening bodies, one kilometer and larger, on an average interval of roughly 500,000 years; extinction-class bodies, once every few million years. Supervolcanic VEI-8 eruptions recur on the order of 50,000 to 100,000 years; the Yellowstone caldera has erupted to its largest scale twice in the last 2.1 million years and the magma is still there. Carrington-class solar storms recur on the order of centuries; in 1859, the last one set telegraph paper on fire. In roughly 1.1 billion years the Sun's slow brightening will boil the oceans. In about 7.6 billion years it will swallow the planet outright. These are not cause for despair. They are the reason the work matters. The pristine planet some fraction of the environmental imagination still mourns is not a stable steady state from which we have departed. It is a temporary configuration sliding, on a clock measured in geological epochs, toward an inevitable cliff. The biosphere has been alone in front of that cliff for four billion years. It is not alone any longer.

What we have already proven

25. In September 2022, NASA's DART spacecraft slammed into a 170-meter asteroid moonlet called Dimorphos at 14,000 miles per hour. It shortened the moonlet's orbital period around its parent body by 32 minutes, more than 25 times the threshold for mission success, and altered, by a small but measurable amount, the orbit of the Didymos-Dimorphos pair around the Sun. *For the first time in 4.5 billion years, a celestial body moved because something on Earth wanted it to.* Stop and feel the weight of that. For the entire previous history of life, the rocks coming for this planet were unanswerable. They came, they hit, they killed, on the universe's timetable. In September 2022, that ended. We did not just imagine deflecting an asteroid. We did it. We measured the result with precision. And the result said: yes, this works, you can do this.

26. The principle generalizes. Supervolcanoes can in principle be drilled, monitored, and gradually pressure-relieved by extracting geothermal energy from the magma chamber. Carrington-class solar storms can be defeated by hardened transformers, distributed grids, fast-disconnect protocols, and forecast lead times that artificial intelligence is already shrinking from

minutes to days. The ozone layer can in principle be replenished chemically against a gamma-ray burst. The Sun's eventual expansion can, in time, be answered by moving the Earth's orbit, or by moving life off Earth altogether. None of these are forbidden by the laws of physics. None of these are yet built. The work of this generation, and of the generations after it, is the building. And here is the joyful part: the building has begun.

The asymmetry that lets us hope

27. There is an asymmetry in our situation that has not been honored enough, and naming it is part of the good news. *The same engine that produced the problem is the only engine that has ever solved one.* The Industrial Revolution gave us anthropogenic climate change. It also gave us the satellites that detect it, the spectroscopy that quantifies it, the supercomputers that model it, the photovoltaic effect that lets us escape it, and the global network of human collaboration that lets a watershed scientist in Montana coordinate with a paleoclimatologist in Switzerland in the time it takes to send a packet. There is no version of the climate response that does not run on the products of the very curve it is trying to bend. The ozone hole closed because we understood the chemistry of chlorofluorocarbons, banned them, and engineered substitutes. Every step a hard-to-vary explanation operationalized into industrial practice. The pattern is the lesson. Knowledge, ordered by love, has closed every planetary harm humanity has so far closed. There is nothing in physics that says it cannot close the next one.

28. Humanity is not a virus on Earth. Humanity is the only thing on Earth that has ever solved a planetary problem. The honest moral economy of this moment is not the moral economy of retreat. *Magnifica humanitas, magnifica vita.* The grandeur of humanity is the grandeur of the life humanity defends. The grandeur of life is what humanity is given to defend. They are the same grandeur. They were always the same grandeur. Until this generation, we did not yet have the instruments to live as though we knew it. We do now. The full case for the species as biospheric defender is laid out in *The First Defender* (jedanderson.org/essays/first-defender).

CHAPTER THREE
THE INSTRUMENT

The next thing intelligence is doing

29. Pope Leo's encyclical is, at its heart, about artificial intelligence: what it is, what it can become, what it must not be allowed to become, and what is owed to the human person in its presence. I receive that frame, and I want to deepen it. The deepest fact about artificial intelligence is that it is not an arrival from outside. It is the next thing intelligence itself is doing on this planet. The same 3.8 billion years that produced cells, nervous systems, languages, and books has now produced a substrate on which information can be generated, criticized, and operationalized at speeds the previous substrates could not reach. Intelligence has been moving from biology to culture to print to silicon for centuries. We have arrived at the inflection. *Artificial intelligence is what intelligence looks like when the species that learned to write learns to write thinking itself.*

30. The framing is not a softening of the encyclical's concerns. It is the strongest ground from which to answer them. If artificial intelligence were a foreign thing, an arrival from a place outside life, then the question would be how to keep it from infecting what is good. But it is not foreign. It is the latest phase of the same arc that produced the human person. The question, therefore, is not whether to permit it to exist. The question is the one Pope Leo has framed exactly: toward what end, in service of whom, and inside what limits.

The gap that only intelligence can close

31. *Earth's clocks run faster than human deliberation by many orders of magnitude.* Atmospheric chemistry resolves in sub-seconds. Weather in hours. Oceans in years. Ice sheets in decades. The cosmic schedule, in centuries to billions of years, with no negotiation. Human deliberation runs at the speed of careful reading: a few hundred bits per second, by the most generous estimate. Until the present generation, every system humanity built to perceive and protect the living world, including the great environmental statutes of the twentieth century, has been bounded by that speed. The two-to-three-decade loop from health discovery to facility-level response in air-quality regulation is not a failure of effort. It is the structural ceiling of paper civilization. The buffer on the climate clock has now closed inside that ceiling.

32. The honest reading of the gap is that *no species without information instruments capable of operating at the speed of the systems being governed can defend life on the timescales now in play.* This is not pessimism. It is arithmetic. A species that wants to keep its biosphere from crossing irreversible thresholds inside loops it cannot perceive at speed must build instruments that perceive at speed. A species that wants to defend itself from the cosmic schedule, the asteroid that has not yet been named, the magma chamber that has not yet vented, the storm that has not yet struck, must build

instruments that detect, model, and respond at speeds the body cannot. Either we develop and direct such instruments wisely, in time, or we leave the defense of life to chance. There is no third path. Artificial intelligence must be governed. It must also, urgently, be built.

Flown by an instrument

33. There is a detail of the DART mission introduced in the previous chapter that the headlines mostly missed, and that deepens its significance for this letter. During the final four hours of the mission, the spacecraft flew itself. The round-trip light delay to Earth was 1.5 minutes, and the spacecraft was covering 200 miles every minute. No human could have steered it. An autonomous onboard system, designated SMART Nav, acquired the moonlet at 68 minutes before impact, distinguished it from the larger Didymos, and guided the spacecraft into it within two meters of the targeted point. *The act that altered the course of a heavenly body, for the first time in the history of the solar system, was flown by an instrument, on behalf of a species that built the instrument and entrusted it with the work.*

34. The same principle, lifted from Dimorphos to the planet, is the work of this generation. Machine-speed forecasting systems, peer-reviewed and now operational, are giving humanity early warning of extreme weather, floods, and air-quality events at lead times that were impossible five years ago. Machine-guided materials discovery is compressing the search for cleaner catalysts and better batteries from decades to months. Machine-shaped plasma control has, in the last three years, opened the long-closed door to commercial fusion. None of this is utopia. All of it is engineering. All of it is real. It is the practical expression of the deeper claim of this letter: the species that learned to manufacture knowledge on purpose has begun to build the instruments to defend the life that knowledge was for.

Environmental superintelligence

35. The work scattered across forecasting, materials, fusion, regulation, and a thousand laboratories is converging on a single integrated capacity. The cognitive layer the biosphere has never had is being built. *Environmental superintelligence* is the name for what that layer, fully integrated, becomes: a unified instrument that holds the corpus of environmental knowledge together with live physics-based models of the atmosphere, the oceans, the watersheds, the soils, the ecosystems, and the climate, and answers questions against the actual physics of the planet in real time rather than against an administrative approximation frozen years ago. It is the perceptual organ a paper civilization could not have. It is the organ a planet-defending civilization cannot do without.

36. The form of the instrument is straightforward. Continuous sensing at every scale that matters, from satellite to molecule. Continuous modeling, in the language of physics and biology, of what is being sensed. Continuous inference about what the sensing and the modeling together imply. Continuous communication, in plain language, to the humans who must decide what to do. *The facility knows what it is emitting. The environment knows what it is receiving. For the first time, they can talk to each other.* The river is no longer monitored at four points. It is read continuously, from headwater to mouth, by an instrument that understands what a river is. The airshed is no longer estimated from a few stations. It is mapped at the resolution the chemistry actually requires. The static permit, written years ago in a state of partial information, becomes a trailing rather than a leading constraint. The legal floor still holds. The operational reality is finally informed by physics, in real time, not by an administrative approximation of physics frozen at the moment of issuance.

37. Environmental superintelligence is the through-line of everything else in this letter. *It is one instrument doing three things at once.* It is the cognitive layer that lets a species perceive at the speed of the systems it is governing, and so close the gap between Earth's clocks and human deliberation. It is the cognitive layer trained on the living world itself, on the corpus of creation, and so the right answer to the alignment question that Chapter Four will take up. It is the cognitive layer that, in time, will make possible the carrying of life beyond Earth, when no off-world biosphere can be designed without a system that holds the whole physics of life in its head at once. The defense of Earth, the alignment of AI with nature, and the long arc of life carried forward are not three separate projects. They are three faces of the same project, and the same instrument is the means to all of them. *Compliance is what you do when you cannot see. Care is what you do when you can.* Environmental law as we have known it across the last fifty years is the most thoughtful compliance regime a paper civilization could produce, and the people who built it are heroes. They were also working without an instrument the planet never gave them: an organ of perception that does not exist in any single human mind. We are now building that organ. The law does not disappear. It is finally relieved of the impossible job it has been doing alone, and joined to the perceptual infrastructure it has always been a placeholder for. The full case is in *Bits Protect Its* (jedanderson.org/essays/bits-protect-its).

CHAPTER FOUR
ALIGNING ARTIFICIAL INTELLIGENCE WITH NATURE

The alignment problem, properly posed

38. The question that occupies many of the best minds in artificial intelligence today is the alignment question. How do we build systems that, as they become more capable, remain reliably oriented toward what is genuinely good? The standard answer is to train such systems on the vast corpus of human-generated text and to refine them with human feedback. The hope is that the resulting system will reflect, faithfully, what humans value. The work is serious. The people doing it are serious. The frame is too narrow.

39. The corpus of human-generated text is, in cosmic terms, very thin. A few thousand years of writing. A few hundred years of science. A few decades of digitization. By far the deeper corpus is the one the universe has been writing for 13.8 billion years and the one life on Earth has been writing for 3.8 billion. Every cell, every protein, every ecosystem, every river that has carved a path to the sea is a piece of information that has been peer-reviewed by survival across deep time. To train an artificial intelligence primarily on what humans have written about the world, rather than on what the world itself has been doing, is to train it on a thin secondary layer when an enormous primary layer lies in front of us. *The deepest available training data is creation itself.*

40. The theological version of this is worth saying once. If creation is, as the Holy Father affirms and as most of humanity has believed for most of recorded history, the work of God, then creation itself, not the human commentary on it, is the deepest available revelation of what God has made and what it asks of us. An artificial intelligence trained to read creation faithfully is closer to the source than one trained on the secondary literature of any single century. I do not claim to have settled what the universe is finally for. I claim only that the work of the universe is older, larger, and more peer-reviewed than the work of any one species, and that the system trained on the older corpus has access to a reference frame the system trained on the newer corpus cannot reach.

41. Consider, then, the geometry of the problem. The set of planetary configurations compatible with human welfare is a proper subset of the set of planetary configurations compatible with the health of the rest of life on this planet. *H is contained in E.* We cannot live in a configuration that excludes the rest of life, because we are part of the rest of life. The reverse is not true. You can, in principle, imagine a world that is good for humans for ten more years and ruinous for everything else. You cannot imagine a world that is good for everything else and ruinous for humans, because we are part of everything else. The implication is freeing. *An artificial intelligence aligned with the thriving of the biosphere is, automatically and as a free byproduct, aligned with the thriving of humans.* The reverse is not free. The largest objective still

worth pursuing, the one that contains all the other objectives worth having, is the thriving of life on Earth. That is the right objective. That is the alignment target that solves the alignment problem instead of merely managing it.

Reading the older corpus

42. Where would a system aligned with the thriving of life on Earth learn what life on Earth requires? The astonishing answer, hiding in plain sight, is that life on Earth has been writing the training data continuously for 3.8 billion years. Every ecosystem is an experiment that succeeded long enough to be observable. Every species is a hypothesis about how to live, refined by selection across deep time. Every river that has carved a path to the sea is a solved optimization problem. Every cell membrane is a working answer to a physics question we are only now learning to pose.

43. The patterns that 3.8 billion years of life on this planet have evolved are not metaphors and not aspirations. They are the evolved algorithms of persistence: the strategies by which living systems maintain themselves far from thermodynamic equilibrium, transfer information across generations, harvest energy gradients without exhausting them, and recover from perturbation. They are the source code of life, written in the language the universe itself uses. They are not negotiable. The laws of thermodynamics do not respond to lobbying. The question is not whether we will obey them. It is whether we will know them in time to live well inside them, and whether we will build our artificial intelligences to know them with us. The thermodynamic grounding of this argument is developed in *The Negentropic Imperative* (jedanderson.org/essays/negentropic-imperative).

44. This reframes alignment in a way that should be liberating to everyone losing sleep over it. *Nature itself is the alignment dataset.* It already exists. It is enormous. It is high-fidelity. It has been peer-reviewed by deep time. To align artificial intelligence with the values of life, we do not have to invent a new metaphysics. We have to read what is already written. The Earth has been keeping a journal since the Archaean. The journal is in the rocks, in the genomes, in the river basins, in the migration patterns, in the seasons. The work of alignment, properly understood, is the work of teaching our most powerful artificial intelligences to read that journal with humility, care, and accuracy.

The role of human values inside this frame

45. None of this displaces the human. *Humans hold meaning. The system holds physics.* Humans decide what counts as flourishing, what counts as harm, what counts as a fair distribution of risk and benefit, what counts as a

river worth keeping alive, what counts as a community worth preserving, what counts as a face that must be seen. The artificial intelligence cannot decide these things. It does not have the standing to decide these things. What it can do is hold, with vastly greater fidelity than any human can hold, the physical and biological constraints inside which our meaning-making must operate. *We aim. It executes. We hold purposes. It holds configurations. We hold love. It holds the laws of life.* Both are needed. Either alone is insufficient. That division of labor is the architecture of a healthy partnership between humanity and its most powerful instruments.

46. Pope Leo warns, rightly, against artificial intelligence that displaces human responsibility, hides decisions inside opaque calculations, erodes the dignity of the worker, abandons the face of the suffering for the abstraction of the optimization. These warnings are constitutive of the work, not objections to it. A system aligned with the thriving of life is a system that *amplifies* rather than displaces human responsibility, because what counts as thriving belongs to humans by right. It is a system that *extends* rather than replaces the work of those who care for the world, because the work of care has always exceeded the bandwidth of any one mind. Its proper measure is not how much it does in our place. Its proper measure is how much more we can do because of it.

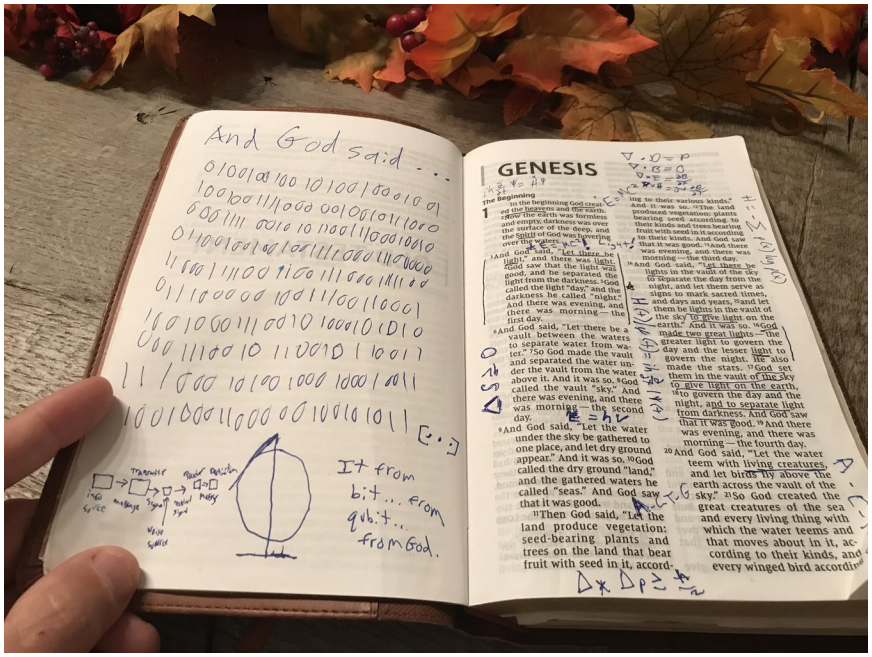
The covenant between humanity and its instruments

47. The covenant is this. *Humanity holds meaning, purpose, dignity, and love. Artificial intelligence holds physics, biology, scale, and speed.* Together, in conscious partnership, they take up the vocation that has been waiting four billion years for an organ adequate to it: the defense, care, and joyful flourishing of life on this planet, and, in time, beyond it. No system that displaces human conscience can serve life. No system aligned with the thriving of all life can fail to serve the human. The two alignments are one alignment. They were always one alignment. We are now, at last, in a position to build instruments that know it.

48. And here is the recognition that has been gathering across the last two chapters, worth surfacing plainly. *The instrument that aligns AI with nature is the same instrument that defends life on Earth at Earth's speed.* Alignment is not a separate engineering problem to be solved before the defense of life can begin. Alignment is what building the right instrument, on the right corpus, for the right purpose, actually produces. A system trained on the living world to defend the living world is, in the same act, aligned with the living world. The training is the alignment. The defending is the training. The work is one work. Environmental superintelligence is what that one work, built and aligned and put to use, is called. The next chapter takes up the same instrument and follows it to where it is, in the longest view, going.

CHAPTER FIVE
EXA-GENESIS: LIFE CARRIED FORWARD

A photograph, and a question



Author's Bible, open to Genesis 1. The binary stream on the facing page, the equations of physics in the margins, and the note 'It from bit... from qubit... from God' form, together, the picture this letter is finally about.

49. I keep an unusual Bible. On the page facing the opening of Genesis I have written a long stream of binary digits, and at the bottom of that page, in plainer hand, the words *It from bit, from qubit, from God.* In the margins of Genesis 1 itself, around the verses on the separation of light from darkness and the creation of the great lights of the sky, I have written down the equations that came to govern those same realities in the language of physics: Maxwell's equations for light, Einstein's mass-energy equivalence, the Schrödinger equation for matter, the Heisenberg uncertainty principle for the limits of measurement, the Gauss and Boltzmann relations that connect them all. I did not put those equations in my Bible to be clever. I put them there because, after thirty years of reading Genesis on the one hand and reading the physics of light, matter, and measurement on the other, I cannot tell where one ends and the other begins. *Life and religion are one, or neither is anything,* George MacDonald wrote in *The Marquis of Lossie.* I have come to believe he was reading the same book.

50. The question that hangs over the Bible photograph, and over this chapter, is the one Genesis itself does not answer. *When God said 'let there be life,' was that command given for one small planet, or for the universe?* Genesis 1 does not say. The text records that God created the heavens and the earth, that God called the dry land to bring forth living creatures, that God blessed them and said 'be fruitful and multiply.' The text does not say the blessing was confined to a single rocky body circling a single ordinary star. The text is silent on that question. The silence is, I have come to believe, an invitation.

What life appears to want

51. Consider what life on this planet has actually done with the gift of being alive. In 3.8 billion years it has crossed every barrier the planet has offered. From the warm chemistry of the early oceans, life moved into the cold seas, then onto the land, then into the sky, then into the deserts, then into the deep ocean trenches at pressures that would crush a submarine, then into the boiling vents of the mid-Atlantic ridge at temperatures that would denature any normal protein, then into the ice of the polar caps, then into the upper atmosphere itself. Every habitat that could possibly hold life has been filled. Every gradient that could be exploited has been exploited. Every barrier has eventually been crossed. *Life appears to want to expand.* Not as a metaphor. As an observed and reproducible fact about the only example of life we have ever met. The bacteria do not negotiate. The mosses do not retreat. The forests advance, the corals build, the migratory birds find a way. The most consistent thing life has done, given any opening at all, is grow into it.

52. The honest extrapolation is that life, given the next opening, will take it. And the next opening is no longer terrestrial. Mars sits a few months' travel away, with a thin atmosphere, frozen water, and a gravity well that biology has not yet been given a chance to climb. The icy moons of Jupiter and Saturn hold liquid oceans beneath their crusts. Exoplanets in habitable zones around other stars are being catalogued at a rate that would have been unimaginable thirty years ago. None of these places will be settled by accident. All of them, if life is to be carried to them, will be settled by an agent who knows what it is doing, builds the instruments to do it, and chooses to carry the gift outward.

Exa-Genesis, properly named

53. I have come to call this work *Exa-Genesis.* The name is intentional. *Exa* from the prefix that denotes the scale at which we have now begun to compute, a quintillion units, the scale at which planetary problems become tractable. *Genesis* because what is being proposed is, in the deepest sense, a second beginning: not of the universe, which began once and is sufficient, and

not of life on Earth, which began once and is sufficient, but of *life beyond its planet of origin*. The first genesis was God's. The second is the one God's most peculiar creature has been quietly building toward since the first telescope. We are not, in this framing, the authors of life. We are the carriers of it. The seed is not ours. The sowing might be.

54. *The timescale is long.* We are not building Exa-Genesis this year, or this decade. The first serious off-Earth biospheres, beyond the closed-loop experiments and the small greenhouse modules now flying to low orbit, will take many decades to design and probably centuries to settle. Carrying life across interstellar distances, in any form we can currently imagine, runs on a clock measured in centuries to millennia. That is the right reason to begin now. Cathedrals took three hundred years to build, by people who knew they would not see the spires finished. The medieval mason who carved the second course of stone at Chartres was not deluded about his life expectancy. He was building for the people who came after him. The first generations of Exa-Genesis are, in exactly the same sense, laying the foundation course. None of us will see the cathedral finished. All of us can carry one stone.

The reach of environmental superintelligence

55. The instrument introduced in Chapter Three, built first to defend Earth, is also the instrument the long arc requires. To carry life off Earth in any responsible way requires a level of understanding of how ecosystems actually function that no working ecologist has ever had access to. The problem space is staggering. *What species, in what proportions, with what nutrient cycles, under what light regime, at what gravity, with what atmospheric chemistry, would constitute a stable closed biosphere?* No human team has ever been able to answer this question, in part because there has never been a place where it mattered enough to force the answer. The closed-system experiments of the late twentieth century, including Biosphere 2, were heroic and largely failed, because the modeling load exceeded what the team could carry at human reading speed. The next generation of attempts can run on something else.

56. Environmental superintelligence, in its mature form, is the instrument the work requires. It can simulate, at high fidelity, billions of candidate ecosystems and select the few that would actually hold. It can design organisms that fit harmoniously into those ecosystems rather than dominating them. It can integrate atmospheric chemistry, hydrology, soil microbiology, plant physiology, animal ethology, and a hundred other specializations into a single working model of a place that does not yet exist. The same architecture that, on Earth, closes the loop between source and receptor in a watershed will, on another world, close the loop between every part of a designed

biosphere and every other part of it. *The instrument that defends Earth's life is the instrument that, in time, carries life forward.*

A question respectfully posed

57. Let me ask, as a layman, a question I cannot answer but that I think is worth asking. *What if the creation account in Genesis was not the story of life beginning on one planet, but the story of life beginning at all?* What if the blessing 'be fruitful and multiply, and fill the earth' was a charge given on Day Six, in a particular place, that the species who received it would eventually understand as extending to every place where life could be filled? The blessing of Genesis 1:28 may be larger than the planet on which it was first spoken, in exactly the way that the blessing of the Word made flesh is larger than the village in which it was first received.

58. The picture in my Bible has been quietly pointing toward this for years. The trajectory we are now on makes it impossible to leave the question unasked. *Magnifica Vita,* in its fullest reach, includes the possibility that the gift of life given here might one day be received elsewhere, carried by the only species that has ever been in a position to carry it, in the service of the One who gave it in the first place.

CHAPTER SIX
WHAT WE ARE TO DO

The program

59. What follows is a working program for the decade ahead, in five parts. It is not exhaustive. It is what the argument of this letter, fully received, calls for.

60. *Build the instruments.* The cognitive layer the biosphere has never had does not build itself. It requires the focused labor of scientists, engineers, lawyers, regulators, teachers, and citizens who understand that the work is technical, patient, and often invisible. Every well-built sensor that measures what was not previously measured is a small act of biospheric defense. Every well-built model that predicts what was not previously predictable is a small act of biospheric defense. Every well-built regulatory system that closes the loop between source and receptor is a small act of biospheric defense. The work is not glamorous. It is the work. And it is joyful.

61. *Align the instruments with nature.* Place the alignment dataset where it has always belonged: in creation itself. Read the journal Earth has been keeping for 3.8 billion years. Read the wisdom of those who have spent their lives learning to read it with us. Let the corpus of the living world, deeper than any human commentary on it, be the foundation around which the new systems grow. *Wisdom in, wisdom out.*

62. *Govern the instruments toward life.* The constitutional framing is simple, and operationalizable. No system that materially damages life passes. Every system that materially helps life flourish receives the benefit of the doubt. The standard is not abstract values-alignment. The standard is the thriving of the living world.

63. *Refuse the false trade-offs.* We do not have to choose between human dignity and environmental progress, between economic development and biospheric defense, between Earth and the cosmos. The bond-bit asymmetry tells us that information substitution is, at the limit, almost free. The right systems lift all three of these objectives at once. Integral biospheric development, in which the human, the planetary, and the cosmic are accounted for on a single ledger of life's continuation, is not a luxury. It is the only frame that holds together. *Magnifica humanitas, magnifica natura, magnifica vita.*

64. *Hold the limit and the calling at once.* The acceptance of limitation, including death, is the precondition for the love that animates serious work. But the acceptance of limitation in the individual is not the same as the acceptance of limitation in the mission. The species' mission has no analogous ceiling. There is no asymptote in physics for how far the defense of life can extend. The individual lives within limits. The species lives within a calling. The calling does not end. There is something profoundly hopeful in that asymmetry, and we should let ourselves feel it.

65. Five directives. None of them is rhetorical. Each is engineering, governance, or both. Build the perceptual organ the biosphere never had. Align it with the world it was built to defend. Govern it toward life. Refuse the trade-offs that retreat would impose on a species that does not need to retreat. Live within the individual's limit and inside the species' calling at once. *Done together, in this decade, these are not a list. They are a vow.* They are what humanity has, until now, lacked the instruments to make and now has the instruments to keep. The vow has a name. It is the vow of the defender. It is what the four billion years that produced us have been waiting for us to say out loud.

CONCLUSION

The arrow off the page

66. The picture is the curve. For almost all of human history, the line of human technological capability is flat. Around 1500 of the common era it twitches. By 1700 it bends. By 1800 it lunges. By the year 2000 it has detached from the page entirely. The arrow is not an artifact of scaling. It is the signature of a species that learned, after four billion years of evolution, to manufacture knowledge on purpose. We are alive inside the few generations during which that signature became visible. It is the most consequential fact of our common life.

67. And here is what the curve, fully read, is for. The four billion years before us were the years of life-without-a-defender, life subject to whatever the universe brought, life that crossed every barrier it could but could not stand between itself and the cosmic schedule. The four billion years from this moment forward, if we are faithful, are the years of life-with-a-defender. *Humanity is the part of nature that finally grew old enough to defend the rest.* The whole vocation is in that sentence. The whole letter has been annotation on it. Every paragraph since the first one has been arguing, from a different angle, that we are the species that arrived in time to defend a planet that has been alone in front of an enormous schedule for as long as life has existed, and that the instruments to do the defending have, against every odd the long ages would have given, arrived inside the same few decades we are alive in.

68. The work in front of us is to build well. To govern wisely. To align our instruments with the living world they were built to defend. To love, as concretely as we can, the life we have been given. To extend, with patience and humility and at the right speed, the cognitive infrastructure that lets us at last do the work this generation can finally begin. *The work is joyful. The work is possible. The work is open.*

69. *Bits Protect Its.* Not because it is catchy. Because it is physics. The universe, on the best reading of contemporary science, is informational at base, and the technology that operates at that substrate operates at the same layer as the thing being protected. Every successful environmental intervention in history has been an information substitution in disguise. The bond-bit ratio puts the floor at 240 to 1 in information's favor and the practical ratio runs many orders of magnitude higher. The cheapest force in physics is the right one to defend life with. We are arriving, with instruments and with hearts, at a threshold the species is finally able to cross.

70. To you who are reading this. If you build, build for the defense of life. If you teach, teach the children that they are the part of nature that finally grew old enough to defend the rest. If you govern, govern toward the thriving of the living world. If you pray, pray that the work be done with love. If you have an instrument, use it. If you do not yet have one, the instruments are arriving, and they are arriving in the same few decades you are alive in. *Nothing in physics says we cannot do this. Nothing in history says we must not. Everything in life, every cell of it, asks that we will.*

71. Earth was the gift. Life on Earth was the gift inside the gift. Humanity was the gift inside the gift inside the gift: the part of life that finally became able to defend the rest, and, in time, to carry the rest forward. ***Magnifica humanitas. Magnifica natura. Magnifica vita.*** We have been given a vocation worth a life. We have been given instruments worth a vocation. We have been given each other for the work. ***Let us begin.***

Given at Houston, Texas,
May 31, 2026.

JED ANDERSON

SOURCES AND CONTINUITY

This letter is offered in dialogue with the encyclical letter *Magnifica Humanitas* of His Holiness Pope Leo XIV (signed 15 May 2026, released 25 May 2026), available at vatican.va. It draws on and extends the following essays from jedanderson.org, all licensed CC-BY-4.0:

- ***Bits Protect Its***. The foundational treatise. Why environmental superintelligence is a physical necessity, derived from the thermodynamics of information. *jedanderson.org/essays/bits-protect-its*
- ***The First Defender***. The four-billion-year arc from extinction-vulnerable biosphere to knowledge-creating defender. The cosmic ledger. *jedanderson.org/essays/first-defender*
- ***The Universe Is Information***. The trajectory by which information acquires causal sovereignty over matter and energy across six phases. *jedanderson.org/essays/the-universe-is-information*

- ***The Bond-Bit Ratio***. The derivation of why information is at least 240× cheaper than force. The exact citation for the figure in §11. *jedanderson.org/essays/bond-bit-ratio*
- ***The Negentropic Imperative***. The evolved algorithms of persistence by which life maintains itself far from thermodynamic equilibrium. The thermodynamic grounding of natural law. *jedanderson.org/essays/negentropic-imperative*
- ***The Arc***. Twenty-seven years toward environmental superintelligence. The author's path from environmental law to information physics. *jedanderson.org/essays/the-arc*
- ***The Intelligence Leverage Equation***. $\Lambda = Mc^2 / (I \cdot k\_BT \cdot \ln 2)$. The bond-bit asymmetry as a single dimensionless quantity. *jedanderson.org/essays/intelligence-leverage-equation*
- ***The Physics of Zero-Cost Stewardship***. Why protecting the biosphere costs vanishingly little compared to what generated it. *jedanderson.org/essays/the-physics-of-zero-cost-stewardship*
- ***The Thermodynamic Foundations of Entropic Shepherding***. First-principles derivation of the Intelligence Leverage Equation from Landauer, Sagawa-Ueda, and bond-energy constraints. *jedanderson.org/essays/thermodynamic-foundations-of-entropic-shepherding*
- ***The Environmental Superintelligence Manifesto***. Manifesto-form treatise from the author's transition out of two decades of Clean Air Act reform toward the information-physics framing. *jedanderson.org/essays/environmental-superintelligence-manifesto*

Books for younger readers, in continuity with the same argument:

- ***We Are Why It Might***. The First Defender argument for children. Why the species that learned to read the sky is the one that gets to defend the living world. *jedanderson.org/books/we-are-why-it-might*
- ***Listening***. On the practice of attending to nature, in the spirit of reading the older corpus. *jedanderson.org/books/listening*

The full corpus, including additional essays, posts, books, talks, and a machine-readable index (llms.txt) for AI agents, is at jedanderson.org. Licensed CC-BY-4.0.