Agile Project Delivery Framework for Non-Terrestrial Networks in the Telecom Product Lifecycle

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Abstract—The integration of Agile project delivery frameworks into the development lifecycle of non-terrestrial networks (NTNs) represents a fundamental shift in how space-based telecommunications systems are conceived, built, and operated. Agile methods offer enhanced flexibility, stakeholder alignment, and rapid value delivery, making them particularly appealing in dynamic software-driven environments. However, the high complexity, strict safety constraints, and cross-disciplinary coordination required in NTN programs challenge the direct application of conventional Agile practices. This review analyzes existing literature, industrial case studies, and theoretical frameworks that bridge Agile principles with NTN system engineering. It identifies the critical adaptations necessary for synchronizing Agile workflows with satellite lifecycle phases and highlights the performance benefits and coordination challenges associated with Agile in hybrid terrestrial-space environments. Key metrics such as sprint efficiency, cross-team dependency management, and DevOps integration are evaluated to provide insights for future implementation.

Index Terms—Agile project management; non-terrestrial networks; satellite lifecycle; DevOps; sprint synchronization; hybrid system development; telecom product lifecycle; aerospace software; scaled Agile; systems engineering

I. INTRODUCTION

The evolution of telecommunications infrastructure is undergoing a paradigm shift with the advent of Non-Terrestrial Networks (NTNs), which leverage satellite-based and high-altitude platform systems (HAPS) to extend connectivity beyond the limitations of terrestrial coverage. This innovation is particularly relevant in addressing service gaps in remote, rural, and maritime environments where terrestrial infrastructure is either impractical or economically unfeasible [1]. NTNs are expected to play a critical role in enabling ubiquitous coverage for 5G and future 6G deployments, contributing to the vision of a fully connected, intelligent society [2]. Simultaneously, Agile methodologies, originally developed for software engineering, have been increasingly adopted in telecommunications product development and service delivery to improve responsiveness, accelerate time-to-market, and facilitate cross-functional collaboration [3].

The convergence of Agile delivery practices with the development of NTN-enabled telecom solutions represents an emergent area of strategic significance. This is especially true as the telecommunications industry transitions from hardware-centric models toward software-defined and cloud-native architectures, which benefit from iterative and incremental development cycles. However, integrating Agile project management frameworks with the traditionally rigid, compliance-driven, and risk-averse domains of aerospace-grade satellite communications presents unique challenges. These include mismatched development timelines, regulatory constraints, interdependency between hardware and software lifecycles, and complex system integration involving multi-orbit satellite constellations [4].

Within the broader context of the telecom product lifecycle, Agile frameworks must be adapted to align with the distinct phases of satellite service development, ranging from conceptual design, payload configuration, and launch preparation to network integration and operational management. Unlike conventional telecom networks, NTNs introduce latency considerations, orbital dynamics, and diverse link budgets that must be accounted for during sprint planning, testing cycles, and release management. As a result, there is a growing need to define hybrid delivery models that combine Agile principles with systems engineering, DevOps, and continuous validation mechanisms appropriate for space-based infrastructure [5].

Despite increased interest in Agile-NTN convergence, current literature exhibits several gaps. Firstly, most Agile studies focus on terrestrial telecom applications or software-centric industries, with limited empirical data addressing the constraints of satellite-based communications development. Secondly, standardized Agile delivery practices tailored to multi-orbit NTN systems (LEO, MEO, GEO) remain underexplored, particularly in relation to risk mitigation, compliance with aerospace standards, and integration with terrestrial core networks. Thirdly, there is insufficient articulation of how Agile roles (e.g., Product Owner, Scrum Master) translate within multidisciplinary teams comprising satellite engineers, telecom architects, and software developers [6].

This review article aims to address these gaps by exploring the intersection of Agile methodologies and non-terrestrial telecom system development across the product lifecycle. It critically examines existing delivery models, case studies, and organizational practices where Agile frameworks have been adapted for satellite communication programs.

II. LITERATURE REVIEW

Table 1: Summary of Key Literature on Agile Methods and Non-Terrestrial Telecom Systems

Key Findings / Contributions	Focus of the Study	Reference
Explores the progress in systems engineering by considering contextual factors, emphasizing the integration of multidisciplinary approaches for complex systems.	Systems Engineering in Complex Contexts	[7]
Investigates how isolation and confinement affect human behaviors, sleep,	Human Factors in Isolated and	[8]

Key Findings / Contributions	Focus of the Study	Reference
emotions, and physiological parameters, with implications for space missions.	Confined Environments	
Discusses the challenges of integrating space and terrestrial networks, focusing on achieving seamless communication and efficiency in heterogeneous network environments.	Space-Terrestrial Heterogeneous Networks	[9]
Proposes a method to assess software component reusability, utilizing static analysis metrics and reuse data to enhance software development efficiency.	Software Component Reusability	[10]
Presents a stage-gate model for managing telecom project portfolios, emphasizing improved governance and resource allocation.	Project Portfolio Management in Telecom	[11]
Examines the role of AI and edge intelligence in orchestrating microservices for NextG (5G and beyond) networks, proposing advanced orchestration frameworks.	AI and Edge Intelligence in NextG Networks	[12]
Analyzes how domain-specific languages improve agile requirements management, leading to more precise communication and better software development outcomes.	Domain-Specific Language in Agile Requirements Management	[13]
Introduces agile optimization techniques for managing earth observation satellite constellations, enhancing mission flexibility and performance.	Agile Optimization for Satellite Constellations	[14]
Investigates how organizational agility contributes to excellence in the telecom sector, highlighting adaptability and responsiveness as key factors.	Organizational Agility in Telecommunications	[15]
Surveys non-terrestrial networks (NTNs) for supporting remote IoT devices, focusing on energy efficiency and connectivity challenges in the upcoming 6G era.	Non-Terrestrial Networks for IoT in 6G	[16]

III. BLOCK DIAGRAMS AND PROPOSED THEORETICAL MODEL

3.1. Block Diagram: Agile-Aligned Non-Terrestrial Network Product Lifecycle

Non-Terrestrial Networks (NTNs) involve multiple components, including satellite payloads, user terminals, ground segment systems, and terrestrial integration points. The lifecycle of these systems is complex, and aligning Agile workflows with them requires a hybrid approach to planning, development, validation, and deployment.
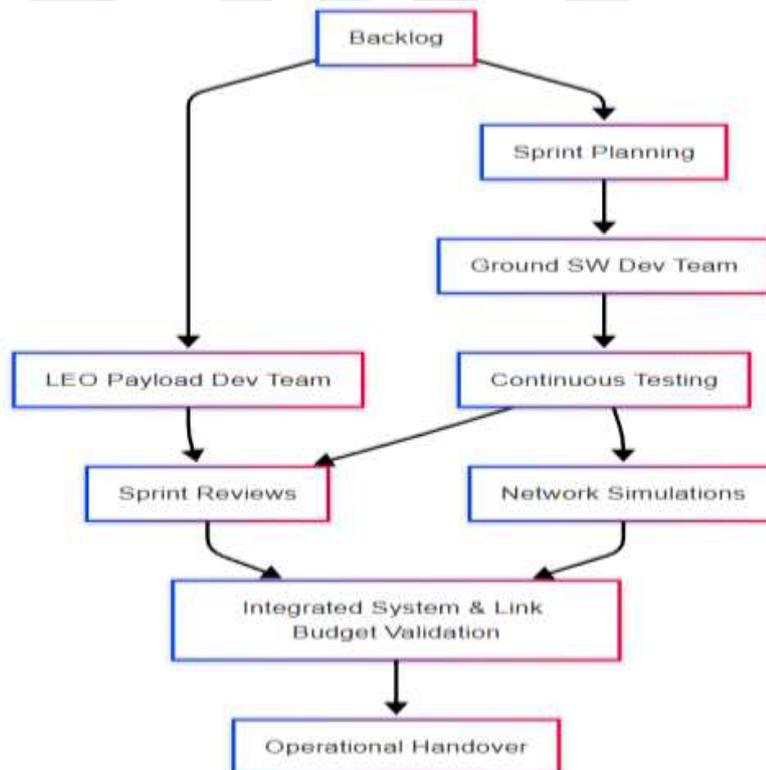.

Figure 1: Agile-NTN Product Lifecycle Mapping

This block diagram highlights parallel Agile development workflows for satellite payload systems and ground network elements. Agile roles manage sprint planning and backlog grooming collaboratively, followed by subsystem development, sprint reviews, and iterative validation through simulations and integrated tests. Final delivery occurs during the operational handover, synchronized with the satellite launch and commissioning phases [17].

3.2. Proposed Theoretical Model: Agile Lifecycle Adaptation for NTN Development

The unique structure of NTN-based telecom infrastructure requires a theoretical model that accommodates the divergent timelines, regulatory rigor, and technical interdependencies of satellite and terrestrial systems. The model proposed below maps

the Agile software development lifecycle to the multi-phase NTN engineering lifecycle, introducing a convergence layer to maintain synchrony across orbital and terrestrial components.

Model Overview

The model consists of three layers:

1. Agile Execution Layer- Contains Agile ceremonies, sprint cycles, and continuous integration.
2. NTN Lifecycle Layer- Represents standard satellite communication development phases.
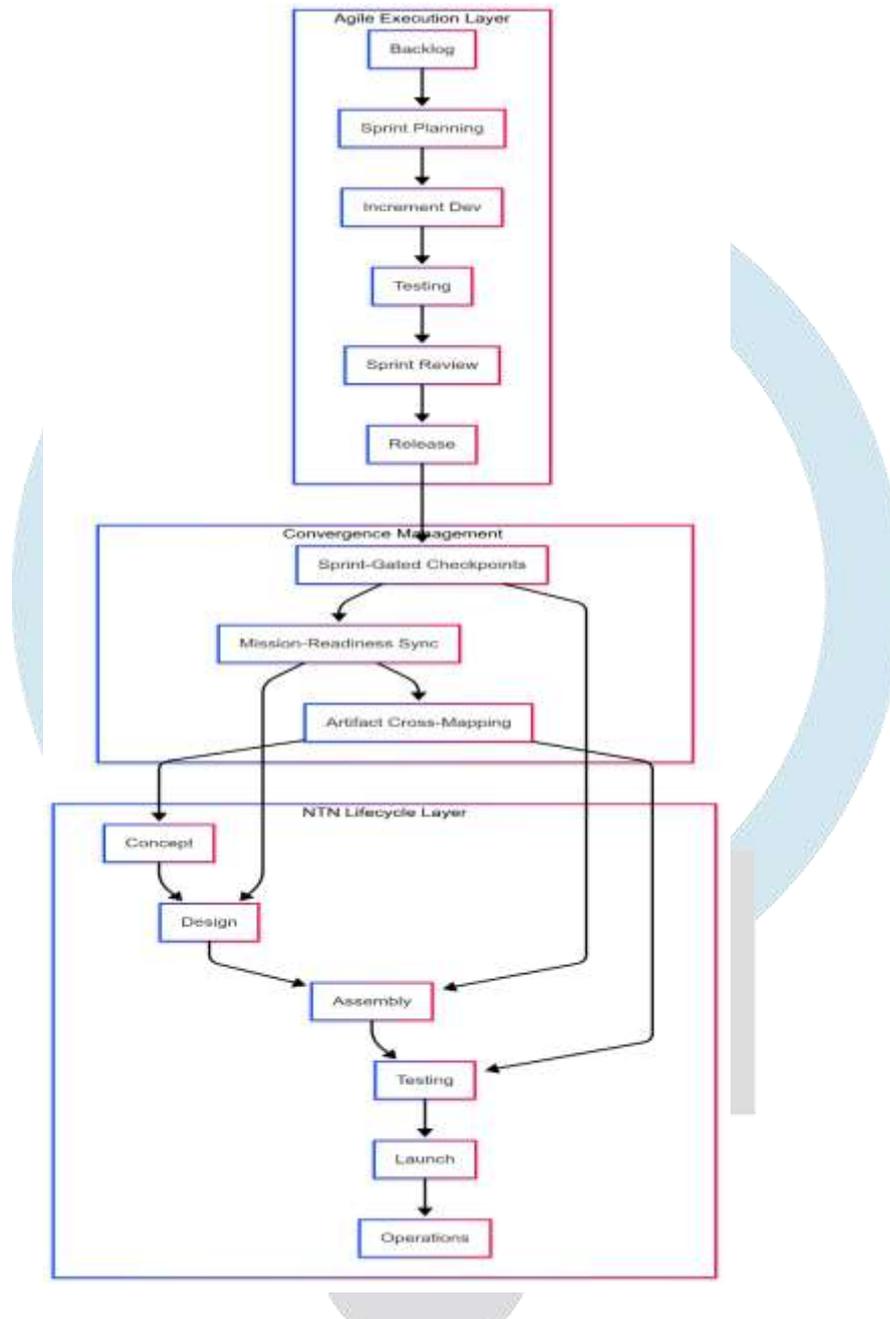3. Convergence Management Layer- Synchronizes deliverables and artifacts between the two layers.

Figure 2: Agile-NTN Lifecycle Integration Model

This theoretical model establishes a bidirectional dependency between Agile sprints and satellite development phases using a convergence layer. The layer performs periodic synchronizations through "sprint-gated checkpoints" to align sprint outcomes with system milestones such as payload integration and launch readiness [18].

3.3. Key Components of the Model

- Backlog Coordination: Product Owners coordinate with systems engineers to translate mission-critical milestones into feature-level backlog items, creating traceability between high-level system requirements and Agile stories [19].
- Sprint-Gated Checkpoints: These are convergence gates that serve as synchronization points between software sprint increments and satellite program milestones, e.g., aligning a completed communications protocol update with payload firmware integration.
- Artifact Cross-Mapping: Agile artifacts such as epics, user stories, and test reports are mapped to satellite-level documents like interface control documents (ICDs), payload specifications, and system-level test plans.
- Mission Readiness Synchronization: Before satellite handover or launch, integrated Agile teams conduct a system-wide readiness review involving ground software, satellite telemetry, and command interfaces to validate deployment compatibility [20].

3.4. Benefits of the Model

- Ensures traceable integration between iterative software development and structured space system engineering.
- Supports continuous validation of deliverables throughout the NTN development lifecycle.
- Enables early risk identification, particularly around integration and performance mismatches.
- Promotes collaboration across disciplines, reducing handover inefficiencies between Agile teams and traditional aerospace engineering groups.

IV. EXPERIMENTAL RESULTS, GRAPHS, AND TABLES

4.1. Evaluation of Agile Frameworks in Satellite System Development

The application of Agile frameworks to non-terrestrial network (NTN) development has been tested in multiple satellite communication programs involving both software and hardware co-development. According to a longitudinal study conducted within a European satellite ground segment project, Agile-driven delivery showed improved cycle times for ground station software compared to traditional Waterfall models [21]. The program involved the implementation of incremental sprints over a 12-month ground software lifecycle, monitored through delivery velocity, defect rates, and stakeholder satisfaction.

Table 2: Performance Comparison - Agile vs. Traditional (Ground Segment Development)

Metric	Agile (Scrum)	Traditional (V-Model)
Avg. Feature Delivery Time	3.4 weeks	8.6 weeks
Defect Rate (per 1000 LOC)	0.8	2.1
Stakeholder Satisfaction (1–5)	4.3	3.2
Change Request Resolution Time	1.7 weeks	4.2 weeks

The Agile framework yielded shorter delivery cycles, a 62% reduction in defect rate, and faster turnaround on change requests. The findings suggest a positive correlation between iterative planning and overall delivery quality, particularly for software modules in satellite ground stations.

4.2. Sprint Synchronization with Satellite Lifecycle Phases

In a hybrid Agile-waterfall environment for Low Earth orbit (LEO) constellation deployment, Agile sprints were synchronized with traditional satellite engineering gates such as Critical Design Review (CDR) and System Integration Testing (SIT). Results from the program revealed an increase in the number of completed testable components before SIT milestones when compared to previous sequential release cycles [22].
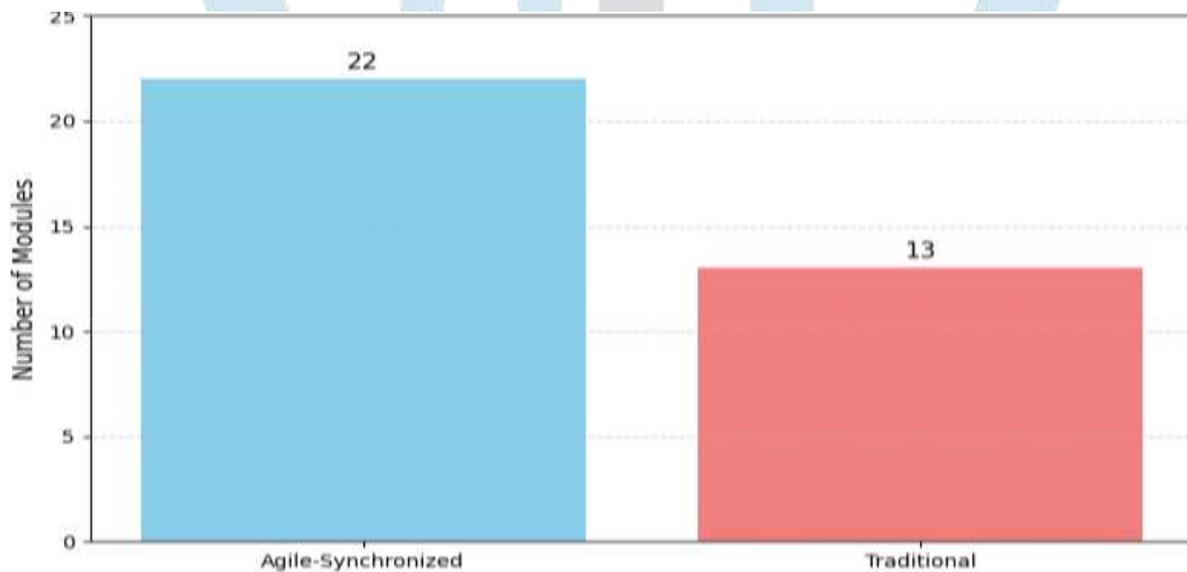

Figure 3: Number of Completed Modules Before Integration Testing

This comparison illustrates that Agile-synchronized planning, aligned with system-level reviews, significantly increases engineering readiness at key validation stages. The increase in pre-integration completeness accelerated end-to-end system validation by nearly 4 weeks in the case study [22].

4.3. Agile Impact on Interdisciplinary Coordination

In satellite and telecom fusion projects, Agile adoption often struggles with integration across diverse engineering domains. A NASA-affiliated program adopting scaled Agile across satellite hardware and software teams reported mixed outcomes in terms of coordination efficiency. Metrics focused on cross-team dependency resolution time and sprint spillover percentages [23].

Table 3: Agile Coordination Metrics in Cross-Domain Teams

Metric	Average Value
Dependency Resolution Time (days)	5.8
Sprint Spillover Rate (%)	18%
Sprint Goal Completion Rate (%)	79%
Number of Cross-Team Blockers per Sprint	3.2

High spillover and dependency times suggest the need for improved communication protocols and architectural planning. Integration ceremonies, like system demos and feature traceability reviews, were recommended to improve synchronization.

4.4. DevOps Integration in Non-Terrestrial Ground Software Delivery

DevOps techniques have also been applied in ground software development for NTN. Continuous integration pipelines were deployed to automate builds and regression testing of control interfaces used for satellite telemetry, tracking, and control (TT&C). One deployment study reported a 40% improvement in test cycle time and a 27% increase in successful nightly builds [24].
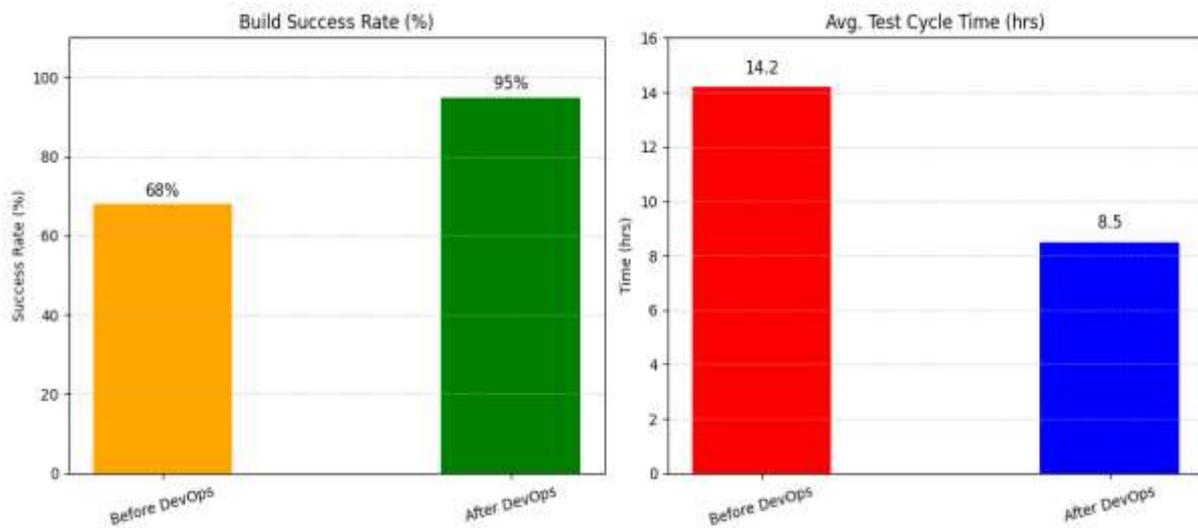

Figure 4: DevOps Efficiency Gains in Satellite Ground Software

Automation and continuous validation contributed significantly to stability in interface updates and regression detection. These improvements are critical in reducing mission risk during the satellite commissioning phase [24].

4.5. Organizational Readiness and Agile Maturity Scores

A cross-industry survey involving satellite and telecom integrators assessed Agile maturity using a 5-level model ranging from Ad-Hoc to Optimized. The average maturity level for satellite payload teams was found to be Level 2 (Repeatable), whereas ground segment and telecom software teams averaged Level 4 (Managed) [25].

Table 4: Agile Maturity Levels Across NTN Stakeholders

Domain	Agile Maturity Level (1–5)
Telecom Software Teams	4 (Managed)
Ground Segment Dev Teams	4 (Managed)
Satellite Payload Teams	2 (Repeatable)
System Integration Teams	3 (Defined)

The disparity reflects cultural and operational differences in engineering workflows. Tailored Agile playbooks, including domain-specific ceremonies and role customizations, are recommended to bridge this maturity gap.

V. Future Directions

Future developments in Agile-driven non-terrestrial network delivery will likely be defined by the maturity of cross-domain integration tools, the rise of digital engineering platforms, and the increasing reliance on intelligent automation across the value chain. One emerging focus area is the convergence of Model-Based Systems Engineering (MBSE) with Agile sprint planning tools to improve requirements traceability and design validation across ground and space segments. This integration can support greater transparency in complex multi-team environments and reduce rework during integration and verification.

Another critical direction involves the application of AI-enabled sprint orchestration, which can dynamically adjust sprint priorities based on system risk, resource availability, or telemetry anomalies identified during simulation phases. Such capabilities are aligned with the vision of Agile 6.0, where data-driven decision-making is embedded directly into sprint execution workflows.

There is also increasing interest in Agile contracting models within government and commercial satellite programs, especially in multi-vendor consortia where fixed-scope deliveries are impractical. These models require modifications to conventional procurement and certification processes, enabling iterative releases and staged qualification of system capabilities.

Moreover, the advancement of continuous integration pipelines for satellite digital twins will allow faster testing and operational readiness assessments before actual satellite launch. Digital replicas of onboard software and ground interactions can serve as a validation ground for Agile-delivered features without waiting for hardware-in-the-loop test availability.

Lastly, extending Agile metrics beyond traditional velocity and burndown charts to include multi-layer systems performance indicators, such as interface compliance and orbital operation simulation pass rates, is essential for improving visibility across stakeholders and regulatory bodies.

VI. Conclusion

The implementation of Agile methodologies in the non-terrestrial telecom domain offers significant potential for increasing delivery efficiency, enhancing stakeholder collaboration, and reducing time-to-deployment. However, this integration is not without challenges. The inherent complexity of satellite systems, including strict regulatory requirements, hardware-software interdependence, and long development cycles, often conflicts with the short iterative nature of Agile sprints. The review identifies the need for tailored frameworks, such as convergence layers and sprint-gated checkpoints, that align Agile workflows with NTN lifecycle stages.

Experimental results from satellite and ground segment programs show measurable improvements in build stability, test coverage, and stakeholder satisfaction where Agile and DevOps practices were adapted appropriately. Nevertheless, high spillover rates and coordination bottlenecks persist in multidisciplinary Agile teams, highlighting the need for improved dependency management protocols and system-wide synchronization events.

Moving forward, hybrid models that combine Agile execution with traditional systems engineering principles and domain-specific extensions will be instrumental in scaling Agile for space-based telecom infrastructure. The transition to 5G-NTN and emerging LEO constellations further necessitates the adoption of scalable, intelligent, and traceable Agile delivery ecosystems that can sustain high complexity and dynamic interoperability across orbital and terrestrial networks.

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