Enhancing Agile Approaches in Earth Observation: the role of Early Adopter Collaboration in the CRISP Project [1]

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Abstract

This article examines the challenges and opportunities involved in applying Agile methodologies to ESA-funded Earth Observation (EO) projects, using the CRISP[2] initiative as a case study. While Agile frameworks emphasize iterative development and continuous stakeholder feedback, their translation into EO contexts, particularly in development-oriented environments, reveals structural and motivational limitations, especially in the role of Early Adopters (EAs).

Through a critical assessment of CRISP and the psychological dynamics of voluntary stakeholder engagement, the paper identifies key failure points: misaligned incentives, procedural overload, and the erosion of intrinsic motivation. These systemic fragilities risk reducing stakeholder participation to symbolic compliance, thereby undermining the goals of user-centered design.

To address these issues, the paper proposes a dual strategy. First, it explores the use of artificial intelligence—especially large language models and chatbots—as scaffolding tools that simulate EA feedback and sustain design iteration in the absence of consistent human input. Second, it advocates for the creation of structured, non-monetary incentive frameworks that include reputational capital, data reciprocity, and temporal targeting of EA engagement. Rather than offering prescriptive solutions, the article aims to inform future ESA frameworks and guide project managers operating in similar contexts. Its recommendations emerge from reflective practice and are positioned to support both institutional evolution and field-level implementation. Ultimately, the work encourages a strategic rethinking of stakeholder engagement as a designed and evaluable component of Agile EO project management.

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[2] Consistent Rice Information for Sustainable Policy

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1 Introduction

The adoption of Agile methodologies has profoundly reshaped project management paradigms by introducing iterative processes, continuous stakeholder collaboration, and adaptive planning [Beck et al., 2001; Highsmith, 2002]. Originally designed for software development where modular deliverables and intangible outputs aligned naturally with Agile principles, these methodologies have increasingly been applied across diverse sectors, typically adopting strict waterfall workflows, including Earth Observation (EO) and space-related programs [Giuliani et al., 2020].

Along with many international organizations such as FAO[3], CGIAR[4], and the Joint Research Centre (JRC), the European Space Agency (ESA) has progressively embraced Agile frameworks in an attempt to enhance the usability and responsiveness of Earth Observation-derived tools. Through programs aimed at converting satellite data into operational services, ESA seeks to bridge the gap between raw geospatial data and actionable intelligence, particularly in support of global policy agendas such as the United Nations' Sustainable Development Goals (SDGs) [Fritz et al., 2019].

However, the transposition of Agile frameworks into EO projects presents significant challenges. Unlike software systems, EO solutions frequently entail rigid workflows, hardware dependencies, and multi-level stakeholder ecosystems that complicate the straightforward adoption of Agile practices. The CRISP (Consistent Rice Information for Sustainable Policy) project exemplifies these tensions. Implemented under the ESA-funded initiative *Earth Observation for SDG Targets and Indicators – Lot-2, CRISP* aims to deliver scalable solutions for rice monitoring and yield fore- casting, with a focus on supporting decision-makers particularly in low- and middle-income countries [Origgi et al., 2025].

The solution proposed within this project combined multi-mission EO data with agronomic and hydrological information to generate products such as rice area maps, crop calendars, and yield estimates. While technically ambitious, CRISP is particularly relevant for this study because it explicitly embedded Early Adopters (EAs) as central stakeholders in the design loop. Their role was to ensure that the developed solutions would align with operational decision-making contexts. Yet, despite this formal integration, CRISP encountered recurrent difficulties in sustaining EA participation, a challenge symptomatic of many EO co-design initiatives.

[3] Food and Agriculture Organization
[4] Consultative Group on International Agricultural Research

This paper focuses on the pivotal but problematic role of Early Adopters (EAs) in Agile inspired EO initiatives. Defined as pre-selected stakeholders intended to guide design decisions and validate intermediate outputs [Rogers, 2003], Early Adopters are formally recognized in ESA's Statements of Work (SoW) as central actors in the user-centered development process. Yet, in practice, their engagement often suffers from structural weaknesses, primarily due to the lack of direct economic incentives, inadequate stakeholder management mechanisms, and an overreliance on voluntary participation.

By critically examining the CRISP project and integrating psychological insights into stakeholder motivation, this study aims to highlight systemic limitations in the co-design models commonly adopted in Earth Observation projects led by public-sector and intergovernmental institutions . To address these issues, it proposes a dual strategy: first, leveraging artificial intelligence (AI)—particularly recent large language models such as GPT-4, GPT-5, Claude 3.5, and Gemini 1.5—as complementary tools for simulating stakeholder feedback during early design phases; second, suggesting restructured engagement models that incentivize active participation through non-monetary rewards and structured reciprocity. The overall aim is to provide project managers with new avenues for sustaining commitment over time and to inform institutional frameworks for future EO projects.

2 Methodological Note: A Pragmatist Inquiry Approach

This study uses the CRISP project as a case to derive broader insights into the design of Earth Observation (EO) initiatives and related domains, emphasizing inquiry as a problem-driven process. Adopting a pragmatist lens (Lorino, 2018) allows researchers to integrate diverse concepts from psychology, project management, and artificial intelligence (AI) into a coherent interpretative framework that remains anchored to practical challenges.

Accordingly, the paper does not claim to provide universal solutions, but instead follows a process of pragmatist inquiry:

- starting from the observed challenges of Early Adopter engagement in CRISP,
- introducing complementary perspectives from organizational psychology,
- exploring AI as a potential scaffolding tool for design phases,
- and considering incentive mechanisms that could strengthen voluntary participation.

The logical progression of the paper follows the flow of argumentation: from problem identification, to dual strategy formulation, to case-based reflection, and finally to general recommendations for EO project management.

3 The Role and Limitations of Early Adopters in ESA Projects

In recent years, the European Space Agency (ESA) has formalized the inclusion of Early Adopters (EAs) as a foundational element in its Earth Observation project design strategy. These stakeholders are expected to contribute actively to requirement elicitation, iterative validation, and service co-design. This approach is grounded in the assumption that their early and sustained involvement will ensure alignment between project deliverables and real-world user needs. While CRISP formally refers to these actors as “Early Adopters”, similar roles appear under different designations across ESA funded projects such as “Champion Users”, “Pilot Users” or “First Implementers”. Despite terminological differences, these roles share a common strategic function: to provide early-stage operational insights that shape solution development before large-scale deployment.

Seven core principles outlined in the CRISP Statement of Work explicitly reinforce this commitment to participatory development: user-centered design, user characterization, active engagement of authoritative EAs, iterative Agile development, and the use of Living Labs as co-creation environments, among others. These directives reflect an advanced understanding of contemporary service design and stakeholder integration, and on paper, represent a robust framework for inclusive development.

However, in practice, the execution of this model reveals fundamental discrepancies between its theoretical premises and its operational outcomes. The first and most evident limitation is the voluntary nature of EA participation. Unlike internal team members or subcontracted entities, EAs are not financially compensated nor formally bound to the project through contractual obligations. Their role is frequently assumed to be self-sustaining based on institutional prestige or the perceived long-term benefits of shaping a high-impact solution. Yet, as numerous project experiences—including CRISP—have shown, such assumptions frequently prove unsustainable in the face of day-to-day organizational priorities and limited operational bandwidth on the part of the EAs.

From a stakeholder management perspective, this introduces an ambiguous classification. Agile theory typically regards any actor involved in iterative feedback loops as an *internal stakeholder*, which inherently implies a sustained level of commitment and shared accountability for the project’s success. However, in the CRISP context, EAs resemble external stakeholders: they contribute only intermittently, often interact solely with the project management office (PMO), and must balance their involvement with other responsibilities. This structural ambiguity directly undermines the intended Agile dynamics.

Moreover, the model fails to address the asymmetry between the effort expected from EAs and the benefits they receive. EAs are tasked with devoting time, internal resources, and domain expertise to a project that will ultimately produce tools distributed openly to a wider community of future users, most of whom contribute nothing to the development process. The resulting dynamic risks fostering disengagement, if not outright disillusionment, especially when the outputs are generic rather than customized to the operational context of the EA.

This tension is well illustrated by adapting a value-effort model originally developed in the context of gamification theory [Burke, 2014], where the perceived value of a reward must align with the effort required to obtain it in order to sustain motivation. As shown in Figure 1, engagement lies within a narrow optimal zone where the value of the reward is perceived as proportional to the effort expended. Outside this zone, systems are judged as either inefficient (high reward but unjustified effort) or ineffective (high effort for low or unclear benefit) [Marczewski, 2015]. The CRISP project's EA engagement strategy, in its current form, risks falling into either of these non-optimal categories, depending on how each EA perceives their unique contribution-to-benefit ratio. Without precise calibration and targeted incentives, the model may fail to foster long-term participation particularly when EAs recognize that others may receive equivalent benefits at zero cost.

Recognizing these challenges, ESA has recently established the Stakeholder Engagement Facility (SEF) to enhance stakeholder participation and support across its EO projects. The SEF aims to bridge the gap between research and operational uptake by providing structured engagement mechanisms, including outreach campaigns, community animation, training events, workshops, helpdesk, and direct technical support. It focuses on four main policy themes:

1. Food Systems;
2. Ecosystem and Biodiversity;
3. Carbon, Energy and Green Transition;
4. Sustainable Development Goals.

While the SEF represents a significant step forward in institutionalizing stakeholder engagement, its effectiveness in addressing the specific challenges faced by EAs remains to be fully assessed and could not be tested directly in CRISP, due to its non-existence during the early phases of the project, precisely those phases most relevant to the issues investigated in this paper. The success of EA collaboration continues to hinge on factors such as the provision of tangible incentives, clear communication of benefits, and the alignment of project outputs with the specific needs of EAs.

Ultimately, while the inclusion of EAs represents a commendable attempt to streamline, humanize and democratize EO system design, the execution suffers from structural underinvestment. Without a rethinking of the incentive structures and engagement models, the contribution of EAs risks becoming symbolic rather than substantive, reducing their role to mere procedural compliance rather than genuine co-creators of value.

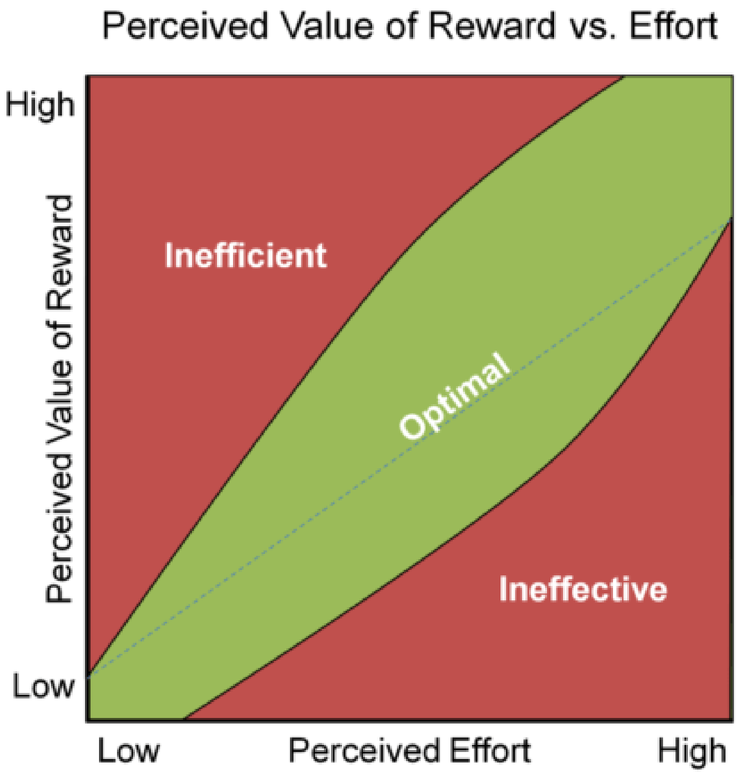

Figure 1: Perceived Value of Reward vs. Effort Model Adapted from [Burke, 2014].

4 Psychological Profile of Early Adopter

To better understand the limitations of Early Adopter (EA) engagement in ESA-sponsored projects such as CRISP, this paper draws on selected models and theories from organizational and motivational psychology as interpretative lenses, rather than as definitive explanations of EA behavior.

Unlike stakeholders with contractual or economic ties to the project, EAs operate within a space governed primarily by intrinsic motivation, institutional goodwill, and reputational incentives. This makes their engagement highly susceptible to cognitive and affective biases, inconsistent effort, and ultimately, attrition.

4.1 Motivation and the Self-Determination Theory

According to Self-Determination Theory, human motivation is structured around three basic psychological needs: autonomy, competence, and relatedness [Deci and Ryan, 2000]. Applied to the EA context, these dimensions can help explain the initial willingness to participate, often linked to a perception of competence in influencing EO tools and relatedness to a prestigious institution such as ESA.

However, this motivational structure is inherently fragile. As projects progress, autonomy may be perceived as constrained by rigid timelines and technical constraints, competence may be undermined by insufficient feedback loops, and relatedness may erode if interactions with the core team are infrequent or transactional. In such scenarios, initial enthusiasm may decline, sometimes leading to passive compliance or withdrawal, especially in the absence of reinforcing mechanisms such as recognition, authority, or tangible outcomes.

4.2 Perceived Value vs. Cognitive Effort

The disparity between the effort required and the benefits received plays a crucial role in shaping Early Adopters behavior. Studies in behavioral economics [Kahneman, 2011] show that individuals tend to discount future rewards steeply in the presence of immediate cognitive or resource expenditures. In the CRISP context, the extensive time and knowledge investments demanded from EAs are rarely offset by proportional, personalized returns, particularly when the final outputs were openly shared with users who had not contributed to the development process.

This imbalance can generate what Festinger [Festinger, 1957] describes as *cognitive dissonance*: a state of psychological discomfort arising from holding conflicting cognitions (e.g., investing substantial effort in a system whose benefits are distributed indiscriminately). Without mitigating this issue through mechanisms such as social recognition, exclusive access, or symbolic rewards, disengagement may emerge as a rational coping strategy.

4.3 Social Comparison and Psychological Distance

Another layer of disengagement stems from social comparison theory [Festinger, 1954], which posits that individuals evaluate their own contributions and rewards relative to others. In projects like CRISP, EAs may quickly realize that their early and intensive involvement yields outputs accessible to non-contributors. This erodes the perceived fairness of the collaboration and fosters a sense of psychological distance between effort and impact, a condition antithetical to Agile's foundational premise of tight stakeholder feedback loops.

Moreover, organizational psychology research [McBey and Karakowsky, 2017] suggests that in voluntary frameworks, perceived low impact stemming from a lack of visibility and influence over outcomes, can be a stronger predictor of withdrawal than the mere absence of reward. In other words, disengagement may arise not from unfair rewards, but from the perception that contributions are futile or inconsequential.

That said, practical experience shows that some EAs, once engaged, adopt an "I want everything" posture seeking full customization or strategic influence beyond what project constraints can accommodate. This mismatch between expectations and feasible responsiveness places additional strain on the project team and reinforces the need for clearly defined engagement boundaries and reciprocal value structures from the outset.

4.4 Framing Participation as Prestige or Burden

The perception of EA participation can oscillate between that of a privileged opportunity to contribute to a high-impact project, and that of an exploitative demand on scarce organizational resources. The framing adopted by project leaders, therefore, plays a pivotal role. Communication strategies that emphasize prestige, exclusivity, and influence are more likely to sustain engagement than those focusing solely on procedural compliance or technical inputs.

In retrospect, CRISP communications unconsciously prioritized procedural compliance over relational reinforcement, which meant that the conditions for highlighting opportunities were less developed than those emphasizing obligations ultimately limiting the motivational potential of EA involvement.

5 Systemic Failures in Voluntary Engagement

The limited efficacy of Early Adopter (EA) engagement in ESA-funded Earth Observation projects such as CRISP is not merely the result of individual disinterest or inadequate project execution. Rather, it reflects a set of systemic failures deeply embedded in the current institutional design for stakeholder collaboration. These failures stem from an over-reliance on voluntary contribution models, insufficient formalization of engagement mechanisms, and a misalignment between project structures and stakeholder incentive architectures.

5.1 The Fallacy of Prestige-Based Motivation

At the core of the engagement strategy lies the implicit assumption that institutional prestige and perceived social capital will suffice to secure long-term stakeholder investment. This assumption may hold during the initial phases of project ideation or proposal development, when senior representatives of potential EAs perceive value in association with ESA-led initiatives. However, as the project enters operational phases, this top-down motivation frequently dissipates, especially at the operational level where actual participation occurs.

This phenomenon is closely related to the initial prestige saturation effect, whereby the symbolic value of participation is exhausted early on, often at the moment of EA selection, leaving little residual motivation for continued contribution. In the absence of secondary motivators such as resource access, influence over outcomes, or institutional incentives, disengagement becomes increasingly probable.

5.2 Disengagement Dynamics and Project Impact

Disengagement does not occur instantaneously but unfolds through a series of micro-decisions that cumulatively erode the participatory commitment of EAs. These include delayed responses to surveys, missed workshops, superficial feedback submissions, and eventually, total withdrawal. Critically, this process is often invisible to the project leadership until it has become irreversible. The consequences for the project are profound. The iterative Agile process, which relies on frequent and meaningful feedback, is structurally undermined, and the co-design approach collapses into a tokenistic consultation process. The tools produced, while technically sound, risk being misaligned with actual user workflows, resulting in low post-project uptake and diminished return on investment, and a perceived betrayal of the Early Adopters' engagement.

5.3 Procedural Overload and Cognitive Fatigue

Another systemic barrier to sustained engagement is procedural overload. Large-scale EO initiatives that follow structured co-design methodologies are frequently characterized by high documentation demands, multiple reporting streams, and structured co-creation frameworks (e.g., Living Labs, requirement traceability matrices, user validation stages). While theoretically sound, these structures impose a cognitive and administrative load on EAs who often lack dedicated resources for their participation.

In practice, the result is a mismatch between project expectations and stakeholder capacity. Participation becomes yet another task among many, with no intrinsic institutional obligation or direct compensation to justify prioritization. This disconnect contributes not only to attrition, but also to a dilution in the quality of engagement where "participation" exists in form but not in function.

5.4 Absence of Enforcement or Incentive Mechanisms

Perhaps the most critical failure is the lack of enforceable agreements or incentive structures governing EA behavior. With no contractual obligations, performance-based feedback loops, or penalties for disengagement, project managers are left with minimal tools to manage stakeholder risk. Unlike in traditional Agile teams where accountability is built into roles such as Product Owner or Scrum Master, ESA's model treats EAs as both essential and exempt.

The recent creation of the Stakeholder Engagement Facility (SEF) represents a positive step in remedying this gap, offering outreach, training, and technical support. However, without mechanisms that operationalize engagement expectations through formalized service-level agreements, incentivized milestones, or tiered participation benefits, the SEF may fall short of resolving the deeper structural issues.

5.5 Summary of Systemic Misalignments

Table 1: Analysis of structural elements and their potential failures.

Structural Element	Intended Function	Systemic Failure
Prestige motivation	Initial stakeholders buy-in	Short-lived and non-operational
Agile co-design	Iterative alignment of outputs	Resource intensive; Collapses without sustained feedback
Living labs	Dynamic engagement environments	Perceived as procedural burdens
Voluntary participation	Flexible and open collaboration	Unmanaged and unbalanced effort distribution
Universal access to outputs	Democratic dissemination	Undermines differentiated value for EAs

6 Artificial Intelligence as a Design Phase Companion

As demonstrated in previous sections, the structural limitations inherent to voluntary stakeholder engagement in ESA-funded Earth Observation projects compromise the iterative, user-centered objectives of Agile methodologies. In an attempt to mitigate this misalignment, while keeping the added value of Early Adopters' involvement and contribution, Artificial Intelligence (AI), particularly generative and conversational AI models, emerges as a promising complement to traditional engagement processes. Properly integrated, AI systems can augment the early design phases, simulate stakeholder perspectives, and generate pseudo-feedback loops that support design refinement when human input is sparse or unreliable. Of course, AI cannot substitute the experience and ingenuity of real EAs, but it can provide continuity in those phases where their lack of involvement would otherwise undermine Agile principles.

The discussion that follows unfolds in three phases. First, we illustrate the potential roles of AI in EO co-design, benchmarking current models and presenting a comparative simulation of EA input. Second, we examine methods to enhance the fidelity of such simulations through different techniques. Finally, we broaden the perspective by considering conversational AI agents as interactive tools for sustaining engagement, and by reflecting on the ethical implications of integrating these technologies into project management practice.

By distinguishing between AI as a simulation tool and AI as an engagement tool, the chapter positions these technologies not as replacements for stakeholder participation but as scaffolding mechanisms that can stabilize and extend Agile dynamics in contexts where human input is limited or inconsistent.

6.1 Potential roles of AI

Recent advances in large language models (LLMs) such as GPT-5 (OpenAI), Claude (Anthropic), Gemini (Google DeepMind), and Mistral (Mistral AI)[5] have enabled nuanced natural language interactions capable of emulating domain-specific reasoning, scenario testing, and user simulation. These systems can be fine-tuned or prompted with domain-relevant corpora—such as technical standards, stakeholder interviews, and use-case documentation—to mimic the feedback that would otherwise be collected from Early Adopters.

In the context of projects such as CRISP, for example, AI can be employed to:

- Generate mock feedback on proposed interface features.
- Simulate divergent user personas (e.g., policy analyst, agronomist, regional planner) responding to prototype tools.
- Assess requirements feasibility and usability using predefined constraints.
- Surface potential friction points in workflows based on learned interaction patterns.

Such capabilities do not eliminate the need for human users, but they provide a resilient backstop when participation becomes sporadic or performative. They expand the design space by offering considerations that can later be validated, adapted, or discarded by real Early Adopters.

The preceding sections have highlighted a central challenge: the structural fragility of voluntary Early Adopter (EA) engagement in complex, EO projects. Concurrently, the demonstrated ability of generative AI to simulate stakeholder perspectives offers a compelling tool to support the

[5] This represents the state of the art of language models as of late 2025. The rapid evolution of this technology suggests that major improvements are likely to occur in the near future; however, the fact that the examples in this paper refer to models that will soon be outdated does not alter the substance. On the contrary, the more advanced the models become, the greater their usefulness and reliability will be.

design process when human input is sparse or unreliable.

Synthesizing these realities, this section proposes a hybrid engagement model that leverages AI not as a substitute for, but as a complement to, human expertise. Such a framework would orchestrate a dynamic interplay between EAs and AI systems. In this model, EAs would be called upon to provide strategic input and contextual validation at key project milestones, where their insights are most valuable. During the intermediate sprints, when human availability is often limited, AI models trained on prior EA input and project documentation, could be used to generate continuous feedback, stress-test assumptions, and ensure that the iterative design process does not stall.

Crucially, any output generated by AI would be treated as a provisional input, subject to final validation and refinement by the human stakeholders in subsequent co-design sessions. This structured, hybrid model aims to reduce pressure on scarce stakeholder availability while allowing project teams to maintain alignment with user needs in the face of fluctuating engagement.

6.2 AI models Benchmarked

To assess the potential contribution of AI to stakeholder simulation, it is necessary to consider the capabilities and limitations of the leading large language models (LLMs) currently available. At the time of writing, these include GPT-5, GPT-4o (OpenAI), Claude 3.5 (Anthropic), Gemini 1.5 (Google DeepMind), and Mistral (Mistral AI). Each system offers distinct advantages in terms of reasoning ability, contextual adaptability, and transparency of outputs.

From a pragmatist inquiry perspective, the benchmarking of these models should not be viewed as an attempt to crown a definitive “best” system. Instead, it represents a comparative exploration of how different AI agents can expand the design space by generating provisional inputs. These inputs are not considered final deliverables but hypotheses to be tested, refined, or discarded through interaction with human stakeholders.

A comparative overview of the main LLMs relevant for EO project co-design is summarized in Table 2, highlighting their relative strengths and limitations for stakeholder simulation.

Table 2: Comparison of Large Language Models for EO Co-Design.

Model	Developer	Strengths for EO Co-Design	Limitations
GPT-4o	OpenAI	High generalization, robust dialogue, integration with external tools (e.g., plugins, APIs).	Closed-source; sensitive to prompt specificity; costly for large-scale use.
GPT-5	OpenAI	Improved contextual alignment, multi-turn consistency, and higher reasoning accuracy.	Early-stage adoption; limited transparency about training data and safety guardrails.
Claude 3.5	Anthropic	Ethical alignment, long context window, strong role-playing and instruction following.	Slightly weaker on technical extrapolation; limited multimodal capacity.
Gemini 1.5	Google DeepMind	Multimodal integration (text, code, images), strong analytical reasoning, good fact-checking.	Restricted public access; data control and reproducibility concerns.
Mistral 7B / Mixtral 8x22B	Mistral AI	Open-weight models, customizable, efficient local deployment, cost-effective for pilots.	Requires domain fine-tuning for high-quality output; weaker general reasoning.

6.3 AI-Human Alignment Assessment: A Comparative Simulation

To empirically assess the viability of using AI in place of, or in support of Early Adopter input during the design phase, we conducted a simulation comparing real stakeholder responses from the CRISP project with AI-generated rankings based on the same prompt.

A group of four Early Adopters from different institutional backgrounds (e.g., IFAD[6], GIZ[7], GEOGLAM[8], and the Syngenta Foundation) were asked to rank 9 rice monitoring product categories by priority. The same prompt was subsequently given to the GPT-4 model, representing a general-purpose, non-domain-tuned AI system[9].

[6] International Fund for Agricultural Development
[7] Deutsche Gesellschaft für Internationale Zusammenarbeit
[8] Group on Earth Observations Global Agricultural Monitoring Initiative
[9] The AI responses were generated using OpenAI's GPT-4-turbo model via the ChatGPT Plus interface. Low- level sampling parameters such as temperature and top-k were managed by the system and are not user-accessible in this

Prompt: *Given the preliminary list of products (Rice Area (actual), Rice Area (historical), Crop Calendar, Yield, Yield (historical), Water availability/management, Drought-related losses, Flood-related losses, Rice Ecosystem), how would you classify them from the most important to the least important for your organization?*

To enable comparison, each EA ranking was normalized by adjusting scores relative to the maximum rank assigned. This yielded a set of *average ranks* for each product across respondents. The resulting averages were then ordered from smallest (highest priority) to largest (lowest priority). In cases of tied average rank, the standard deviation across EA responses was used as a discriminant: the product with lower variance was given higher priority, reflecting stronger consensus.

Formally, the average rank for product *p* was computed as:

$$\bar{r}_p = \frac{1}{N}\sum_{i=1}^{N} r_{i,p}$$

where $r_{i,p}$ is the rank assigned by EA i to product p_i and N is the number of EAs.
For tied averages, the variance criterion was applied:

$$\sigma_p^2 = \frac{1}{N}\sum_{i=1}^{N}(r_{i,p} - \bar{r}_p)^2$$

with the product having the lower σ_p^2 assigned the better position in the final ordering. The same ranking exercise was conducted with GPT-4. Its generated ranking was then compared against the aggregated EA ranking, enabling a structured assessment of alignment and divergence between human and AI perspectives.

6.4 Results and Lessons from Simulation

The comparative simulation provides important insights into the extent to which AI can approximate stakeholder input during the design phase of EO projects. The analysis shows a high degree of convergence between AI-generated rankings and human input on the most critical priorities. Both EAs and AI placed Yield and Rice Area (actual) at the top, while Water Availability also emerged as a shared high-ranking variable. This alignment on the “core triad” of productivity and resource indicators suggests that AI can reliably capture the dimensions most valued by stakeholders in early design phases. Divergences were more evident in secondary categories: AI

context. The output represents standardized conditions reflecting the usage of the end user in project co-design scenarios tended to undervalue temporal datasets such as Crop Calendar and Yield (historical), while assigning relatively greater importance to Drought-Related Losses and Rice Ecosystem. Yet these differences largely concerned dimensions less central to immediate decision-making. When accuracy is weighted toward core variables, the AI alignment with EA input reaches an estimated 75%, indicating that simulated outputs can meaningfully scaffold design iteration, particularly when direct stakeholder engagement is intermittent.

Figure 2 shows the divergence and convergence across all product categories. The blue dots indicate the rank given by Early Adopters, while the orange dots reflect the simulated results. This comparative exercise reveals both strong overlap in core operational indicators and notable divergence on contextual and environmental layers, which some human stakeholders valued more than the AI predicted.

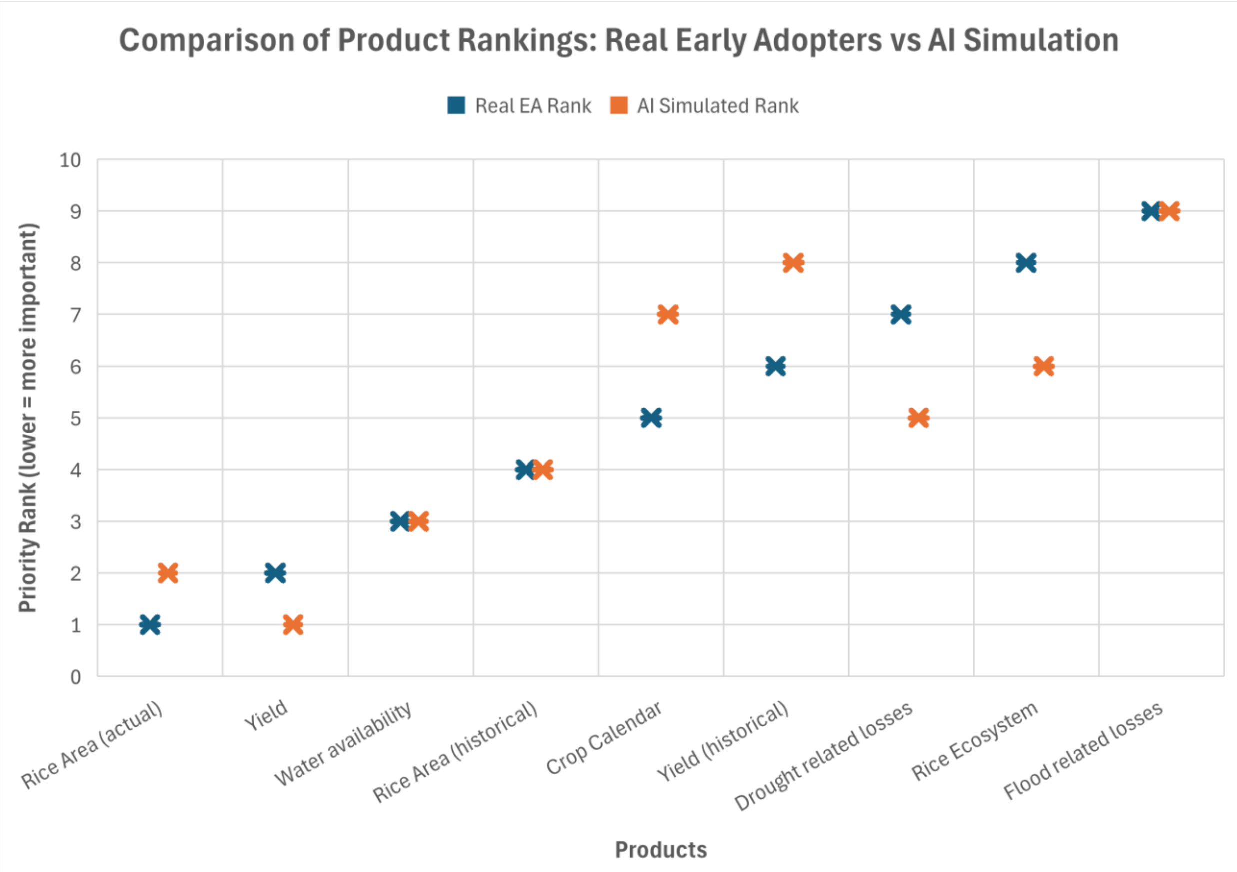

Figure 2: Comparison of Product Rankings: Real Early Adopters vs AI Simulation

These findings support the hypothesis that AI can effectively approximate stakeholder priorities in the absence of direct human feedback, especially in relation to generic institutional needs. However, AI-generated input must be interpreted cautiously when dealing with values that are:

- Culturally or regionally specific.
- Politically or ethically nuanced.
- Grounded in organizational mandates or long-term commitments.

The experiment strengthens the proposition, articulated throughout this chapter, that AI (at the moment) can complement but not replace real stakeholder engagement in the Agile design process. Its role is best conceived as that of a complementary tool: one that sustains continuity of iteration and highlights areas of divergence requiring targeted engagement. In the following sections, this perspective is extended to explore how incentive mechanisms and interactive engagement strategies can operationalize such complementarity in practice.

6.5 Simulation Fidelity Strategies

While the comparative simulation in Section 6.3 revealed promising convergence between AI and Early Adopter (EA) input, it also exposed limitations: AI tended to emphasize generic indicators while undervaluing context-specific or temporally nuanced variables. To move beyond static or superficial replication, AI-supported simulations could be refined through methodological enhancements that increase realism, interpretability, and factual grounding.

Contextual Prompt Engineering

The simplest and most effective enhancement strategy involves crafting prompts that simulate the decision-making environment of a specific stakeholder. Instead of issuing generic instructions, project teams can construct role-based prompts that describe the stakeholder's institutional role, regional context, and strategic goals. Prompt design techniques such as these have been shown to significantly improve realism in domain-specific tasks [Chen et al., 2025]. For example:

"You are a technical advisor at a development agency in Southeast Asia focused on food security and water management. Given the following EO data products, rank them by importance for policy support."

This kind of contextual framing has been shown to improve the coherence and realism of model outputs without requiring access to confidential data or post-training adjustments.

Role Simulation and Prompt Chaining

To capture the cognitive and organizational logic of different stakeholder types (e.g., nongovernmental organizations, academic researchers, intergovernmental bodies), prompts can be expanded into multi-step chains. This layered prompting mimics human deliberation and supports better reasoning continuity, an ability demonstrated consistently in transformer-based models such as GPT-4 [Brown et al., 2020]. For instance:

1. Identify key organizational objectives.

2. Generate a list of EO priorities consistent with those goals.

3. Justify the prioritization based on operational constraints.

This approach encourages more structured and interpretable output and mimics how real stakeholders reason through trade-offs.

Retrieval-Augmented Generation (RAG)

For more sophisticated applications, AI simulations can be enhanced using retrieval-augmented generation, a technique in which the model is dynamically provided with relevant documents or excerpts at inference time. This method has been shown to significantly increase factual grounding in complex NLP tasks [Lewis et al., 2020].

Multi-Model Aggregation and Validation

Simulations can also be improved by cross-referencing outputs from multiple large language models (e.g., GPT-5, GPT-4, Claude 3, Gemini 1.5), which follow different architectural and alignment strategies. Recent advancements such as Constitutional AI offer promising methods to encode behavioral alignment constraints into model responses [Anthropic, 2025].

Finally, simulations must avoid overfitting, mimicry of individual organizations, or use of private data without consent. Transparency in methodology and attribution is key to maintaining trust and scientific integrity.

6.6 Enhancing Engagement with AI-Powered Chatbots

Beyond simulation, a second trajectory for applying AI in EO projects lies in directly enhancing stakeholder engagement. Instead of approximating EA input offline, conversational AI agents (or chatbots) can interact with stakeholders in real time, guiding their contributions through structured, adaptive, and even gamified dialogues. This shifts the role of AI from a passive simulator of feedback to an active facilitator of participation, helping to overcome many of the motivational and procedural barriers observed in CRISP.

Recent studies confirm the value of such systems in participatory research. Zamfirescu [Zamfirescu-Pereira et al., 2023] demonstrates that well-designed conversational agents can increase both completion rates and the quality of responses in complex survey tasks, particularly when they adopt a supportive or empathetic tone. Similarly, [LivePerson, 2024] reports that adaptive AI chatbots capable of adjusting their style and complexity to the respondent's background, significantly improve stakeholder satisfaction and data richness compared to static questionnaires.

In the context of EO projects, these findings suggest that chatbots could serve as *"co-design* *companions"*, performing functions such as:

- **Adaptive prompting:** adjusting the level of detail or technical language to the user's expertise.
- **Dynamic feedback:** offering immediate validation of responses ("your prioritization aligns with other agencies") to reinforce motivation.
- **Gamified interaction:** presenting tasks as challenges or milestones to counteract cognitive fatigue.
- **Iterative guidance:** breaking down complex requirements into smaller, conversational steps, thereby reducing the perception of procedural burden.

Importantly, the goal is not to replace direct human facilitation but to augment it by lowering participation barriers and providing continuity between formal workshops or surveys. By embedding AI agents into existing engagement strategies, project managers could foster a more sustained and responsive dialogue with EAs transforming intermittent contributions into a continuous feedback loop. In this sense, chatbots represent not a replacement for human interaction but a scalable complement, capable of making engagement more dynamic, personalized, and sustainable over time.

6.7 Implications & Ethical Considerations

The comparative simulation between AI-generated and real EA rankings showed that AI can approximate stakeholder priorities with a degree of reliability, particularly for core variables such as *Yield* and *Rice Area.* Fidelity-enhancing techniques such as contextual prompt engineering, role simulation, retrieval-augmented generation, and multimodal validation are expected to further improve alignment. Complementarily, conversational agents have been shown to sustain participation by reducing cognitive burden and making interaction more engaging. Taken together, these results suggest that AI can both *simulate* and *facilitate* stakeholder engagement, provided methodological safeguards and governance structures are in place. Despite these opportunities, deploying AI in EO projects raises a series of ethical and strategic challenges that cannot be overlooked. Chief among them is the risk of *feedback hallucination*, where the model confidently generates plausible but invalid insights. This risk must be mitigated by human oversight, ensuring AI-derived contributions are treated as provisional inputs rather than authoritative validations.

Another concern is the erosion of stakeholder legitimacy. Although useful in many aspects, AI cannot replace real-world EAs, particularly in fields where social, psychological, and behavioral nuances are difficult to deeply understand and simulate, such as concrete adoption signals or institutional alignment. Hence, its use must be framed not as a substitute for EAs, but as a scaffolding mechanism that sustains project momentum when human input is delayed, misaligned, or absent. Accordingly, any integration of AI tools must respect the principles of transparency, consent, fairness, and accountability. Stakeholders should be informed when AI is used, sensitive data should never be incorporated without consent, and human validation must remain the final arbiter of design decisions. Within this ethical frame, several operational lessons emerge:

- **Safe zones for AI application** include early scoping of product categories, prioritization triage, and highlighting divergence areas for targeted engagement.
- **Caution zones** include context-sensitive variables (e.g., policy-sensitive indicators, regionally specific datasets) where human expertise is indispensable.
- **Institutional embedding** could occur via dedicated tools, where AI agents might extend workshops with pre-engagement surveys or post-engagement validation dialogues.

7 Strategic Redesign of Engagement: Rethinking Incentives and Participation in ESA Agile Projects

Beyond AI implementation and the methodological safeguards outlined in Chapter 6, robust stakeholder engagement tools and strategies are still required to secure Early Adopters' (EAs) direct involvement when their input is indispensable. AI can sustain iteration during periods of low participation, but it cannot substitute the motivational, relational, and institutional drivers that determine whether EAs remain committed over the project lifecycle. Accordingly, the following subsections present a set of complementary strategies that, together, form a strategic redesign of engagement.

7.1 From Structural Fragility to Strategic Realignment

The previous sections have highlighted a critical misalignment between the aspiration to adopt Agile project philosophy and the actual mechanisms made available to sustain stakeholder engagement. Voluntary participation, while conceptually inclusive and politically elegant, has revealed structural fragilities when transposed into resource-constrained institutions. Traditional engagement models, relying on prestige or project visibility, have proven insufficient to secure the sustained, informed, and iterative input required by co-design processes.

As showcased in the CRISP case, this failure is not circumstantial, but systemic, rooted in the absence of enforceable expectations, tangible rewards, and value differentiation. If it is intended to preserve the participatory ethos of Agile while enhancing operational outcomes, a strategic redesign of engagement models is essential.

7.2 Beyond Budget: Constructing Non-Monetary Incentive Frameworks

A core challenge in ESA-funded projects lies in designing value-driven collaboration without relying on financial transfers. Drawing from motivational theory and participatory design literature, several non-monetary levers can be institutionalized:

- **Reputational Capital:** Early Adopters can be granted co-authorship or formal mention in policy briefs, dashboards, and launch events.
- **Priority Access:** Provide EAs with pre-release access to tools and analytics dashboards, enabling them to gain operational advantage.
- **Influence Rights:** Recognize the input of EAs in strategic steering committees or roadmap validation panels.
- **Learning and Certification:** Offer structured technical capacity building, possibly culminating in certification or badges that support institutional capacity.
- **Reciprocal Data Sharing:** Incentivize with data analytics tailored to EA-specific geographies and needs, in exchange for deeper input.

These mechanisms create a reciprocal ecosystem in which the perceived value of participation is no longer symbolic but operationally actionable. Comparable strategies have proven effective in other collaborative innovation contexts, such as open-source software and crowd-sourced research, where non-monetary motivators like reputation, learning, and influence drive sustained contributions [Osterloh & Frey, 2000; Lakhani & Wolf, 2005].

7.3 Temporal Targeting and Role Differentiation

Not all phases of a project demand the same intensity of EA engagement. To optimize effort and focus, engagement should be temporally segmented:

- **Exploration Phase:** High value from exploratory interviews and user story mapping.
- **Prototype Phase:** Targeted validation of usability and clarity; lower commitment windows.
- **Deployment Phase:** Reengage EAs for real-world testing and localized calibration.

Likewise, not all EAs need to perform the same role. Projects can benefit from differentiated EA clusters: validators, advisors, field users, policy shapers—each with tailored expectations and engagement modalities.

7.4 The Project Manager's Role in the Engagement Economy

Project Managers must evolve from coordination nodes to engagement architects. Their role now includes:

- Designing incentive pathways.
- Matching EA profiles to engagement moments.
- Monitoring participation signals (e.g., interaction logs, feedback latency).
- Activating AI support where human input drops off.

Crucially, the PM becomes the orchestrator of the hybrid model: balancing AI-enabled simulations with real-world incentives, sequencing engagement to avoid fatigue, and ensuring fairness in the distribution of value. This integrative role ensures that AI complements rather than replaces human collaboration, and that EAs are treated not as symbolic figures but as empowered co-creators**.**

8 Discussion and Conclusions

The CRISP project exposes a persistent dilemma in Agile development applied to Earth Observation (EO) for the public good: how to reconcile iterative, user-centered design with the intermittent and non-committal participation of stakeholders. The introduction of Artificial Intelligence as a scaffolding tool offers part of the answer, but it must be accompanied by a rethinking of stakeholder value models. For this type of user-driven initiative, the next wave of innovation in project design must not be technical alone—it must be institutional, behavioral, and strategic. Creating structured, reciprocal, and meaningful engagement models is no longer a soft ambition; it is a condition for success.

8.1 Discussion

The core of this study is the structural fragility of voluntary Early Adopter (EA) engagement within an Agile context like the CRISP project. To make this model more resilient, this paper proposes a dual strategy. On one hand, Artificial Intelligence, particularly LLMs and chatbots, acts as a technical scaffold, providing a surrogate for EA feedback to ensure the continuity of the iterative process when human input is absent or intermittent. On the other hand, a strategic redesign of non-monetary incentives (such as reputational capital and priority data access) provides the motivational and relational scaffold that AI alone cannot offer. It is crucial to see these two strategies not as alternatives, but as complementary and synergistic: one ensures process continuity, while the other ensures the quality and relevance of human contribution.

However, the challenge observed in CRISP is not merely a weakness of the Agile methodology but rather a structural tension arising from applying an Agile framework within an institutional context (ESA) that retains many elements of traditional "waterfall" models. Projects like CRISP must manage the flexibility and iteration of Agile while simultaneously meeting the rigid reporting requirements, fixed deliverables, and strict deadlines typical of a traditional approach. This forced hybridization creates the "procedural overload" and cognitive fatigue that alienate voluntary stakeholders. The solutions proposed here—AI and incentives—can therefore be seen not just as enhancements to Agile, but as mechanisms to make Agile *functional* and sustainable within these hybrid institutional settings.

8.2 Limitations

As with any study grounded in reflective practice, this work has several limitations. First, its nature is primarily conceptual and qualitative, based on the in-depth analysis of a single case study (CRISP). The findings do not stem from a large-scale empirical survey and are therefore not statistically generalizable. Second, the comparative simulation between AI and EAs should be understood as exploratory and illustrative, not as a rigorous validation. Its purpose was to demonstrate a potential and stimulate reflection, rather than to definitively measure the substitutive efficacy of AI. Consequently, the generalizability of the findings is limited. While the dynamics observed in CRISP are symptomatic of broader challenges in EO projects, every initiative has a unique context. The proposed solutions should therefore be considered an adaptable framework rather than a prescriptive recipe.

8.3 Future Research

Based on the limitations and proposals of this paper, three promising avenues for future research emerge. A first path is the development and field-testing of conversational AI agents ("*co-design companions*") within a live EO project to quantitatively measure their impact on stakeholder participation rates and feedback quality. A second line of inquiry could analyze the relative effectiveness of the different non-monetary incentives proposed, investigating through a cross-institutional study whether different stakeholders (e.g., NGOs, government agencies, private sector) respond differently to incentives based on reputation, data access, or strategic influence. Finally, a comparative study across a broader sample of ESA projects would be valuable to more robustly validate the "systemic fragilities" identified here, comparing the effectiveness of different project management models in mitigating stakeholder fatigue.

8.4 Closing Remarks

This reflective framework aims to transform the notion of stakeholder engagement from a procedural requirement into a dynamic, adaptable, and designable system of mutual value exchange. If implemented thoughtfully, the following recommendations could foster a more resilient, scalable, and human-centric evolution of Agile practices in Earth Observation and beyond.

A. For Project Implementers (PMs, coordinators, Agile leads)

(a) **Design non-monetary incentive architectures from day one**
Identify and plan tangible value returns for EAs—early access, co-branding, influence points, or visibility—as part of the user engagement strategy, not as post-hoc gestures.

(b) **Tailor engagement by role and phase**
Avoid one-size-fits-all participation. Segment EA involvement into clusters (advisors, testers, validators) and activate them selectively during exploration, prototyping, and validation.

(c) **Embed AI systems as feedback scaffolds**
Use language models and conversational agents to simulate input, validate assumptions, and maintain continuity when human engagement lags, while preserving the primacy of real user needs.

(d) **Monitor engagement as a dynamic signal**
Track participation metrics (e.g., response time, input depth, feedback quality) as part of Agile sprint retrospectives and course-correct early where signs of disengagement appear.

(e) **Make stakeholder economy visible in reporting**
Document the real effort of engagement (successful or not) in deliverables, to support cross-project learning and transparency.

B. For ESA and Funding Institutions

(a) **Include incentive design explicitly in Statements of Work**
Rather than assuming intrinsic motivation, mandate that bidders include structured incentive models for stakeholder involvement, appropriate to project type and region.

(b) **Recognize AI-supported engagement tools as valid project components** Enable budget lines and evaluation criteria that legitimize the integration of AI- based co-design support (e.g., stakeholder simulators, adaptive chatbots) in proposal assessment.

(c) **Provide engagement templates, not just technical guidelines**
Develop and circulate engagement design toolkits alongside EO technical requirements, covering use-case co-definition, stakeholder mapping, and commitment structuring.

(d) **Create a feedback repository across projects**
Establish a mechanism for aggregating lessons learned about EA participation across ESA programs, to evolve standards and identify systemic friction points.

(e) **Promote evaluability of engagement impact**
Embed performance indicators for stakeholder participation to assess and compare engagement quality across projects and time.

By embracing these strategies, stakeholder engagement can finally be transformed from a procedural hurdle into a dynamic system of mutual value exchange, becoming the core asset of user-driven innovation.

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