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Design for mission-driven technology maturation

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ABSTRACT: This paper investigates how advanced manufacturing firms mature technologies within mission-driven ecosystems. Two multi-partner case studies show how the design across six innovation dimensions—purpose, strategy, leadership, governance, innovation process, and budgeting & planning—enable co-maturation of novel technologies. Findings demonstrate that strategic partnerships with a shared mission, dual iterative/linear processes, and aligned governance accelerate mission-driven innovation from idea to scaled implementation.

KEYWORDS: innovation management, technology development, mission-driven innovation, collaborative design

1. Introduction

Advanced manufacturing is increasingly tasked with delivering solutions to contemporary societal challenges—net-zero emissions, resource circularity, and resilient health systems—rather than incremental product improvements. In this context, mission-driven innovation has emerged as a compelling approach: it steers technology trajectories toward clearly articulated outcomes and evaluates success by contribution to the mission rather than novelty alone (Mazzucato, 2018; Hekkert et al., 2020; Larrue, 2021). Yet turning mission intent into deployed, scalable manufacturing capabilities remains difficult. In practice, organizations must translate mission goals into innovation progress in day-to-day innovation efforts across internal units and external partners—including suppliers, technology providers, and research centers—while navigating uncertainty, regulatory constraints, and scale-up risks.

Conventional maturity tools such as Technology Readiness Levels (TRLs) help track technical progress from lab to field (Sauser et al., 2006; Wang et al., 2018). However, when missions are at stake, technical readiness alone is insufficient. Maturation toward deployment also depends on manufacturability and scale-up, sustainability and regulatory integrity, ecosystem capacity, and stakeholder legitimacy – dimensions that extend beyond a single firm's boundaries (Hallstedt et al., 2017; Trump et al., 2025). At the same time, studies of Agile–Stage-Gate show that iterative learning nested within decision regimes can accelerate development and improve quality (Sommer et al., 2015; Cooper & Sommer, 2018; Cooper & Sommer, 2020). Recent work indicates similar benefits for additive manufacturing, where uncertainty and supplier coordination are pronounced (Pisanu et al., 2025). These findings point to a needed synthesis: a design-led view of mission-driven technology maturation that integrates iterative innovation processes with governance, processes and structures that cut across multiple organizations.

A critical barrier is that most product-development and portfolio frameworks remain firm-bounded, while contemporary innovation is ecosystem-embedded. Empirical studies of industrial ecosystems highlight the importance of orchestration practices—partner alignment, shared artefacts, joint learning—but offer limited operational guidance for how to design collaboration across maturity stages under mission conditions (Shen et al., 2024). Policy analyses similarly show that mission programs underperform when targets, plans, and monitoring are not jointly owned across actors (Larrue, 2021). From an organizational perspective, enabling agility at ecosystem scale requires dual governance that balances stability (safety, compliance, accountability) with adaptability (rapid experimentation,

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cross-boundary iterations). This logic is echoed in a recent study on governing successful enterprises, which argues that striking a balance across the enterprise system elements determines competitiveness including, among others: purpose and values, strategy, leadership, structure and governance, innovation process, and budgeting and planning (Rigby et al., 2020).

This paper responds to these gaps by examining how companies innovate for mission-driven technology maturation across value-chain partners. We investigate two multi-partner ecosystems in advanced manufacturing: (i) A manufacturer of high-end plastic products for fast-moving consumer goods market and its key suppliers for additive manufacturing equipment and processes. Their mission is to be the first in the market to enhance consumer experience with 3D printed components in consumer products (ii) A mission-oriented research center collaborating with a manufacturer of processing equipment to scale biological methanation. Their shared mission is to develop solutions for the emergent market for fossil-free products based on captured CO2. Two highly different cases of ecosystem technology innovation within advanced manufacturing, both guided by strong missions.

Using semi-structured interviews, focus groups, and document analysis, we analyze innovation along six mission-driven design dimensions distilled from the literature: (1) shared purpose & values, (2) joint/shared strategy, (3) leadership, (4) enabling structure & governance, (5) joint innovation process (including collaboration across TRLs), and (6) shared budgeting & planning.

The study makes three contributions. First, it provides empirical support to better understand how to innovate in ecosystems in mission contexts with advanced manufacturing. Rather than waiting for suppliers to reach full maturity, focal firms and partners co-mature technologies through shared build–test–learn loops; transactional partnerships, by contrast, lack the knowledge sharing needed for maturation. Second, it advances mission-driven innovation as a multi-dimensional construct with six dimensions mentioned above—encompassing a systemic view to designing innovation efforts. Third, it offers concrete implications for industry governance across value chain relationships.

2. Literature background

Mission-driven innovation treats R&D innovation and technology development as coordinated mechanisms to deliver clearly defined societal outcomes rather than isolated product improvements. It emphasizes directionality—innovation trajectories are purpose-steered and evaluated against measurable mission targets (Mazzucato, 2018; Larrue, 2021). Within advanced manufacturing, mission-driven innovation supports alignment between long-term industrial strategy, technological capability, and societal value creation. The Mission-Oriented Innovation Systems framework shows that delivering missions requires orchestration of actors, institutions, and infrastructures (Hekkert et al., 2020). In manufacturing contexts, mission-driven innovation therefore becomes a design problem across the system framework variables. Rigby, Sutherland and Noble (2020) argue in Harvard Business Review that companies must align both through mutually reinforcing elements including; purpose and values, strategy, distributed leadership, enabling structure and governance, innovation process, and budgeting and planning. This offers a systemic logic for mission-driven technology maturation across ecosystems as illustrated below (Figure 1).



Figure 1. Framework for mission-driven innovation, adapted from (Rigby et al., 2020)

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Building on the mission-driven, ecosystem and maturity perspectives, a parallel stream of design research has addressed how innovation processes themselves can be purposefully designed for success. For example, the Design Council's Framework for Innovation summarizes a structured process of Discover-Define-Develop-Deliver, emphasizing iteration, collaboration and visual communication as key enablers of impactful innovation processes. In the academic domain, Hernández et al. (2018) review how design acts as "the language of innovation" by creating links among people, processes and artefacts, thereby enabling successful innovation outcomes when process design is aligned with organizational and ecosystem goals. Moreover, research on design-driven innovation process models (e.g., Acklin, 2010) presents six phases—Impulse, Research, Development, Strategy, Implementation and Evolution—that integrate strategy building, stakeholder involvement and iterative loops rather than relying solely on linear development. These contributions illustrate that innovation process design must address not only internal R&D milestones, but also stakeholder orchestration, iteration across artefact and organization boundaries, and feedback-loops embedded in the governance system. When aligned with the six dimensions of mission-driven maturation mentioned above, this design process perspective strengthens the argument that collaboration must be designed for – not only managed.

Technology Readiness Levels (TRLs) remain a dominant tool for expressing technical maturity across R&D and production domains (Sauser et al., 2006). They provide a shared language for assessing progress from proof-of-concept to operational use (Wang et al., 2018). Yet, TRLs insufficiently represent the organizational, ecosystem, and societal readiness needed for large-scale deployment (Hallstedt et al., 2017; Trump et al., 2025). In practice, advanced manufacturing missions must consider the combination of technology, innovation, organization, ecosystem, and governance capabilities.

Traditional new-product-development studies focus on intra-firm processes, but modern innovation – particularly in advanced manufacturing—occurs across ecosystems of OEMs, suppliers, technology providers, and research centers. Ecosystem-orchestration research shows that partner alignment, shared artefacts, and joint learning are essential to success (Shen et al., 2024). OECD analyses of mission-oriented innovation policies further underline that collaboration failures stem from insufficiently shared targets and weak governance across actors (Larrue, 2021). Recent contributions highlight similar challenges: design activities increasingly span multiple organizations and require explicit coordination mechanisms (Hallstedt et al., 2017; Pisanu et al., 2025). Despite this, empirical knowledge of how to design and govern such cross-boundary maturation processes remains limited.

Evidence from manufacturing firms adopting Agile–Stage-Gate hybrids demonstrates that iterative learning within structured decision regimes improves speed and quality of innovation outcomes (Sommer et al., 2015; Cooper & Sommer, 2018, 2020). For additive manufacturing, agile design practices have proved particularly valuable in managing uncertainty and supplier coordination (Pisanu et al., 2025). These findings parallel broader management research emphasizing that agility must extend beyond teams to the enterprise level.

Across the literature, three insights emerge. Mission-driven innovation establishes why directionality and societal outcomes matter but provides little operational guidance for multi-actor manufacturing systems (Mazzucato, 2018; Hekkert et al., 2020). TRL frameworks offer a necessary technical lens yet overlook organizational, regulatory, and ecosystem readiness (Hallstedt et al., 2017; Trump et al., 2025), and Agile and ecosystem research demonstrates how iterative learning and shared governance improve innovation performance (Sommer et al., 2015; Rigby et al., 2020) but has not been explicitly connected to mission-driven technology maturation.

Based on current literature, it is found relevant to explore how advanced manufacturing ecosystems in practice orchestrate their innovation efforts according to the systemic view for mission-driven technology maturation. We aim to understand how they operate, and what they deem successful and unsuccessful practices to advance towards their mission. To frame this exploratory effort the following research question has been formulated: How have companies in advanced manufacturing ecosystems structured their innovation efforts within the systemic elements of mission-driven technology maturation?

3. Exploratory case studies

To explore how organizations innovate for mission-driven technology maturation, two multi-partner ecosystems in advanced manufacturing were examined through exploratory, qualitative case studies. These two cases are chosen from different markets and ecosystem structures in order to explore the same systemic categories in differing contexts, with the hypothesis that for mission-driven technology

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maturation, we may find generic similarities on the six systemic constructs. The first case is a manufacturing company producing high quality fast-moving consumer goods in the plastic industry, with an ambitious manufacturing mission to enable additive manufacturing for speed and quality to be competitive to moulded plastic products by offering new design capabilities at the same development speed. Second, is a case within the mission to combat climate chance through fossil-free product alternatives – in this instance a research center and an advanced manufacturing supplier of processing equipment developing first-of-its-kind production facilities of CO2-to-methane through biological processing. Semi-structured interview guides were designed from the theoretical framework of mission-driven innovation, focusing on six dimensions: (1) purpose & values, (2) strategy, (3) leadership, (4) structure & governance, (5) innovation process, and (6) budgeting & planning. Across both cases, twelve individual interviews and four focus-group discussions were conducted with project managers, engineers, and supplier representatives. Each session lasted 45–90 minutes and was captured in contemporaneous notes.

Supplementary documents such as internal communication summaries and project plans were used for data triangulation. Data were coded thematically and analyzed through within- and cross-case comparison following qualitative guidelines in engineering design research (Blessing & Chakrabarti, 2009). All company and participant names were anonymized: "Design4AM" denotes the focal manufacturer in the additive-manufacturing ecosystem, and "CO_2-to-X" the mission-driven research center for biological methanation.

3.1. Case 1: Design4AM and its additive manufacturing suppliers

The first case investigates collaboration between Design4AM and three principal suppliers in its additive-manufacturing mission: ChemicalAM (material and water-treatment systems), AMPolish (unpacking and depowdering equipment), and SurfaceParts (post-processing and coloring systems). Collaboration on specific innovation for fast-moving consumer goods has been ongoing for years for the three suppliers. Recent breakthrough with first market launch has proven the collaboration to have a successful outcome for the joint mission, and more product launches are planned for the coming years, which is starting to generate return on investment on the long-term innovation efforts.

Purpose and values. All partners emphasized a commitment to the joint mission with the focal manufacturer, i.e. joint problem-solving and learning to build additive manufacturing capabilities for fast-moving consumer goods. Suppliers generally viewed Design4AM's openness and trust as central to progress. Similarly, they found that high ambitions for product quality was a key enabler for pushing the boundary for radical innovation efforts that would otherwise not have been tried. Differences in value orientation emerged, however: while AMPolish and ChemicalAM sought genuine co-development, some platform providers treated the relationship transactionally, which was identified as highly limiting for mutual knowledge exchange.

Strategy. While the mission was shared across the ecosystem, suppliers in addition pursued technologies applicable beyond a single customer and were therefore to come extent cautious about over-customization. Alignment improved when Design4AM and their suppliers mutually shared medium-term roadmaps. In situations with lack of strategic transparency, it created uncertainty about future demand and investment pay-offs, which became an inhibitor for technology maturation until strategies were shared and commonalities identified.

Leadership. Projects led by experienced Design4AM innovation leaders were consistently reported as "smoothest," with clear planning, early identification of risk, and rapid escalation procedures. Their leadership focus on creating trusting long-term relationships focused on joint passion for additive manufacturing technologies was identified as an important enabler. In cases of leadership turnover, it created friction and delayed validation activities as trust and relationships were lost and had to be rebuilt.

Structure and governance. Governance included clear contractual agreements on innovation including IP rights, supplier rights after tech development, and non-disclosure agreements (NDAs), which enables the sharing of technology progress and innovation strategies without concern of loss of competitive advantages. Prototype equipment was occasionally deployed in each other's production, demonstrating trust and increasing learning loops for mutual advantage, which was only possible due to the strategic nature of the relationship. Corporate functions (safety, cybersecurity, environmental compliance) engaged directly with suppliers at higher TRLs, forming cross-organizational governance lattices.

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Innovation process. Development followed an Agile–Stage-Gate pattern but using the TRL scale for reference—iterative design sprints within formal decision checkpoints. For example, the AMPolish unpacking system underwent four major design reviews with weekly-to-daily contact approaching installation. During periods leading up to a gate review, such as Factory Acceptance Test (FAT)and Site Acceptance Test (SAT), collaboration became highly agile – daily communication, rapid decision loops, and ad-hoc digital channels supplementing formal reporting. Across suppliers, the TRL scale was considered application-specific: technology mature for one sector required renewed testing for Design4AM's quality standards.

Budgeting and planning. Budget frames were agreed contractually up front, which enable collaboration with fair shared expenses, along with clear long-term plans. Suppliers requested planning security, shared risk visibility, and clear cost-allocation principles, which was accommodated by the focal company. A major challenge creating frequent delay sources was lack of cross-organizational day-to-day planning, which did generate some resource collisions and event-driven constraints (e.g., trade-fair schedules).

Case summary: Design4AM and their suppliers had a clear, shared mission purpose, and aspiration for mutual value creation. Their leadership approach was based on building trusting relationships, and when exchanging the leader delays happened before a new relationship was built back up. Governance included contractual frames for IP and investments, including expected benefits from products, the innovation process was governed by an Agile-Stage-Gate approach, and budgeted in collaboration, however planning was not always shared, which generated project delays. Despite the challenges, the collaboration has produced a successful mission outcome.

3.2. Case 2: CO_2-to-X and Liquid-Pro

The second case concerns a sustainability-oriented research center (CO_2-to-X) and its industrial partner Liquid-Pro, a manufacturer of liquid processing equipment. The shared mission is to develop scalable biological methanation systems that convert captured CO_2 into methane. Right now, the first of its kind commercial plants is being built at a customer site, but not yet in operation. However, it is expected to go live within a year proving the technology can generate a return on investment for all participants in the innovation ecosystem.

Purpose and values. Participants repeatedly framed the shared societal mission as a key enabler for collaboration as "partners, not customers". Shared purpose and mutual respect were reported as conditions for openness in data and design iteration. They also highlight the shared curiosity for solving problems as a key enabler for collaboration on a groundbreaking advanced manufacturing technology.

Strategy. The ecosystems strategy was to cover the entire process chain – from microbial conversion to system integration – with explicit attention to scale-up potential. CO_2-to-X orchestrates multi-partner projects combining public research, industrial pilots, and end-user validation. Liquid-Pro employs standardized yet customizable modules to ensure replicability across future Power-to-X initiatives. The strategy was fully transparent for both parties, enabling the ability to align strategic ambitions both ways.

Leadership. The project leader at CO_2-to-X maintained a visible leadership role characterized by proactive alignment of partner expectations, mapping of motivational drivers, and flexible cadence management. Leadership also extended to funding orchestration, where the research center prepared joint proposals and handled administrative complexity on behalf of smaller firms, including Liquid-Pro, who did neither have capacity nor competences to manage this.

Structure and governance. Work packages are explicitly organized around TRL milestones with clear rules for intellectual-property ownership, data confidentiality, and publication rights. Transparency in goal definition reduces misinterpretations of maturity progress. Partners are encouraged to self-manage within these boundaries.

Innovation process. Development follows a non-linear TRL trajectory: early laboratory validation was followed by radical scaling experiments ("million-times" increases in volume) before returning to controlled laboratory refinement. This cyclical progression was deliberate—fast learning through bold pilots while maintaining credibility of ultimate scalability. Liquid-Pro uses modular scaling (multiple parallel prototypes) deliberately to de-risk manufacturing. The meeting cadence varied, but with weekly planning meetings and check-ins inspired by Agile methods.

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Budgeting and planning. Project planning and budgeting was aligned up front to ensure shared financial accountability. Since the projects demanded substantial upfront capital, EU and foundation grants were crucial enablers. Risk-sharing agreements were also defined before initiation, which played a key role in successful collaboration.

Case summary. CO_2-to-X and their manufacturing innovation partner collaborated from clear mission alignment and towards a target market of mutual interest. The central project leader role was essential for synchronizing partners and maintaining trust through high-risk experimentation. Transparent governance enabled unusually rapid scaling despite technical and organizational complexity. The innovation process was a lightweight type of informal Agile-Stage-Gate with the TRL model as the linear process- logic and iterations conducted across the maturity steps by deliberately scaling to high levels of maturity in order to learn fast and scale back to earlier maturity levels. Finally, budgets and plans were organized from the project leader and highly transparent for all. The final project outcome is still in process, but with the expectation of a financially viable commercial plant going live within the next year.

4. Results

Both ecosystems overall show significant similarities across their mission-driven innovation systems as shown below (Table 1). With regards to the shared mission across ecosystems partners, this is highlighted by both ecosystems as foundational for driving joint technology innovation. The mission includes a clear sense of purpose for the ecosystem partners, and shared value set in both cases, despite the strategic goals for the collaboration differing. Sharing of strategic aims across ecosystems partners was highly beneficial in developing shared understanding of incentives and direction for technology development.

Across cases, visible and trustworthy project leadership proved decisive. When project leaders and their dedicated teams at both sides of the relationship maintained continuous presence – through investment in trusting relationships, creating project visibility, clear agenda setting, stakeholder motivation building, and flexible cadence management – collaboration advanced more smoothly. Conversely, leadership discontinuity produced re-work and ambiguity about maturity responsibilities. These observations echo prior research on distributed project ownership in complex design networks.

Partner orientation influenced collaboration depth. Development-oriented partners co-invested in iterative testing, whereas sales-oriented partners (or suppliers) limited engagement once contractual obligations were met. Organizational capacity constrained responsiveness; smaller firms depended on the focal partner's coordination and planning security. Effective maturity governance therefore requires segmentation of partners by collaboration posture and resource base.

Both ecosystems demonstrate that TRL advancement is context specific. ChemicalAM's mature water-treatment technology required re-maturation for Design4AM's stringent environmental parameters, while CO_2-to-X deliberately alternated between up- and down-scaling to validate biological reactions at realistic operating conditions. Both exhibit an Agile–Stage-Gate dynamic: intensive interaction peaks near formal milestones, followed by consolidation phases. Iterative learning loops within these gates accelerated technology validation and alignment of expectations. In Design4AM, weekly design reviews evolved into daily exchanges approaching installation; in CO_2-to-X, TRL-defined work-package reviews served an analogous function.

Across cases, resource availability and event scheduling emerged as first-order determinants of progress. Periods of intense external engagement (trade fairs, grant cycles) produced bottlenecks. Incorporating resource-readiness checkpoints into gate reviews and reserving shared test windows could mitigate these effects.

The comparative analysis indicates that successful mission-driven maturation depends on alignment of cadence and governance across TRL stages and organizational boundaries. Purpose and leadership establish trust; structured yet flexible governance sustains learning; and budgeting mechanisms allocate risk proportionally to capability. Together these elements form an emergent framework for mission-driven technology maturation – a multi-dimensional governance system that couples iterative learning with mission coherence.

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Table 1. Cross-case comparison of innovation characteristics

Dimension	Design4AM ecosystem	CO_2-to-X ecosystem	Study Summary
Purpose & values	Shared mission to generate AM capabilities for consumer market. Established co-innovation mindset; but varying openness across suppliers; trust building through shared experimentation and strategy.	Shared mission for fossil-free production of methane anchors collaboration. Explicit partnership ethos.	Common mission, and sharing of purpose and values is foundational for mission-driven innovation
Strategy	Transparent strategy and roadmaps enhancing join innovation performance. In transactional case, delays occurred.	Consortium strategy covering full process chain; transparency through formal frameworks, which created alignment and focus.	Shared strategy and roadmaps/ frameworks enhance ecosystem innovation. Transactional relation with no strategic sharing can be a barrier for innovation
Leadership	Trusting project-leader relation enables innovation, continuity is crucial; ad-hoc escalation is needed in crises.	Visible, facilitative leadership created motivation. Clear lead on funding orchestration necessary for commitment.	The role of the project leader is central to innovation success across the ecosystem, including individual trust building, creation of project visibility, and financial orchestration ect.
Structure & governance	Contractual agreements on NDA and IP, informal channels fill gaps. Broader organizational governance support (e.g. IT security, safety ect.)	Work packages by TRL; formal IP and disclosure governance. Transparency on target goal definitions, self-management within agreed frames.	Contractual agreements on IP and NDA are part of innovation initiation. Not detailing deliverables, instead shared mission is agreed and timeline for value deliverables (roadmaps).
Innovation process	Iterative loops within gates (Agile-Stage-Gate) and across maturity levels (TRL) with +2 jumps backwards. Agile governance peaks near FAT/ SAT;	Non-linear TRL cycles (scale-up ↔ refinement) with large jumps forward into pilot scale (scaling +X100 times) to purposefully activate a learning loop back to TRL 1-4. Agile approach to day-to-day collaboration.	Both expresses variants of an Agile/Linear innovation process (Agile-Stage-Gate/ Agile/TRL), both with significant iterations across their linear maturation models (+2 jumps backward learning loops).
Budgeting & planning	Agreed budget frames up front. Need for planning safety; resource collisions when day-to-day planning not shared.	High capex requires predefined risk-sharing and external funding. Weekly check-ins mitigate drift.	Budget frames aligned up front. Shared planning needed for alignment and avoiding drift or delay.

5. Discussion & conclusion

Across both cases, the findings show that as the complexity of mission-driven innovation increases, the ability to collaborate effectively becomes a competitive advantage. This resonates with ecosystem-orchestration studies emphasizing collaboration capability as a core competence for industrial transformation (Shen et al., 2024). Mission-driven technology development is characterized by uncertainty, interdependence and multiple maturity trajectories; no single organization can conduct technology maturation in isolation. Hence, for mission-driven innovation, co-innovation is not a supporting activity but a design dimension in its own right – one that cuts across joint purpose and values, shared strategy, trust-building leadership, enabling structure and governance, iterative and linear innovation processes, and aligned budgeting and planning.

The results confirm that shared purpose and values form the cultural and motivational foundation for cross-organizational innovation. In the CO_2-to-X ecosystem, the statement "partners, not customers" translated mission directionality (Mazzucato, 2018; Hekkert et al., 2020) into everyday coordination,

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creating trust and psychological safety for experimentation. Where this purpose was not explicit, as in some Design4AM supplier relationships, collaboration defaulted to transactional behavior and restricted knowledge exchange. This supports Rigby et al.'s (2020) claim that common purpose is the stabilizing element of agile enterprises: it binds adaptive teams without relying on hierarchy. In mission-driven ecosystems, purpose alignment thus seems to act as relational governance, mitigating opportunism and enabling iterative learning across organizational boundaries.

The two cases further illustrate that effective mission-driven innovation depends on joint strategic framing and distributed leadership. Shared strategy allows actors to see how individual technology trajectories contribute to the larger mission (Larrue, 2021), while distributed leadership maintains momentum across organizational interfaces. In CO_2-to-X, visible project leadership and high-trust personal relationships aligned partners with heterogeneous goals; in Design4AM, projects with stable leadership advanced faster through maturity gates. This reflects the systemic logic presented by Rigby et al. (2020) where strategic alignment and empowerment coexist—leadership defines direction but allows autonomous adaptation. Consequently, leadership in mission-driven ecosystems becomes a design practice: shaping cadence, routines, and interfaces that sustain joint learning.

Mission-driven ecosystems require enabling structures and governance systems that combine stability and agility. Both cases displayed dual governance patterns: formal contracts, safety procedures, and regulatory frameworks provided legitimacy for experimentation, while agile work packages and informal communication channels ensured responsiveness. This combination transformed classical stage-gates into cross-organizational decision nodes where partners jointly validated progress, reviewed resources, and re-aligned the mission trajectory – extending the Agile–Stage-Gate principles established by Cooper and Sommer (2018). Such integrative governance structures allow organizations to balance control with learning, maintaining accountability while accelerating maturation.

The case study supports and extends research on hybrid Agile–Stage-Gate processes (Sommer et al., 2015; Pisanu et al., 2025). Collaboration occurred iteratively across TRL stages, not sequentially. Firms could not wait until suppliers reached full technological maturity before engagement; instead, they co-developed solutions through shared prototyping and validation loops. This co-maturation behavior constitutes a new pattern of innovation process design for missions: maturity is achieved through continuous interaction among ecosystem partners. A transactional partnership, by contrast, proved ineffective because it limited feedback on technical details and prevented mutual adjustment. These findings reinforce the notion that mission-driven innovation in advanced manufacturing must extend beyond internal teams to relevant ecosystem partners.

Budgeting and planning mechanisms played a decisive role in sustaining innovation. Strategic collaboration agreements – jointly defining milestones, cost-sharing and risk allocation – created mutual commitment and ensured continued engagement through uncertainty. Such arrangements turned potential asymmetries into win–win situations: suppliers gained developmental experience and market credibility; lead firms secured early access to maturing technologies. However, challenges arose when expectations of partnership maturity were unclear or when any actor behaved as if the relationship remained a traditional buyer-supplier transaction. Ambiguous governance led to delays and conflict over investment responsibility. This underscores the importance of financial alignment and transparency – elements often absent from classical TRL frameworks but central to mission readiness.

The empirical insights reinforce and extend calls to broaden maturity assessment beyond the innovation process (Hallstedt et al., 2017; Trump et al., 2025). Mission-driven innovation captures the combined maturity of the systemic factors within its operating context. The cases show that firms did more than execute pre-defined processes; they designed the innovation process itself – instating standing sprints, cross-partner reviews, and flexible gates – akin to how design process models emphasize iteration, stakeholder involvement and dynamic feedback (Acklin et al., 2010; Design Council, 2019). By treating the innovation process as a design object, the ecosystem partners enabled co-maturation across TRLs, rather than sequential hand-offs. This supports Hernández et al.'s (2018) insight that design acts as the language of innovation: it aligns artefacts, actors and activities into coherent flows of value creation. Thus, designing the innovation process becomes an additional layer of capability for mission-driven technology maturation.

To summarise, the cases show how mission-driven technology maturation is orchestrated as a systemic configuration of six interdependent design elements: shared purpose and strategic transparency; visible, cross-organizational leadership; enabling structures and governance mechanisms that combined formal agreements with flexibility; iterative learning loops embedded within TRL-based trajectories; and

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aligned budgeting and risk-sharing arrangements. Innovation thus unfolds as co-maturation across ecosystem boundaries, where gates and milestones function as joint synchronization points within an integrated ecosystem-level governance design rather than as handover moments in a firm-bounded development process.

5.1. Practical and theoretical contributions

For practitioners in advanced manufacturing, several implications emerge. First, mission-driven innovation begins with purpose alignment: partners should establish clear, shared missions and value propositions to ensure motivation and direction throughout technology maturation. Second, firms should design strategic partnerships rather than transactional contracts, creating long-term agreements that share risks, rewards, and learning responsibilities across the ecosystem. Third, visible project leadership is critical. Appointed innovation leaders coordinate interaction rhythms, manage dependencies, and maintain trust across organizations. Fourth, companies should institutionalize co-maturation by engaging suppliers or partners early, embedding iterative loops, and conducting joint maturity reviews instead of relying on linear hand-offs. Finally, aligned investment logic – through shared budgeting and transparent cost allocation – prevents discontinuity as projects advance from research to production. Together, these practices transform innovation from a cost center into a strategic capability, enabling firms to mature technologies faster and more effectively within complex mission-driven ecosystems.

This study suggests that mission-driven innovation functions as an integrated design approach, in which successful technology maturation depends on how organisations align around shared purpose, formulate joint strategy, employ coordinated leadership, establish enabling governance, combine iterative and linear innovation processes, and share budgeting and planning responsibilities. By conceptualizing innovation as a designable capability, the paper advances the view that innovation outcomes depend as much on the architecture of relationships as on the technologies themselves. Furthermore, it extends Agile–Stage-Gate theory (Cooper & Sommer, 2018) beyond the boundaries of a single firm, showing how stage-gates function as ecosystem governance events that synchronize learning, decision-making, and resource allocation across partners. This reframing positions agility not merely as a team-level method but as a cross-organizational design principle. Finally, the study links design research on process and governance with contemporary debates on mission-oriented innovation, providing constructs for innovation framework to analyze how design decisions influence the success of technology maturation within an ecosystem.

For the academic community, the findings open several avenues for future inquiry. There is a clear need to develop and validate mission-driven innovation frameworks that capture cross-organizational maturity and provide operational tools for assessing ecosystem innovativeness. Further research should investigate design governance artefacts – including mission charters, value measure/performance indicators for innovation impact assessment, shared project information etc. that translate strategic intent into daily coordination mechanisms. A promising direction is to examine innovation governance and processes capable of balancing stability and agility across organizational boundaries, advancing understanding of dual governance in mission-driven innovation. Finally, longitudinal studies are needed to evaluate the long-term performance effects of strategic innovation agreements and to measure how iterative, technology-focused collaboration shapes the trajectory from early research to industrial scale. Together, these directions will deepen the theoretical and methodological foundations of design for mission-driven innovation.

The exploratory nature and limited number of cases constrain generalizability. Future research should extend to other mission-driven innovation domains and use mixed methods to quantify the effect of the systemic dimensions on deployment speed and innovation outcomes. In sum, as complexity rises, the ability to collaborate iteratively – anchored in shared purpose, strategy, leadership, governance, process, and budgeting & planning – determines success. Transactional partnerships cannot deliver missions; strategically designed collaborative innovation can.

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