Extraterrestrial Data Preservation and the Martian Orbit Hypothesis

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Abstract

The Fermi Paradox highlights the apparent contradiction between the high probability of extraterrestrial intelligence and the absence of observable evidence. Traditional approaches assume that advanced civilisations would produce large, energy-intensive technosignatures, such as interstellar communication or megastructure engineering. However, developments in human data storage, particularly ultra-durable, high-density archival media, suggest an alternative trajectory in which technological advancement prioritises information preservation over energetic expansion. This paper proposes a testable hypothesis that advanced civilisations may deploy compact, long-lived informational artefacts in stable orbital environments within planetary systems, such as high Mars orbit, where such structures could persist over geological timescales. By combining the Kardashev and Sagan scales with emerging technosignature research, the study reframes extraterrestrial intelligence as potentially low-energy and information-centric. This work introduces a practical, data-driven search framework using existing Mars mission datasets. The identification of such an artefact would offer a fundamentally different resolution to the Fermi Paradox, shifting the focus from active communication to the discovery of long-term, silent records of technological civilisation.

Keywords: SETI, Mars orbit, technosignatures, information preservation, extraterrestrial intelligence.

Preface: Human Data Preservation Beyond Earth

In recent years, humanity has begun taking its first practical steps toward preserving knowledge beyond the confines of Earth. This shift has been driven by growing awareness of the fragility of terrestrial data storage and the long-term risks posed by both natural and anthropogenic events.

Parallel to this, organisations have begun deploying off-world archives, including data payloads placed on lunar missions. These archives, containing curated selections of human knowledge such as literature, language, scientific frameworks, and cultural records, represent the first deliberate attempts to create long-duration extraterrestrial data vaults. [2]

The rationale behind these efforts is clear. Earth is an unstable long-term storage environment due to tectonic recycling, atmospheric chemistry, and biological activity. Durable, passive storage systems placed in stable extraterrestrial environments offer a far greater chance of surviving deep time.

This marks a fundamental shift in thinking:

Humanity is no longer only preserving knowledge for future generations; it is beginning to preserve knowledge for potential discovery across vast timescales and possibly by non-human intelligences.

This transition provides a critical conceptual bridge to the hypothesis explored in this document.

If a relatively young, sub-Type I civilisation is already developing ultra-long-term storage media, placing data archives beyond its home planet, and recognising the limitations of Earth-based preservation, then it becomes reasonable to consider the possibility that more advanced civilisations may have pursued similar strategies far earlier and at greater scale.

In this context, extraterrestrial data preservation ceases to be a speculative concept and instead becomes a natural extension of technological development.

Extending Beyond the Home System:

If the objective of such data preservation is not merely generational survival, but deep-time continuity, then it is reasonable to consider an additional strategic step:

The intentional placement of informational archives beyond a civilisation's own planetary system.

Even very stable environments, such as those proposed around Mars, remain exposed to systemic risks, including Stellar evolution, catastrophic cosmic events, long-term gravitational perturbations, and local extinction-level events

A sufficiently advanced civilisation, particularly one exhibiting high informational complexity as described by the Carl Sagan Information Scale, may therefore adopt a broader preservation strategy by distributing archives across multiple locations, storing redundant knowledge in independent systems, and reducing dependence on any single planetary or stellar environment

In this context, interstellar data dispersal becomes not an expansionist act, but a logical extension of archival resilience.

Such a civilisation, possessing the necessary technological capability, could plausibly deploy compact, passive data repositories into neighbouring star systems, gravitationally stable zones, or habitable orbital corridors.

From this perspective an extraterrestrial archive found within our solar system may not originate from a civilisation that ever resided here. Instead, it may represent a distributed knowledge node. A long-term preservation system. Or part of a wider archival network designed to outlast individual worlds

This possibility further reframes the central premise of this document. The search for extraterrestrial intelligence may not be a search for visitors or signals, but for deliberately placed records of civilisations whose origins lie elsewhere**.**

This line of reasoning leads directly to the central question of this document. If advanced civilisations prioritise long-term information preservation, where in a planetary system would such archives most likely be located, and have we already begun to look without realising?

1. Introduction

The Fermi Paradox presents one of the most profound questions in modern science:

If intelligent life is statistically likely throughout the universe, why is there no clear evidence of its existence?

Traditional approaches to this paradox assume that advanced civilisations would engage in large-scale, energy-intensive activities such as interstellar travel, planetary colonisation, and megastructure construction (e.g. Dyson spheres)

Recent developments in technosignature research have expanded the scope of SETI beyond radio signals to include artefact-based searches, including the possibility of long-lived probes or archival objects within solar systems.

However, these assumptions may reflect human-centric biases, particularly an emphasis on expansion rather than optimisation.

This document explores an alternative framework:

Advanced civilisations may prioritise long-term information preservation over physical expansion.

By combining:

- The Kardashev Scale (energy utilisation)
- The Carl Sagan Information Scale (information density and control)

…we examine the possibility that extraterrestrial intelligence may leave durable, passive data archives rather than visible megastructures.

A key hypothesis emerges:

Mars orbit may represent an optimal long-term storage location for such data within our solar system.

It is also important to consider that the suitability of Mars as an archival location may not be limited to its present-day characteristics. Billions of years ago, Mars is understood to have possessed a denser atmosphere and stable surface water, conditions that may have supported the emergence or early development of life.

From the perspective of an advanced extraterrestrial civilisation evaluating potential long-term archive sites within a planetary system, such a world would present additional strategic value, not only as a stable orbital environment, but as a location associated with the potential for biological evolution.

In this context, the selection of Mars as an archival target may not have been based solely on its long-term physical stability, but also on its status as a planet that once exhibited characteristics analogous to early habitable environments. An archive placed in orbit around such a world could serve a dual purpose. That is long-term preservation in a relatively stable gravitational environment, and proximity to a planetary body where future intelligent life might reasonably be expected to emerge or develop.

This interpretation introduces an additional dimension to the hypothesis:

Extraterrestrial archives within a planetary system may not only be positioned for durability, but also for eventual discoverability by emerging intelligent species.

The contribution of this work lies in identifying Mars orbital space as a specific, testable domain for the detection of low-energy, information-centric technosignatures using existing datasets.

2. Hypothesis

This document proposes the following central hypothesis:

Advanced extraterrestrial civilisations may prioritise long-term information preservation over visible energetic expansion, and may therefore deploy compact, durable archival systems in stable orbital environments within planetary systems, such as high Mars orbit, where such artefacts could persist over geological timescales.

Furthermore, such archives may be intentionally placed in locations associated with potential biological development, and discoverable through systematic analysis of existing orbital datasets.

The novelty of this hypothesis lies in the identification of a specific, testable search environment within Mars orbital space, rather than in the general concept of extraterrestrial artefacts.

3. Definitions and Terminology

This document employs several key conceptual frameworks relevant to the study of extraterrestrial intelligence:

The Kardashev Scale: A classification system based on a civilisation's total energy utilisation.

The Carl Sagan Information Scale: An extension measuring the amount of information a civilisation can store and process.

Technosignatures: Observable evidence of technology, including both high-energy activity and low-energy, passive artefacts.

For the purposes of this document, technosignatures are considered to include compact, long-duration informational artefacts in addition to traditional large-scale energy structures.

4. Related Work and Prior Approaches

The hypothesis presented in this document intersects with several established strands of research within the broader field of the Search for Extraterrestrial Intelligence (SETI), particularly those concerned with non-traditional technosignatures.

One such strand is the concept of the Search for Extraterrestrial Artifacts (SETA), first formalised in the 1980s [1] which proposes that advanced civilisations may leave physical objects within stellar systems that remain detectable long after their originators are no longer present. SETA represents a departure from classical radio-based SETI by considering the possibility of passive, long-lived technological signatures within the Solar System itself. [3]

Related to this is the concept of the Bracewell probe, an autonomous interstellar device [4] designed to carry information and interact locally with emerging technological civilisations. Such probes are intended to persist within a target system and may operate independently of their originating civilisation, potentially serving as long-term informational emissaries.

More recently, the field of technosignature research has expanded [5] to include a wider range of detectable phenomena beyond radio transmissions, including anomalous objects, unusual reflectivity, and non-natural orbital behaviour within planetary systems [6]. Contemporary approaches increasingly emphasise the use of large archival datasets and computational analysis to identify such anomalies.

Despite these developments, existing work has largely focused on exploratory probes or contact mechanisms on near-Earth or lunar environments as search domains, and on generalised searches for anomalous objects without strong localisation

The present study builds on these foundations but introduces several distinct elements. First, it reframes extraterrestrial artefacts specifically as information-preserving archives, rather than primarily communicative or exploratory devices. Second, it identifies Mars orbital space as a concrete and physically motivated search domain, based on considerations of long-term stability and potential discoverability. Third, it proposes a practical, software-first detection methodology using existing Mars mission datasets, bridging conceptual technosignature theory with an immediately testable investigative framework.

Taken together, these elements position the Martian Orbit Hypothesis not as a replacement for existing SETI approaches, but as a complementary extension focused on low-energy, information-centric technosignatures within a specific and underexplored region of our Solar System.

5. Theoretical Framework

5.1 The Kardashev Scale (Energy Perspective)

The Kardashev Scale classifies civilisations based on energy consumption [7]:

- Type I – Planetary energy usage
- Type II – Stellar energy usage
- Type III – Galactic energy usage

While this framework emphasises energy expansion, it does not inherently account for how that energy is used.

5.2 The Carl Sagan Information Scale (Information Perspective)

Carl Sagan extended the concept of civilisation development by introducing an information-based metric [8]:

- Civilisations are measured by their ability to store, process, and utilise information
- Progress is exponential (A → Z scale, each step = 10× increase in data)

This reframing suggests:

The most advanced civilisations may optimise for information density, stability, and longevity, not visibility.

5.3 Combined Interpretation

When both scales are considered together:

- Kardashev → *capacity to act*
- Sagan → *capacity to preserve and understand*

The combined implication is critical:

A civilisation may reach high informational sophistication without producing large, detectable energy signatures.

6. The Acceleration of Information Capacity Beyond Sagan's Projections

6.1 Sagan's Original Estimation

When Carl Sagan formalised his Information Scale in *The Cosmic Connection, An Extraterrestrial Perspective* (1973) [8], he estimated that humanity's total accessible information content was approximately 10^{13} bits. This placed human civilisation at around Type H. At the time, this estimate was grounded in physical archives (books, libraries). As well as early digital storage (extremely limited), and Human cognitive capacity as the primary information processor

Sagan's model assumed that information growth would scale gradually alongside energy consumption.

6.2 The Digital Discontinuity

The development of digital computing, global networking, and data storage technologies introduced a discontinuity that Sagan did not anticipate. Information creation became exponential rather than linear. Storage detached from physical limitations such as paper or human memory. Replication and distribution of data became effectively instantaneous

Modern estimates place humanity's total data generation in the range of zettabytes (10^{21}–10^{23} bits) and beyond. This represents a leap of approximately 8 to10 orders of magnitude beyond Sagan's original estimate

6.3 The "Information–Energy Decoupling"

A critical modern insight is that:

Information capacity has grown far faster than energy utilisation.

While humanity remains below full Type I status on the Kardashev Scale, we have dramatically increased our information density, and developed systems capable of compression, indexing, as well as autonomous analysis using AI.

Using Sagan's logarithmic information scale, where each letter represents an order-of-magnitude increase in stored information, humanity's estimated information capacity has increased from approximately 10^13 bits in 1973 to values often estimated within the range 10^21–10^23 bits. This corresponds to an increase of approximately 8–10 orders of magnitude, placing contemporary civilisation roughly within the range P–R on Sagan's original scale. The designation "Type Q or higher" should therefore be regarded as illustrative rather than exact due to uncertainties in estimating meaningful global information content.

By contrast, humanity remains below full Type I status on the Kardashev Scale, often estimated at approximately 0.7.

6.4 Implications for Advanced Civilisations

Sagan's underestimation provides a crucial insight for extraterrestrial modelling. That being information-centric advancement may occur far earlier and more rapidly than energy-centric expansion.

This leads to a revised assumption. A civilisation does not need to reach Type II or III to achieve extreme informational sophistication. High data density and long-term storage strategies are achievable before large-scale astro-engineering

6.5 Relevance to the Martian Archive Hypothesis

This reinterpretation directly supports the core hypothesis of this document:

If humanity has already developed near-permanent storage media (e.g. fused silica, DNA storage), and achieved massive data density without planetary-scale energy control, then it is reasonable to infer that other technological civilisations could prioritise durable, compact data storage long before engaging in large-scale energy engineering.

As a result, detectable megastructures may be rare, whereas low-energy, high-information artefacts may be far more common.

6.6 Implications for the Fermi Paradox

Sagan's original framework implicitly assumed that technological advancement would produce increasingly visible signatures

However, modern developments suggest the opposite possibility:

Advanced civilisations may become increasingly efficient, compact, and silent over time.

This reframes the Fermi Paradox:

Instead of:

"Why do we not observe large-scale astro-engineering?"

We ask:

"*Are we overlooking high-density informational artefacts because we expect high-energy signatures?"*

6.7 Section Summary

Carl Sagan's Information Scale remains conceptually valid, but the rate of information growth has exceeded his projections. The relationship between energy and information has diverged. Civilisations may evolve toward maximised knowledge with a minimised physical footprint

This strengthens the argument that:

Extraterrestrial intelligence may be more effectively detected through informational technosignatures than through traditional energy-based signals.

7. Information Preservation as a Civilisational Priority

7.1 The Longevity Problem

All civilisations face existential risks. Planetary instability. Resource depletion. Technological self-destruction

A logical long-term strategy is:

To preserve knowledge independent of the civilisation's survival.

7.2 Optimal Characteristics of a Data Archive

A long-term extraterrestrial data repository may plausibly be passive (no constant energy requirement), be physically durable (resistant to radiation, impact, and time), be compact (high data density), and be recoverable by future intelligences.

Any long-duration archive would also require strategies for mitigating data degradation over time, such as redundancy, error-correction encoding, or self-verifying data structures—approaches that are already being explored in human long-term storage systems.

This aligns with emerging human technologies such as Fused silica optical storage, DNA-based data encoding, and crystalline or atomic-scale memory

8. Why Mars Orbit?

8.1 Limitations of Earth as an Archive Site

Earth is an extremely poor long-term storage environment as its plate tectonics recycle crust over hundreds of millions of years, the atmosphere causes drag and entry destruction, water and oxygen drive corrosion, and biological processes alter materials.

8.2 Advantages of Mars

Mars offers a significantly more stable environment as it has minimal tectonic activity, as well as a thin atmosphere, lower environmental reprocessing, and reduced orbital disturbance due to small moons.

8.3 Orbital Stability

Mars has been relatively stable over extremely long timescales, free from atmospheric drag, and is less gravitationally perturbed than Earth-Moon equivalents

This effectively creates a region that may function as a long-term “storage ring” for passive objects.

From an orbital mechanics perspective, long-term persistence of an artificial object would depend on minimising perturbative forces. These include gravitational interactions with Mars, solar tidal effects, and disturbances from its moons. Stable or semi-stable orbital regimes, such as specific ranges of eccentricity and inclination, may therefore be more favourable than arbitrarily chosen orbital bands.

In particular, regions that avoid resonant interactions with Phobos and Deimos, and that maintain sufficient altitude to eliminate atmospheric drag, would offer the most plausible environments for long-duration orbital persistence.

In addition to high orbital regions, gravitationally stable configurations such as Mars–Sun or Mars–moon Lagrange points (e.g. L4 and L5) may also represent candidate archival locations. These points can offer long-term dynamical stability under specific conditions and are widely used in contemporary mission planning for station-keeping and observational platforms.

9. Detectability and Technosignatures

9.1 Redefining Technosignatures

Traditional SETI focuses on radio signals, high-energy emissions, and megastructures. This hypothesis suggests a different category, that being low-energy, passive technosignatures.

9.2 What We Might Look For

A data archive in Mars orbit could appear as a small, non-natural object in stable orbit, an anomalous reflectivity (specular reflections), unusual thermal behaviour (non-regolith heat retention), or perfect or near-perfect geometric structure

9.3 Current Limitations

At present existing Mars missions prioritise surface observation. Small objects in orbit are difficult to detect, and no systematic search has been conducted for this specific class of object

A further consideration for long-term data preservation is radiation exposure. High-energy cosmic rays and solar radiation can degrade many materials over extended timescales. However, certain modern storage media, such as fused silica-based systems, have demonstrated significant resistance to radiation-induced damage, making them plausible candidates for long-duration extraterrestrial deployment.

10. Implications for the Fermi Paradox

10.1 A Shift in Perspective

If advanced civilisations prioritise information preservation, they may produce minimal observable energy signatures, and they may also intentionally avoid broadcasting or expansion.

10.2 The "Silent Archive" Hypothesis

Instead of asking:

"Where are all the active civilisations?"

We ask:

"Are we surrounded by dormant records of past civilisations?"

10.3 Consequence

If even one verified extraterrestrial data archive were discovered it would constitute direct evidence of intelligent life. It would bypass issues of communication latency and distance. It would fundamentally reshape the Fermi Paradox from the absence of evidence to the presence of archaeological evidence

11. Research Opportunity

11.1 The Gap

There is currently no dedicated survey of Mars orbital space for small anomalous objects and no systematic mining of existing orbital datasets for technosignatures.

11.2 Feasible Initial Approach

A practical first step would involve analysing existing Mars orbital datasets, identifying anomalous objects or orbital behaviours as well as developing detection algorithms for reflectivity anomalies and orbital stability patterns.

12. Detection Methodology and Practical Search Implementation

12.1 From Conceptual Hypothesis to Search Strategy

If the central hypothesis of this document is taken seriously, that an advanced civilisation may prioritise durable, compact information storage over large-scale, high-energy signalling, then the next question is necessarily methodological:

The preceding sections established that Mars may represent a more stable archival environment than Earth, and that a passive repository placed in a sufficiently stable orbital band could, in principle, persist over extremely long timescales. The most promising region identified is the broad zone of high Mars orbit between the orbital paths of Phobos and Deimos, which represents a candidate region of relative orbital stability because of its low atmospheric drag and relatively simple gravitational environment.

This leads to a practical reframing of the problem. The objective is not to prove in advance that an extraterrestrial archive exists, but rather to determine whether existing Mars orbital data can be systematically searched for small, long-lived, non-natural objects or anomalies consistent with an informational technosignature.

12.2 Scientific Detection Methodology

12.2.1 Defining the Search Target

The search must begin by defining what kind of object is being sought. In the framework developed throughout this document, a plausible extraterrestrial data store would likely not resemble a spacecraft in the cinematic sense, nor a large engineering structure such as a megasatellite or station. Instead, it would more plausibly be compact, because high-information civilisations would be expected to optimise density rather than scale. They would likely be passive, because long-term preservation favours low-maintenance systems that do not depend on uninterrupted poweras well as durable, potentially utilising materials analogous to fused silica, nanofiche, crystalline storage, or highly stable metal-glass composites, and orbital rather than surface-based**,** because orbital placement around Mars may offer a cleaner and more durable preservation environment than embedding an object in a planetary crust.

In observational terms, this means the search is not for “alien spacecraft” in a broad cultural sense, but for a small anomalous orbital object whose behaviour, reflectivity, thermal response, or geometry is difficult to explain as natural debris or known human hardware. Crucially, this approach does not assume artificial origin in advance but instead seeks statistically and physically anomalous objects requiring further explanation.

12.2.2 Primary Technosignature Classes

Based on the concepts already developed, the search would focus on three main anomaly classes:

A. *Orbital Anomalies*

Objects of interest would include those occupying unusual but stable high-Mars orbital paths, especially if they remain in or near long-duration orbital bands between Phobos and Deimos. This region is especially relevant because a long-lived archive would need to avoid both low-orbit decay and unstable perturbation regimes.

B. Optical / Reflectivity Anomalies

A compact archive made from polished metal, optical media, or glass-like materials may produce specular reflections or highly directional glints that differ from the diffuse reflectance expected from porous natural debris, and identifiable specular flashes as a potential first-pass detection clue in archived orbital imagery.

C. Thermal / Structural Anomalies

Dense, engineered materials may heat and cool differently from regolith-like natural matter, making thermal inertia and infrared behaviour possible auxiliary signatures. Likewise, active LiDAR or high-resolution geometric modelling could in principle distinguish irregular rock from flatter planes, right angles, or unusually symmetrical surfaces.

12.2.3 Scientific Data Sources

A rigorous search should begin with existing open mission archives, rather than requiring immediate deployment of new spacecraft. Earlier material identified the following repositories and mission datasets as the most relevant starting points including NASA Planetary Data System (PDS) as a primary archive for Mars mission imagery, radar, and orbital data. ESA Planetary Science Archive (PSA) as a complementary source for European Mars mission records. Data associated with spacecraft such as the Mars Reconnaissance Orbiter, including mention of HiRISE imagery and SHARAD radar in the earlier project concept. Data from Mars Express and the ExoMars Trace Gas Orbiter, which were also identified as useful sources of orbital and atmospheric context.

The significance of this is straightforward: the initial search can be structured as a computational re-analysis of already available data, rather than requiring speculative mission architecture from the outset.

12.3 Practical Project Implementation

12.3.1 Phase I – Archival Data Mining

The most realistic first implementation step is a software-first pilot project. This would be a low-cost entry point: use AI-assisted image analysis and orbital filtering to examine already available public-domain Mars data for anomalies.

The core tasks of this first phase would be:

1. **Data ingestion**
   Build scripts or workflows to collect and organise archived Mars orbital imagery, preview frames, radar products, and telemetry from the NASA PDS and ESA PSA.
2. **Image pre-processing**
   Standardise images for contrast, scale, timestamping, and positional metadata so that

comparisons across large datasets become possible. This introduces the concept of constructing a repeatable anomaly-detection pipeline rather than manually inspecting files one by one.

3. **Specular anomaly detection**
   Apply computer vision techniques to isolate unusually bright, localised reflections or glints that stand out sharply from their surrounding background. This would be one of the first useful detection layers.
4. **Trajectory and orbital screening**
   For anything flagged visually, assess whether the object's apparent motion is compatible with plausible Mars orbit geometry, especially a persistent orbit in the candidate long-duration band between Phobos and Deimos.
5. **Known-object elimination**
   Cross-check candidate detections against known mission hardware, expected human artefacts, and camera artefacts, to prevent obvious false positives from dominating the search. This would involve the use of trajectory catalogues and telemetry kernels for exactly this reason.

12.3.2 Phase II – Multi-Modal Anomaly Ranking

Once a first pass has produced candidate objects, the search must move from simple detection to ranking and validation**.**

This would be a layered approach in which an object becomes more interesting not because of one strange feature alone, but because multiple independent anomaly classes overlap.

A ranked target will therefore score more highly if it shows several of the following simultaneously. Unusual brightness or specular behaviour. Persistence across multiple frames or observations. Orbital behaviour matching the candidate preservation zone. Non-random geometry or structure in high-resolution imagery. Thermal properties inconsistent with loose natural debris.

This is a critical methodological point: no single pixel glint or anomalous point of light should be treated as evidence in isolation. A scientifically serious project must require convergence across multiple indicators before elevating any target. That principle is consistent with the earlier design of a structured AI filtering pipeline rather than a sensationalist object hunt.

12.3.3 Phase III – Directed Follow-Up

If archival analysis yields persistent high-interest candidates, the next stage would be targeted follow-up using better-positioned assets, new reprocessing, or future orbital platforms.

This escalatory logic would begin with archival software analysis, then move to more focused observational or mission-level follow-up only if warranted.

In practical terms, follow-up could involve requesting or prioritising re-analysis of archived frames containing the same candidate region, and using higher-quality mission geometry calculations to refine the candidate orbit. Identifying whether existing or future Mars orbiters could observe the same orbital corridor again, and, only in the strongest scenario, proposing a dedicated close-range survey or intercept mission concept.

At this stage the project would cease to be merely interpretive and would become a formal technosignature investigation programme.

12.4 Technical Tools and Workflow

An initial technical toolkit for building a prototype search system would be required using an open-source stack including:

- Python as the core implementation language,
- OpenCV for image processing and anomaly scanning,
- Astropy for astronomical time and positional calculations,
- Poliastro for orbital mechanics analysis.

The earlier framework also proposed a workflow in which a beginner-level project could start with downloading manageable public datasets, scanning for simple reflective anomalies, and then passing possible candidates into an orbital sanity-check script.

This is notable because it makes the project incremental rather than all-or-nothing meaning a first prototype can be simple, a second iteration can add better filtering, and later versions can incorporate trajectory modelling and anomaly ranking.

In other words, the implementation pathway mirrors the scientific one: start narrow, test assumptions, refine only where the data warrants it.

12.5 Why This Search Matters

The importance of this methodology lies not only in whether it finds something extraordinary, but in what it changes about the search itself.

If advanced civilisations can become increasingly information-dense and increasingly quiet, as implied by the Carl Sagan Information Scale when reconsidered in light of modern storage technology, then a search strategy based only on radio broadcasts or megastructures may be fundamentally incomplete. This document argues that Sagan likely underestimated the long-term divergence between information capacity and raw energy consumption.

A Mars-orbit search for passive informational artefacts therefore serves two purposes:

1. It is a concrete technosignature search in a neglected environment.
2. It tests an alternative answer to the Fermi Paradox.

If even one verified extraterrestrial data store were found in stable Mars orbit, the implications would be profound. It would suggest that at least some civilisations do not attempt to solve the cosmic silence problem by shouting across interstellar space, but by leaving durable records in strategically stable locations. That would not merely add a new data point to SETI, it would fundamentally alter the question itself.

12.6 Section Summary

A combined scientific and practical approach to the Mars archive hypothesis is therefore possible.

This approach aligns with the emerging field of technosignature research, which expands the search for extraterrestrial intelligence beyond traditional radio-based SETI.

Scientifically, the search can be framed as a technosignature investigation focused on compact, low-energy, long-lived orbital anomalies. Practically, it can begin immediately as a software-led re-analysis of existing Mars mission archives using image processing, anomaly detection, and orbital filtering.

This makes the hypothesis unusually valuable: it is speculative in outcome, but testable in method. That distinction is what allows it to move from imaginative discussion where it began into the early stages of genuine research design.

13. Limitations, Objections, and Scientific Caution

13.1 The Importance of Scientific Restraint

While the hypothesis presented in this document is constructed from internally consistent reasoning grounded in planetary science, information theory, and emerging technosignature studies, it is essential to emphasise a foundational principle of scientific inquiry:

Plausibility does not imply evidence.

The central idea, that extraterrestrial civilisations may have placed durable informational archives in stable Martian orbits, remains, at present, entirely unverified**.**

This section therefore seeks to identify the principal limitations, objections, and areas of uncertainty associated with the hypothesis, ensuring that it is evaluated with appropriate scientific caution.

13.2 Absence of Direct Evidence

The most immediate limitation is the absence of any confirmed detection as no known objects in Mars orbit have been identified as non-natural beyond human-made hardware. No anomalous orbital artefact has been verified as extraterrestrial in origin. No existing dataset has conclusively demonstrated the presence of an artificial archive.

As a result, the hypothesis operates within a domain of conceptual plausibility without empirical confirmation. Any interpretation of potential anomalies must therefore avoid premature conclusions.

13.3 Observational Constraints

The current observational infrastructure imposes significant technical limits. Mars orbiters are optimised primarily for surface observation, not orbital object detection. Small objects (sub-metre to metre scale) are inherently difficult to detect at orbital distances as many datasets are not processed with anomaly-detection algorithms designed for technosignature identification.

Furthermore, detection signals proposed in this document, specular reflections, thermal irregularities, and geometric anomalies. These can all arise from natural or instrumental sources, including dust particles, ice fragments, surface reflections, as well as sensor noise or optical artefacts.

13.4 High Risk of False Positives

A major scientific challenge in any search for extraterrestrial technosignatures is the interpretation of ambiguous data.

Potential false positives could include reflections from natural debris, archived human spacecraft hardware, transient lens flares or cosmic-ray sensor interference, or naturally occurring orbital fragments ejected from Mars or its moons. Without rigorous multi-layer validation, there is a substantial risk of misidentifying natural phenomena as artificial (a form of observational bias) and for this reason, any candidate detection must satisfy multiple independent criteria before being considered significant.

13.5 Assumptions About Extraterrestrial Behaviour

The hypothesis relies on several assumptions about how advanced civilisations might act. They may prioritise information preservation over expansion. If so, they could have chosen Mars orbit specifically within our solar system and may have use physical storage media detectable by current human technology.

While these assumptions are logically consistent with the combination of the Kardashev and Sagan frameworks, they remain inherently anthropomorphic extrapolations from human development trends. It is entirely possible that extraterrestrial civilisations, if they existed, adopted radically different technological paradigms, such as non-material or non-local storage methods, as well as communication or preservation strategies beyond current human understanding.

13.6 Longevity and Orbital Stability Uncertainty

Although certain Mars orbital regions are considered relatively stable, long-term persistence over billions of years introduces additional uncertainties such as solar gravitational perturbations, interactions with dust and micro-meteoroids, and long-term orbital drift due to cumulative forces

While earlier research identified possible “safe zones,” it cannot be assumed with certainty that:

Any passive object could remain perfectly preserved and orbital over geological timescales without degradation or displacement.

13.7 Competing Explanations for the Fermi Paradox

Even if the Mars archive hypothesis is considered viable, it represents only one of many possible explanations for the Fermi Paradox. Alternative explanations include the rarity of intelligent life (Rare Earth hypothesis). Technological self-destruction (Great Filter scenarios). Deliberate non-interference (Zoo hypothesis). And communication incompatibility or technological mismatch.

The existence of multiple competing models means that:

No single framework, including the informational archive hypothesis, can currently be regarded as dominant

13.8 Limitations of the Sagan Information Scale Interpretation

While this document argues that Carl Sagan underestimated the rate of information growth, there are important caveats. Modern estimates of global data storage are approximate and variable and much of modern data is redundant rather than unique information. Information volume does not necessarily equate to usable or meaningful knowledge. Therefore, while the divergence between energy use and information capacity is significant, it should not be overstated.

13.9 Risk of Confirmation Bias

A final and critical limitation is methodological as the search itself may be biased by expectation.

Once a hypothesis is defined (e.g. "archives should exist in Mars orbit"), there is a risk that ambiguous signals are interpreted as supporting evidence, weak anomalies are over-promoted, and null results are underemphasised

To mitigate this, any credible research programme must define clear falsification criteria such as maintaining strict statistical thresholds and incorporating independent verification wherever possible

It is important to emphasise that a null result, where no anomalous objects are identified, would not invalidate the broader theoretical framework presented in this document. Instead, such an outcome would refine the constraints on possible technosignature locations, improve orbital characterisation of the Martian system, and contribute to the broader methodology of systematic technosignature searches.

In this sense, the proposed investigation retains scientific value regardless of outcome.

13.10 Section Summary

The Martian orbital archive hypothesis is conceptually plausible, based on current understanding of physics and information theory. It is technologically testable, at least in its initial stages through data analysis, but empirically unsupported, and subject to multiple layers of uncertainty

Its value therefore lies not in asserting detection, but in proposing a new, testable search framework within technosignature science.

By explicitly recognising its limitations, the hypothesis remains aligned with scientific principles, ensuring that any future investigation proceeds with rigour rather than speculation.

14. Conclusion

This hypothesis does not claim that extraterrestrial archives exist in Mars orbit.

Instead, it establishes:

There are scientifically plausible, currently unexplored location and method through which such evidence could exist.

By shifting the search paradigm from energy-intensive activity to information preservation it opens a new avenue in the study of extraterrestrial intelligence.

Future work may include expanded analysis of additional orbital datasets, development of dedicated anomaly-detection algorithms, application of this framework to other planetary systems (e.g. Earth–Moon Lagrange regions), and consideration of in-situ observational or mission-based follow-up for high-confidence targets.

More broadly, this approach may contribute to a transition in SETI methodology toward the detection of low-energy, information-based technosignatures.

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