TECHNOLOGY-RELATED BUSINESS DISRUPTION IN THE INDIAN AEROSPACE SECTOR

by

JOFY JOSEPH PRASAD, BE

DISSERTATION

Presented to the Swiss School of Business and Management Geneva

In Partial Fulfillment

Of the Requirements

For the Degree

DOCTOR OF BUSINESS ADMINISTRATION

SWISS SCHOOL OF BUSINESS AND MANAGEMENT GENEVA

FEBRUARY 2026

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JOFY JOSEPH PRASAD

APPROVED BY

Dissertation Chair

RECEIVED/APPROVED BY:

Renee Goldstein Osmic

Admissions Director

Dedication

This thesis is lovingly dedicated to my family. To my wife, whose unwavering support, patience, and encouragement have been my constant source of strength. To my son and daughter, whose joy and curiosity inspire me to strive for excellence. And to my parents, sister who instilled in me the values of perseverance, integrity, and lifelong learning.

Acknowledgements

I would like to mention that I would not have achieved my DBA without my mentor whose advice and support have played a very significant role in my journey towards completing my doctoral degrees. Your support and advice have been my constant push to keep going and reach this milestone.

I would also have to say a word of gratitude to SSBM Geneva, which has offered me a greater level of knowledge and academic excellence and has enhanced my research and expanded my vision.

I also owe a debt of gratitude to the organizations that I am affiliated with, their assistance and chances that helped me to carry out this work. My clients and well-wishers in the aerospace and defence industries are the beneficiaries of my heartfelt gratitude who have actively participated in surveys to make this study a success. Your knowledge and assistance has been invaluable. Lastly, I offer the love of my family my wife, son, daughter and parents who have loved, been patient and made sacrifices. I would not have been able to do this without your support and faith in me.

ABSTRACT

TECHNOLOGY-RELATED BUSINESS DISRUPTION IN THE
INDIAN AEROSPACE SECTOR

JOFY JOSEPH PRASAD
2026

The aerospace industry in India is changing due to recent policy changes, and entry into the industry by the private sector, although, regulatory barriers, certification and a fragmented supplier base are threatening to restrain the adoption of technology predictably. The gap that this thesis will fill the issue of perception of regulation as a self- restrictive phenomenon, and a reproducible framework in order to predict and handle the disruptive change in the aerospace ecosystem of India. This study adopts a comprehensive research approach that integrates dynamic policy simulation, value-chain mapping, and policy Analysis. Primary data are drawn from purposive surveys with regulators, original equipment manufacturers, startups, and suppliers; these sources set up the simulations and shape standard evaluation criteria. Sensitivity and robustness tests assess policy interventions and indicate the strength and the relative impacts of model changes. The findings prove that regulatory and institutional forces play a significant role in the implementation of new technologies. Simulations reveal that long approval timelines, ambiguous evaluation criteria, and unclear liability regimes constitute the most significant bottlenecks, creating a “liability of disruption” for new entrants and increasing risks further down the supply chain. The gains in speed of approval and legal predictability create greater and more enduring gains in the survival of startups and market access compared to capacity expansion. Reliance on imports and one-supplier systems continue to enhance the effects of regulatory delays. The study concludes that effective aerospace innovation in India requires coordinated reforms that coordinate clear regulations, sufficient certification, strong supply chains, and skilled workers. The thesis contributes theoretically by including how regulations are designed and how institutions function into models of how new ideas spread, and practically by providing a reproducible framework for policy testing and decision support. While limitations related to targeted sampling and simulation assumptions remain, using multiple methods and reliability checks support practical, policy-related findings to help India compete globally in aerospace.

Key words: Space economics, Aerospace innovation, Disruptive change, Policy simulation, Value chain mapping, Regulatory barriers, Technology adoption.

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LIST OF ABBREVATIONS

AI: Artificial Intelligence

CDI: Christensen's Theory of Disruptive Innovation

FDI: Foreign Direct Investement

GDP: Gross Domestic Products

GERD: Gross Domestic Expenditure on Research and Development

GST: Goods and Services Tax

IN-SPACe: Indian National Space Promotion and Authorization Center

ISRO: Indian Space Research Organization

ISP: Indian Space Policy

LoD: Liability of Disruption Framework

MSME: Micro, Small and Medium Enterprises

NGEs: Non-Governmental Entities

NGP: Norms, Guidelines and Procedures

NWKV: Network Access to Knowledge and Value

OEM: Original Equipment Manufacturer

PSU: Public sector undertaking

ROI: Return of Investement

R&D: Research & Development

SD: System Dynamics

TRA: Theory of Reasoned Action

TReDS: Trade Receivables Discounting System

USD: US Dollar

USRV: User Involvement

VC: Venture Capital

VCM: Value chain mapping

VSSC: Vikram Sarabhai space Center

₹: Ruppe

CHAPTER I:

INTRODUCTION

1.1 Introduction

Technological change in the aerospace and space sectors has shifted from occasional innovation to ongoing, widespread change. This shift is more acute in India: policy changes, digitalization and the emergence of new privately-owned companies are altering a traditionally-state sector. Decentralization the transformation of a state-run model into a competitive public-private ecosystem is a national strategic priority, which is driven by measures including Make in India, Aatmanirbhar Bharat and the revisited Indian Space Policy. The aim of these reforms is both to increase the production and the reorganization of capability development, certification and integration into military and commercial applications. Nevertheless, the vibrant aerospace ecosystem is still plagued by the lack of strength in regulations, insufficient certification capacity, and a fragmented innovation and supplier channel.

This thesis addresses this gap by examining how policy, public trust in institutions, and ecosystem structure shape the trajectory, speed, and resilience of technology adoption in India's aerospace sector. It addresses four connected challenges:

1. Easier regulations and private involvement;
2. IN-SPACe and innovation pathways;
3. Global competitiveness and policy effectiveness;
4. Economic benefits and long-term outcomes.

These barriers prevent stakeholders from converting policy intentions into reliable, scalable results and hinder India's goal of expanding its share of the global space economy.

This study develops and validates an unified, repeatable framework to model disruptive change in India's aerospace sector. It combines simulating policy changes, value-chain mapping, and consistent evaluation criteria, making the interaction of factors visible, measurable, and actionable. The thesis thereby advances theory-by reconceptualizing regulation as an endogenous, capacity-constrained factor in diffusion models and practice, by equipping regulators, committees, and industry with decision-support tools that curb arbitrariness and enhance policy operational alignment.

To address these questions, this thesis employs a research design using various methods and focusing on systems. Dynamic simulation provides the main analysis method, modeling feedback loops, time delays, certification capacity, and constraints across regulators, OEMs, and suppliers. This quantitative foundation is triangulated with qualitative data from targeted surveys of regulators, committee members, startups, OEMs, and suppliers. Value-chain mapping and index analysis link simulation outputs to key operational factors-funding thresholds, training capacity, supplier lead times, and R&D patterns. Tests for model stability and reliability assess model stability and isolate relative effects; policy documents and cross-validation mitigate limitations in perception- based survey data.

The thesis makes three main contributions. First, it provides a reproducible modeling framework that incorporates regulatory design and enforcement capacity into models of how technology spreads, extending theory of how things spread to regulated, high-stakes sectors. Second, through adjusting based on real-world data and survey validation, it identifies key bottlenecks and shows how they intensify supply-chain stress and delay adoption. Third, it develops decision-support tools-standardized guidelines and templates-that make evaluations more consistent, boost transparency, and align committee decisions with policy goals. These outputs bridge academic modeling and policy practice with rigorous, practical tools.

This research has direct policy relevance. India aims to increase its share of the global space economy, as stated in national policies (Sivan, 2025),(Mani, Dadhwal and Shaijumon, 2025). To succeed, India must convert regulatory reforms into swifter, more transparent, and authorization processes that match available resources. This study pinpoints order of regulations, capacity investments, and design of guidelines as prime levers for maximum gains-thus delivering a precise roadmap for reforms.

The quality of data will directly influence the extent of the model validity it is but a given fact.The sampling will be targeted, and so the results may not be applicable across the board. And as the focus is centered on the aerospace industry in India, can it be extrapolated on other industries? Proceed with caution. These weaknesses are, however, counterbalanced by triangulation of multiple sources, sensitivity analysis of model robustness and emphasis on relative policy understanding and not absolute predictions.
This lead is an exposition of a thesis that converts the policy movement into foreseeable, actual actions. It combines systems modeling, observation-based investigation and decision-support design. Therefore, the study enables Indian policy-makers and industry players to drive aerospace dislocation into nationally-strategic and scalable gains.

1.2 Research Problem

Indian aerospace is in the strategic act of changing to a more innovative and competitive ecosystem as opposed to state dominated.While governmental reforms and the integration of Industry 4.0 technologies have demonstrably facilitated opportunities for private sector engagement, the sector still faces three persistent and interrelated impediments that hinder its comprehensive disruptive transformation:

1. Absence of Systemic, Quantitative Models

Today, studies in this area remain largely to qualitative initiatives. Solid for context, sure. However, it lacks on the quantitative front -the rigorous, data-driven models that might trace the real impact and trend of disruptive technologies in the Indian aerospace industry.That is an issue. It makes all people, including policymakers, to investors, unable to determine the extent of technology changes.Or their bottom-line impacts.

Consequently, the ability to design useful actions and policy actions remains significantly constrained by a lack of real-world validation and prediction capabilities. Furthermore, the limited availability of complete, comparable data across various smaller sectors restricts the development of strong data-based methods needed to benchmark performance against international standards and identifying critical areas for intervention (Vértesy, 2011) (Bakar et al., 2025). Moreover, the absence of standard measures for assessing technology maturity levels and market presence further exacerbates this gap, hindering objective evaluation of new aerospace companies and their potential for scalable disruption (Bansal & Aggarwal, 2019).

2. Institutional and Regulatory Friction

Despite the adoption of IN-SPACe and the Indian Space Policy 2023, the new private firms still face the same problem, which is acceptance, ineffective regulations, and liability. These institutional frictions thus impede the intended impact of reforms and slow the sector's disruptive transformation. The lack of clear operational guidelines and a simplified approval process, even under updated policies, causes investor uncertainty and hinders the growth of innovative aerospace companies (Bisht et al., 2023). These bureaucratic hurdles disproportionately affect smaller enterprises and startups, which possess fewer resources to navigate complicated administrative systems, thereby creating a significant barrier to entry and equal competition (Deshpande et al., 2024).

3. **Fragmented Innovation Ecosystem and Skill Deficits**

It is difficult to integrate the Industry 4.0 technologies in the Indian aerospace industry. Global networks? Hardly there. Worst of all, skilled workers are in short supply it's a real bottleneck. This patchwork setup stifles everything. Private firms struggle to grow to gain that competitive edge they desperately need.

These issues highlight the need for a strong research structure to quantify disruptive impacts, propose actionable strategies for reducing regulatory obstacles, and foster a connected, skilled innovation system. The germinal research problem therefore consists in the fact that there exist no unified, data-rich models that can be used to examine and model the dynamic interaction of policy, organizational acceptance and use of technology in this dynamic sector. Without such models, stakeholders cannot accurately forecast disruption, develop targeted solutions, or fully achieve India's strategic potential in the global space economy (Uwaoma et al., 2023). This gap is particularly acute due to the fast development of global space technologies and the critical importance of this sector for national security and economic growth. Specifically, the study will address how simplifying regulatory processes through dynamic policy simulation models can quantify the impact of changes to authorization timelines or changes to liability clauses on market behavior. This methodology would help fill a very important gap in the current literature by offering how potential solutions can be modeled and their economic impacts measured to go beyond identification of problems.

There is a lack of systematic, data-driven models of disruption measurement; institutional and regulatory drag despite the efforts such as IN-SPACe and the Indian

Space Policy 2023; and a disjointed innovation system and shortage of skilled labor, which restricts the growth potential and intense development. The literature that is available gives rather explanatory insights into these issues, but does not provide the fact- based methods of analysis and prediction that would allow one to fully explore the problem. This study fills this gap by establishing a quantitative framework of analysis and simulation of the dynamic interaction of policy, institutional legitimacy, and technological adoption of Indian aerospace industry. In the absence of such models, the various effects of change cannot be precisely estimated and become central in the development of specific actions, as well as making the best out of India as a strategic location in the global space economy.This weakness in analysis hinders creating effective policies and smart resource allocation necessary for India to establish itself as a global leader in aerospace innovation (Rao et al., 2019) (Vértesy, 2011).

1.3 Purpose of Research

This study aims at creating a coherent, quantitative model that is used to simulate the disruptive change of the Indian aerospace industry. The purpose of this research is to develop an comprehensive, data-driven approach that models the disruptive transformation of the Indian aerospace sector. This framework will analyze the interplay of policy reforms, institutional legitimacy, and technological adoption. The study aims to generate actionable insights for policymakers and industry leaders to reduce widespread obstacles, enhance innovation ecosystems, and accelerate private sector competitiveness.

The Indian aerospace sector is undergoing a profound strategic transition, moving from a historical state-monopolized model to a dynamic, competitive public-private ecosystem. This structural reform, deemed a National Strategic Imperative, is driven by a convergence of proactive government policies and advanced technological adoption.

This transformation? It's fueled by some game changing reforms. The Indian Space Policy 2023 stands out-it upends the whole sector, flinging open doors for Non-Governmental Entities to tackle every kind of activity(Department of Space,2024).

Right alongside that, you've got the Indian National Space Promotion and Authorization Centre. This single-window regulator handles authorizations, cuts through red tape, and builds a real competitive vibe (Department of Space,2024).

The big ambition here: ramp up India's share of the global space economy from a modest ~2% to 8-10% by 2030 or 2033. Private sector muscle makes it happen.

Identifying Research Gaps: Although the new progressive policies have been introduced, the successful voyage of the disruption is undermined by the structural and methodological gaps existing in the ecosystem and the existing literature.

Lack of Systemic, Quantitative Models for Measuring Disruption: A major research gap is that there no quantitative systems to examine the dynamic interactions of the changing ecosystem and quantify the effects of disruptive activity at the level of value-chain. Research that is currently being conducted mostly employs a descriptive or qualitative approach, restricting the ability of stakeholders to predict the outcome or determine how sensitive the ecosystem may be to a certain variable.

Regulatory and Institutional Frictions: Despite policy reforms, new private entities encounter institutional resistance and face significant regulatory hurdles. These include a complex, multi-stage authorization process, which can extend up to 120 days, and strict responsibility rules that make companies protect the government from blame.

Fragmented Innovation Ecosystem and Skill Deficits: Disruptive technology is finding it very difficult in our fragmented innovation ecosystem. International experience in technology and management? Tough to come by Skills shortage hits even harder a mismatch between what academia spits out and the sharp, specialized know-how needed for fresh digital business models.

This research has a three main goals, focusing on quantitative solutions beyond problem identification:

1. To create an efficient, evidence-based model of disruptive impacts simulation and quantification. These include building of dynamic policy simulation models to evaluate regulatory situations and building a detailed value-chain map to empirically monitor technology, capital, and knowledge flows.

2. To propose actionable strategies for mitigating regulatory hurdles. The research will use simulation models to quantify the economic implications of adjustments, such as streamlining IN-SPACe authorization timelines or revising liability clauses, thereby yielding empirically validated interventions.

3. To reinforce the policy, skills, and stakeholder approach to the innovation ecosystem. The study will help estimate the value of return-on-investment of specific targeted skill-building programs and ecosystem integration initiatives by quantifying the bottlenecks in the value chain (e.g. barriers to user integration and collaborative networks).

Research Impact: The impact of the research is to offer predictive actionable advice to key stakeholders, to support national strategic goals:

Support Evidence-Based Policymaking: Inform Evidence-based policy decisions: Provide a prospective, predictive framework, streamline competitiveness in the private sector and utilize strategic assets optimally. Empower Private Aerospace Enterprises: Provide the private firms and entrepreneurs with quantitative devices..

Empower Private Aerospace Enterprises: Equip private firms and entrepreneurs with quantitative tools. Strategic insights, too. So they can wrestle through regulatory complexities and unleash their full disruptive innovation potential.

Advance Academic Knowledge and Industry Practice in Disruption Modeling: Advance Academic Knowledge and Industry Practice in Disruption Modeling:

By rolling out system-level simulation methodologies, we can finally dig into those tangled technological and political dynamics. The time has come we threw out the archaic, descriptive analysis constituting the clutter in innovation research. This drives the field in an uneven pace, yet definitely. The study offers a predictive model to simulate the interaction between the drivers and inhibitors and evaluate the disruptive power and trend of the aerospace industry in India in the global space economy. The paper presents a predictive model to model the interaction between the drivers and inhibitors and determine the disruptive power and trend of the aerospace industry in India within the global space economy.

1.4 Significance of the Study

The 2025 Nobel Prize in Economic Sciences, which was given to study on innovation-driven growth and creative destruction, emphasizes the importance of innovation in the global economic transformation. The Indian aerospace sector exemplifies how disruption differs from destruction: unlike Schumpeter's model of replacing old industries with new ones, this research shows aerospace disruption as **transformative**, fostering innovation networks, private sector engagement, and Industry 4.0 adoption.

The research is proposed with addressing strategic priorities on a country-level, disparities in the methodology of the current research and the need to have predictive tools. It offers scholarly and practical information in policy, industry, and technology using quantitative modeling and systems analysis. In particular, this study fills a very essential gap in existing literature one that is long overdue. It conjectures detailed evidence-based frameworks that accurately calculate the effect and path of technological- based disruption in the Indian aerospace industry.

Strategic and Economic Imperatives

The aerospace change of India has become a national strategy, which involves its economic and geopolitical future.

Global Market Share Expansion: Reforms seek to increase India's share of the global space economy from 2–3% to 10% by 2030 (Sivan,2025). With the global market projected at $1.1 trillion by 2040, this research models the required growth trajectory.

Alignment with National Programs: Aerospace disruption is commensurate with Make in India and Aatmanirbhar Bharat, which focus on minimizing the level of imports and establishing India as a manufacturing-technology center. Disruption modeling is essential for these goals.

Societal and economic benefits: Disruption will create millions of high-tech jobs, drive modernization, and establish India as an aerospace innovation leader.

Addressing Gaps in Research Methods and Prediction

This research fills a key gap by developing integrated quantitative frameworks to measure disruption's dynamic effects.

Beyond Static Analysis: Previous studies stick to descriptive policy reviews. Qualitative surveys, too. They offer insights, sure but static ones. Frozen frames of a moving world.

This changes everything. Dynamic simulations make the action alive and follow-up the changes, experimenting with situations, and uncovering the next step.

Predictive Capability: Stakeholders cannot predict the disruption, or test the impacts of policies on the ecosystems in the absence of quantitative models. This paper uses policy simulation and value-chain mapping as the forward-looking analysis tool.

Quantifying Interventions: The available studies have found a range of problems such as regulatory delays or staff shortages but rarely measures solutions. Here, we model economic impacts, such as shortening IN-SPACe authorizations from 120 days.

Policy and Governance Impact

This study provides practical insights for data-driven policymaking and resource allocation.

Reducing Policy Barriers: It models regulatory and institutional obstacles, offering strategies to address the challenges associated with disruptive innovation for new non-governmental entities.

Enhancing the Ecosystem: It measures such aspects as a lack of user engagement and low international access and advises specific investment in skills and integration to increase returns.

Empowering Private Sector Competitiveness

The New Space startups in India such as Skyroot Aerospace and Agnikul Cosmos are rocking. However, they have high technological obstacles and organizational restrictions.Getting past those won't be simple. This research bolsters their competitiveness by providing:

Strategic Tools: Quantitative metrics (e.g., research and development efficiency, and reduced launch costs) and insights for effective navigation of the technological and political landscape.

Linking Research to National Goals

This research takes those standard descriptive analyses of India's aerospace reforms and flips them into sharp, quantitative predictive tools. It arms policymakers. Industry leaders. Entrepreneurs, too. Helping them tackle risks, ramp up growth, and smash national targets.

- **Economic Growth Targets**: by 2033, India is targeting a huge space economy of 44 billion dollars. Taking 8 percent of the world market. This paper trails the road to that fivefold increase that we have the statistics to support.
- **Private Sector as Growth Engine**: The Indian Space Policy 2023 puts non-governmental institutions in end-to-end space activities on the forefront. This study defines and measures impediments such as regulatory complexity, funding gaps, and discontinuous ecosystems.
- **Strategic Investment Facilitation**: The study sheds light and certainty to bring in capital and helps in facilitating the softening of foreign direct investment policies and the ₹1,000 crore space industry Venture Capital Fund.

Implementing Accelerated Technological Development

This paper advocates adoption of disruptive technologies to enhance overall impacts in view of the long-term competitiveness of India. By quantifying disruption, it bolsters policy credibility, guides reforms, and improves institutional efficiency especially IN-SPACe's role in authorizing and supporting non-governmental entities.

Conclusion

This research transforms assessments of aerospace reforms. Out with vague qualitative overviews. In with rigorous quantitative metrics. Data-driven frameworks bridge that longstanding gap, pinpointing exact policy shifts and tech advancements. They power India's Viksit Bharat @ 2047 vision. Aerospace disruption? It drives explosive economic growth and sharpens global standing. Take the Indian Space Policy 2023. It signals bold government backing for a booming space economy ignited by public-private synergy.

1.5 Research Purpose and Questions

This research focuses on developing quantitative tools to guide the disruptive transformation of the Indian aerospace sector. This study aims at formulation of quantitative instruments to spearhead the disruptive change of Indian aerospace industry. The ongoing change alters the industry model to a closed and state-monopolized model to a dynamic public-private ecosystem.

Research Purpose

This study will be able to formulate a quantitative, integrated framework in order to model the disruptive change of Indian aerospace industry.The framework dives into the interplay of policy reforms, institutional legitimacy, and technological adoption. I'll unpack these dynamics to deliver actionable insights. These will empower policymakers and industry leaders to dismantle systemic barriers, nurture vibrant innovation ecosystems, and propel private sector competitiveness forward.

This research plugs a major hole in the literature. Right now, we're missing systemic, quantitative models. Models that can handle the dynamic back-and-forth in this new ecosystem, and nail down exactly how disruptions hit the value chain. Current research relies predominantly on descriptive policy analysis, high-level economic reports, or qualitative stakeholder surveys, providing a static view rather than a predictive model. The overall goal is to go beyond identification of the problems to quantitatively modeling their solution. This consists of development of dynamic policy simulation models and building a detailed value-chain map.

Research Questions

The research questions that are discussed in the framework of the given research imply significant drivers and inhibitors that the current literature outlined: **Policy Dimension**

- What impact would recent changes, including the Indian Space Policy 2023 and the creation of IN-SPACe, have on disruptive changes in aerospace value chains?
- One of the structural reforms, which officially opens the sector to Non-Governmental Entities in all activities, is the Indian Space Policy 2023.
- IN-SPACe was instituted as the Single-Window Regulator and Facilitator which has the mandate of ensuring a stable, predictable regulatory environment and a level playing field among NGEs.
- The reform will expand the Indian contribution to the world space economy by taking up approximately 2 percent of the global space economy to a possible 8-10 percent in 2030 or 2033.

- What implications are there, measurably, of authorization timelines, and liability clauses, on the participation of the private sector?
- Nevertheless, even though the purpose of the streamlining is accomplished, the Norms, Guidelines, and Procedures published by IN-SPACE provide a multi-level process of authorization that may take up to 120 days.
- Clauses of strict liability apply to the private applicants and make them highly liable, as they are required to compensate the government on all their losses.
- The study will measure the economic effect of shortening the IN-SPACe authorization process or changing liability provisions. These are known problems, but existing literature lacks measurable solutions.

Institutional Dimension

- What is the impact of institutional barriers and resistance to change by the aerospace sector?
- New entrants encounter the "liability of disruption," a unique challenge to their legitimacy, alongside resistance from regulators and established companies against their disruptive business models.
- This pushback appears as regulatory scrutiny and resistance from established state-owned companies, which may influence authorities to hinder new competitors.
- How does institutional legitimacy influence private sector competitiveness?
- Legitimacy refers to the perception that an entity's actions are desirable and appropriate within the social system. Disruptive firms naturally find it difficult to gain this acceptance because their business models challenge established norms and practices.

- To sustain successful and competitiveness in the long-term, it is important that the institutional hurdles facing the private firms are overcome.

Technological & Ecosystem Dimension

- What macro elements are increasing or slowing the adoption of Industry 4.0 technologies in aerospace businesses?
- Artificial Intelligence, Machine Learning, and Digital Twins are all Industry 4.0 technologies and essential to make transformative changes. An example of such is Digital Twins, which are elaborate digital models employed in simulation, testing, and predictive maintenance(Dinter, Tekinerdogan and Catal, 2022; Baalbergen, Marchi and Klerx, 2023).

  Adoption is significantly inhibited by persistent structural problems identified empirically:

  1. Lack of effective User Participation: The end-user is often seen as having limited influence and insufficient ways to integrate their expertise into innovation processes (Buer, Kamsvag and Strandhagen, 2024).

  2. Inadequate Access to Global Networks: Indian firms have limited access to international networks for technological and managerial knowledge.

- Lack of appropriate standard models or requirements data.
- How can skill-building programs and ecosystem integration efforts be quantified in terms of return on investment and innovation outcomes?
- Despite a persistent critical skills shortage and mismatch between educational output and industry needs especially for disruptive digital business models requiring a "self-disruption" mindset existing literature lacks quantitative models

to assess the economic impact of interventions, such as specific skills-building programs on startup growth.

- This research will use system-level simulation and value-chain mapping to quantify the return on investment from targeted interventions in skill development and network integration.

Significance

Answering these guiding questions puts our study right in the thick of policy, institutional legitimacy, and tech adoption.We end up with a multi-dimensional focus. It's academically on point. Strategically, a real winner.

Academically Relevant:

This study plugs a key methodological hole. Existing work sticks to qualitative insights and basic descriptions. Ours doesn't. We bring in system-level simulations to dissect disruptions amid tangled techno-political dynamics.

We advance disruption modeling here. It's by empirically testing frameworks like the "liability of disruption" smack in the middle of India's aerospace sector- something that's long overdue.

Strategically Valuable:

The findings will offer predictive guidance and forward-looking insights that current research lacks.

It really backs evidence-based policymaking.

We hand over tools here practical ones to quantitatively test how sensitive the ecosystem is to those key variables.

By unlocking the private sector's potential, we can really push forward.

This drives India's big strategic aim: ramp up competitiveness and claim a solid share of the global space economy.

This analytical approach ensures that the output is not just a description of challenges but a predictive diagnostic tool that empowers private aerospace enterprises and informs strategic resource allocation.

CHAPTER II:

REVIEW OF LITERATURE

2.1 Theoretical Framework

The analytical framework for technology-driven business disruption in the Indian aerospace sector is grounded in three core, interrelated theoretical perspectives. These perspectives collectively clarify the essential characteristics, underlying dynamics, and institutional barriers shaping this disruptive transformation. It's framed right now as a national strategic priority-one that's really kicking the Indian aerospace sector into high gear. Out with the old state-dominated model. In with a competitive vibe, full of public-private partnerships. "Make in India" and "Aatmanirbhar Bharat" are steering the ship.

Diving into the theories behind this shake-up, I've got Christensen's Disruptive Innovation on deck. The Liability of Disruption framework fits too. And Industry 4.0? It's transforming those innovation ecosystems in big ways.

It is described in this section that the analysis of disruption in the aerospace industry in India is based on the key theoretical frameworks.

2.2 Christensen's Theory of Disruptive Innovation (CDI)

CDI will be used to determine how far the transformation of the Indian aerospace sector has been a radical change of the conventional industry structures.

Core Concepts and Application: This theory shows how startups and fresh entrants rattle the big established companies. They roll out simpler stuff,cheaper, handier options that first hooks those ignored market corners. Meanwhile, incumbent firms pursue sustaining innovations for their high-value customers. They often overlook these disruptors until it is too late.

Relevance to India: Christensen's framework is particularly apt for the Indian aerospace sector.Non-governmental entities are surging ahead. Skyroot Aerospace. Agnikul Cosmos.These newcomers are boldly confronting the sector's entrenched state dominance a dynamic straight out of disruptive innovation theory.

Adaptation and Empirical Limitations: A study applies Christensen's framework straight to India's aerospace and defense sector. Punchy conclusion: those disruptive forces underway? Not empirically strong enough. Not for game-changing innovation, anyway.The researchers tailored it adding two vital factors to Christensen's four core dimensions to match the sector's one-of-a-kind setup.

1. The authority of the user (defense forces and government entities) to drive the process of innovation.
2. Company access to global technology and management innovation networks. This analysis revealed a critical tension: while driving factors such as "Signals of Change" and "Non-market Forces" (e.g., Government of India initiatives like Make in India and Start-Up India) are robust, their impact is significantly mitigated by structural inhibitors. The primary inhibiting factors identified were weaknesses within the User and Network domains. This highlights a significant impediment to achieving large-scale disruptive innovation, as identified by the inadequate user participation and insufficient integration into global technology and management expertise networks within the Indian aerospace and defence industry (Rao et al., 2019).

2.3 The Liability of Disruption Framework (LoD)

Liability of Disruption model analyses the institutional challenges to entry that face the private players in the aerospace industry of Indian state. It is regulatory stonewalling, incumbent pushback and even side-eye within the society side against these newcomers.

Take regulations. The entry companies are subject to the additional scrutiny. And fitting into old rules? Ruthless, particularly of permissionless entry into new markets without local signature.In the case of Indian aerospace, this has been manifested in repeated problems to the Ease of Doing Business and complicated procedures that, even with the Indian Space Policy 2023 that aims to provide fair competition, have yet to permit entry by companies such as Skyroot Aerospace and Agnikul Cosmos.This resistance is further made worse by the inherent challenges of the aerospace and defense sector, which demands strategic planning and creative thinking to overcome obstacles like complex contemporary warfare and asymmetrical threats (Anto, 2024).

In India's aerospace sector, Ease of Doing Business issues just won't quit-they linger alongside those endless, frustrating approval mazes. The Indian Space Policy 2023 pushes for fair competition across the board . Still, it's private newcomers like Skyroot Aerospace and Agnikul Cosmos who keep slamming into roadblocks.

Core Concepts and Institutional Pushback: Disruptive companies? They pile on extra costs and real headaches. The Liability of Disruption framework spells this out: business models that straight-up defy industry norms and regulations (Marano, Tallman and Teegen, 2019).

For disruptive firms, securing legitimacy that deep-seated belief that their actions are appropriate, even desirable is absolutely essential. It's not just nice to have; it's the key to surviving institutional resistance and thriving long-term.

LoD manifests as three interconnected types of institutional resistance:

Regulatory Pushback: This means government bodies turn up the heat with extra scrutiny. They roll out new rules to box in disruptive firms especially when those companies rush into markets without local approvals first.

Incumbent Pushback: Established firms push back hard. Reflect Public Sector Units-they perceive these new entrants by the private as being sneaky unfair competitors. And they lobby regulators to block them.

Societal Pushback: Concerns from stakeholders regarding potential negative side effects, such as issues related to safety, security, and labor rights, resulting from disruptive operations.

Policy Friction in India

Academic literature often questions the fairness of India's new regulatory framework, (‘’Need for Space Law in India and A Critical Appraisal of the Indian Space Policy, 2023,’’ 2024) despite the Indian Space Policy 2023's goal of promoting equitable competition (Sachdeva, 2024).This is in contrast to ongoing problems with the ease of doing business and complicated approvals that are still a barrier to new entries into the private sector (Basu, 2018).

2.4 Industry 4.0 and the Innovation Ecosystem Framework

This framework defines the technological setting of disruptive forces in the field, and it is necessary to have a coordinated innovation ecosystem to bring these technologies together. This implementation is required to take advantage of the advanced manufacturing, artificial intelligence, and data analytics to optimize the aerospace production and operational efficiencies (Iyer et al., 2024).

Technological Drivers of Disruption:

1. **Industry 4.0:**Industry 4.0. The Fourth Industrial Revolution. It fuses digital and physical systems in ways that reshape everything. Core technologies? Artificial intelligence. Big data analytics. The Internet of Things. Advanced robotics. All transforming manufacturing. And aerospace operations too (Kumar et al., 2023) .

2. **Key Technologies:** Key enabling technologies? You know, Artificial Intelligence and Machine Learning they develop, study, expand limits. Cyber-Physical Systems combine computing intelligence with the physical basement. The Internet of Things then draws it into an interconnected web.

3. **Transformative Applications:** These advancements transform manufacturing, design, and service delivery, notably through Digital Twins and Advanced Manufacturing Techniques, which accelerate development and reduce costs.

Ecosystem Challenges and Human Capital Deficit:

Ecosystem Dependence: Disruptive success hinges on comprehensive innovation ecosystems, networks, and external partnerships, extending beyond individual firms.

Fragmentation Challenge: The first issue that has caused a challenge in technology adoption in India is the long-standing fragmentation of the home ecosystem accompanied by a shortage of skilled labor.

Skills and Attributes: According to the studies, the required skills include innovation, critical reasoning, leadership, management, and a mindset of self-disruption to move in the disruptive digital businesses.

2.5 Theory of Reasoned Action

The inclusion of the Theory of Reasoned Action into the research framework helps in uniting the high-level policy reforms with the implementation of individual decisions that are driving the changes in the Indian aerospace sector. The paper elaborates on the human and institutional variables that contribute to adoption or rejection of disruptive change by considering the attitudinal beliefs and normative demands as well as the description analysis. Trying to explain the behavior of the users in relation to rational considerations and social pressures, the Unified Theory of Acceptance and Use of Technology gives hints in understanding and predicting the probability of technology acceptance and use by users (Thoti, 2024).

Sealing a Behavioral and Quantitative Gap: The existing literature lacks systematic quantitative models that can be used to quantify the dynamics of the interactions within the new ecosystem in aerospace. The gap in the literature review and the methodology will be addressed by introducing the concepts of TRA that will explain how the data points of the simulation model will be explained (why).

Attitudinal Beliefs and Technological Adoption: Stakeholders develop attitudes based on perceived benefits of reforms, encompassing efficiency gains through Industry 4.0 technologies, including AI and machine learning and digital twins (Thoti, 2024),(Nadeem et al., 2023). The study measures the intentions to invest and innovate by mapping these beliefs, which quantifies the preference of views on GST exemptions or high-levels of FDI.

Normative Pressures and Institutional Friction: The threat of new entrants is connected to the liability of disruption by regulators and existing companies that oppose the standard models that attempt to change the existing norms (Marano, Tallman and Teegen, 2019).

Enhancing prediction ability through making it practical: Mapping survey responses from households enables setting up parameters of models with behavioral factors (Niamir et al., 2019).

1. Forecasting Disruption: Unlike fixed inputs of the policy, TRA predicts the effect of regulatory changes on the market-entry intentions of the private firms (Kingsley, Bergh and Bonardi, 2012).

2. **Reducing Regulatory Obstacles**: Measures can be made to overcome the hostility to quicker IN-SPACe authorizations, differentiating between risk attitudes and national security standards.

3. **Strengthening the Ecosystem**: The framework quantifies skill programs' ROI by tracking changes in the "self-disruption" mindset for digital business models (Alotaibi, 2018).

Significance of the Behavioral Dimension: This integration enhances the study's strategic value. India's goal of capturing 8–10% of the global space economy by 2033 (Deshpande, Palit and Hazra, 2024) depends equally on stakeholder buy-in and technological capability. TRA turns the research into a predictive diagnostic tool, helping policymakers link micro-level drivers to macro-level disruptions. Moreover, think about this framework-how it weighs personal factors right alongside situational influences. It delivers a truly nuanced view. Trust in those ecosystem elements? It sparks entrepreneurial behavior. And from there, it nurtures real success stories in India's aerospace sector (Rehman et al., 2022).

Table: 2.0 TRA based Hypothesis Mapping, source: Author's output, 2025

TRA Construct	**Variable (Survey/ Proposal)**	**Hypothesis**	**Survey Question Link**
Attitude	Regulatory efficiency perceptions	H1: Positive attitudes toward regulatory efficiency increase regulators' intentions to adopt streamlined workflows.	Q9 (Authorization workflow), Q17 (Policy metrics)

Subjective Norms	Inter-agency expectations, global competitiveness	H2: Stronger subjective norms matter a lot. Picture inter-agency coordination humming along, global benchmarks pushing hard. They nudge regulators toward real intentions: slashing those authorization lead times.	Q16 (Engagement mechanisms), Q21 (Data sharing)
Behavioural Intention	Policy enforcement outcomes	H3: Behavioural intention to implement reforms will mediate the relationship between attitudes toward liability frameworks and actual enforcement outcomes.	Q13–Q15 (Liability, insurance, dispute resolution)
Attitude	Perceived benefits of disruptive technologies	H4: Positive attitudes toward disruptive technologies will increase OEMs' intentions to adopt advanced aerospace subsystems.	OEM Form Q8 (Innovation source), Q11 (Adoption example)
Subjective Norms	Peer adoption, regulator collaboration	H5: Subjective norms from OEM–regulator collaboration and peer adoption will positively influence firms' intention to invest in Industry 4.0 technologies.	OEM Form Q23 (Collaboration examples)
Behavioural Intention	Time-to-market performance	H6: Behavioural intention to adopt new technologies mediates the relationship between attitudes toward certification bottlenecks and time-to-market performance.	OEM Form Q13 (Certification bottlenecks), Q14 (Mitigation strategies)
Attitude	Supplier risk mitigation strategies	H7: Positive attitudes toward supplier risk mitigation will increase firms' intention to restructure supply chains.	Supplier Form Q15 (Capacity utilisation, bottlenecks), Q16 (Supplier risk management)

Subjective Norms	Government procurement policies	H8: Subjective norms from procurement policies will positively influence firms' intention to increase local sourcing.	Supplier Form Q24 (Policy instrument most impactful)
Behavioural Intention	Investment decisions	H9: Behavioural intention to restructure supply chains mediates attitudes toward financing instruments and investment decisions.	Supplier Form Q19 (Payment terms), Q20 (Access to finance)
Attitude	Workforce training perceptions	H10: Positive attitudes toward workforce training will increase firms' intention to invest in skill-building programs.	OEM Form Q19 (Scarce skills), Q20 (Time to competency)
Subjective Norms	Industry association mandates	H11: Subjective norms arising from industry associations and regulatory mandates will positively influence firms' intentions to adopt structured knowledge transfer mechanisms.	OEM Form Q21 (Tacit knowledge transfer)
Behavioural Intention	Training outcomes	H12: Behavioural intention to invest in workforce development will mediate the relationship between attitudes toward skill scarcity and actual training outcomes.	OEM Form Q20 (Training approach), Q22 (R&D spend %)

This framework, therefore, posits that understanding and quantifying these behavioral elements are critical for accurately predicting the impact of policy interventions and technological advancements on the aerospace sector's growth and sustainability.

2.6 Summary

Literature examining technology-induced disruptions in the Indian aerospace sector reveals a complex interplay of structural, Research on technology-driven disruptions in India's aerospace sector uncovers a intricate mix of structural, institutional, and behavioral forces. Christensen's theory of disruptive innovation shows how startups like Skyroot Aerospace and Agnikul Cosmos are challenging long-dominant government monopolies, yet studies reveal key limitations such as low user engagement and limited global networks. The Liability of Disruption framework visualizes the institutional obstacles to new entrants, such as regulatory obstacles, lobbying by existing companies, safety issues, and even as reforms such as the Indian Space Policy of 2023 come into effect. Industry 4.0 approaches and innovation ecosystems highlight the exciting potential of artificial intelligence, digital twins, and advanced manufacturing, despite ongoing challenges like sectoral fragmentation and skill shortages. The Theory of Reasoned Action ties macroeconomic reforms to individual choices through attitudes and subjective norms, paving the way for better regulatory adoption, stronger investment commitments, and a maturing ecosystem. The combination of these frameworks will allow linking structural limitations to behavioral motivators and make effective evaluations of the Indian ambition to seize 8-10 percent of the global space economy by 2033 (Deshpande, Palit and Hazra, 2024).

This integrated perspective helps us understand how digital transformation-accelerated by the COVID-19 pandemic-is reshaping strategies in India's aerospace sector. It fosters hybrid enterprises that blend time-tested traditional approaches with innovative digital ones. This change is also fuelled by the increased use of technologies of the Fourth Industrial Revolution, including artificial intelligence, data analytics, and 5G connectivity, which are beginning to drive the dynamics of the New Space characterized by the end-to-end efficiency (Shaijumon.CS, 2022).

CHAPTER III:

METHODOLOGY

3.1 Overview of the Research Problem

The Indian aerospace sector is undergoing a strategic shift. From a long-standing state-controlled monopoly, it moves toward a dynamic public-private ecosystem, one that's competitive and innovative. In my assessment, this transformation stands as a vital national priority. Crucial. For unlocking India's full potential. It aligns with such significant initiatives as the Make in India program and the Aatmanirbhar Bharat program. The purpose of these is to minimize the dependency on foreign imports and turn the country into a manufacturing and high-technology powerhouse.

Why Disruption Matters for India

The transformation in this sector is the determinant of the strategic and economic destiny of India. What a bet.The government is exploiting reforms to grab a bigger portion of the global space economy which will grow to 1.1 trillion by 2040. Out of our current 2% portion, the future goal would be to reach 8-10% in 2030 or 2033. In my opinion, this jump will guarantee a technological leadership, strengthened nation security, high-tech employment, and overall social and economic development. It is driven by progressive policies, the key one being the Indian Space Policy 2023.Layer in Industry
4.0 tools, Artificial Intelligence, Machine Learning, Digital Twins and the shift accelerates.

Despite these ambitious goals, widespread gaps in quantitative modeling, regulatory obstacles, and disconnected innovation networks currently hinder the sector's ability to achieve its full disruptive potential, critical for both academic knowledge advancement and global competitiveness .

The Core Research Problem: Systemic Gaps Limiting Potential-Persistent, interrelated systemic barriers continue to undermine the Indian aerospace sector's immense economic and strategic promise.What strikes me most about this impasse is the stark absence of strong analytical tools. We desperately need integrated quantitative frameworks ones that can analyze and model the complex, changing interaction between policy tools, institutional credibility, and technology adoption. These are essential for steering the sector through its complex, high-stakes transition.

Without these frameworks, evidence-based policymaking is undermined, and making the best use of resources is hindered, particularly in resolving the interdependencies that drive aerospace innovation.

The studies currently conducted rely on descriptive studies, high level reports, or qualitative surveys, giving the aspects of a system in a static form instead of dynamic and predictive form.This methodological flaw allows research to identify problems, but struggles to model solutions or measure their economic impact.

This overarching lapse is compounded by issues of structure, among which include:Institutional and Regulatory Friction: IN-SPACe wanted to make things easier by being a one-stop shop regulator. But individual entrants? They continue to find their way around a web of regulation barriers. What bothers me more is the liability of disruption.It is manifested through institutional resistance against disruptive models by the old firms and regulators to the traditional norms. The outcome: the never-ending, complex authorization wars.This opposition may slow down the entry into the market and increase the operational expenses, thus weakening the innovation and deterring the investment in disruptive technologies (Rao et al., 2019).

Fragmented Ecosystems and Lack of Skills: These two structural barriers are severely disrupting the adoption of tech in the entire aerospace industry in India. Global expertise networks? Private players simply cannot access them in an appropriate way. Global expertise networks? Private players just can't tap into them properly. And users in the innovation cycle barely a whisper. In my view, it's all too fragmented. Everything feels isolated, ripe for skills shortages to pile on.

The issue is made worse by a critical lack of skills. In my view, the mismatch between workforce skills required for digital disruption and available talent is very clear, stopping progress at every turn.Moreover, the limited use of advanced prototyping technologies like additive manufacturing, beyond a few cost-intensive applications, further constrains the rapid development and deployment of innovative solutions within the broader industry (Bisht, Sridhar and Janardhanan, 2023).

Bridging the Gap: The Urgent need of Quantitative Modeling, the absence of quantitative data of these complex interactions impedes the decision making and advancement of stakeholders. In my estimation, this divide between regulatory frustrations to lag in technological adoption is not only stalling the progress, but also requires a data-driven urgent examination in case the Indian aerospace aspirations can fly. Policymakers and industry leaders cannot properly forecast disruptive directions or formulate particular evidence-based interventions without built-in quantitative models. This research bridges the gap between industry realities and academic insights. I advocate for deeper, more thorough system analysis to make that connection real.

At its core, the work builds adaptive simulation tools. Plus value-chain maps. They'll track economic outcomes from critical levers the savings from streamlining IN-SPACe approvals, say. Or the ROI from skill programs designed with precision.

It is these challenges that must be overcome in order to enhance academic knowledge beyond the analysis of descriptive information and offer the practical, prediction-based information necessary to enable the aerospace industry in India to effectively manage complexity and compete in the global context.

3.2 Operationalization of Theoretical Constructs

In this study, the methodological rigor will be achieved because abstract concepts of disruption are measured using definite indicators, variables, and data resources. This addresses a central literature gap: the lack of systematic quantitative models, simulations, or analyses to forecast outcomes or test ecosystem sensitivity to variables.

The operationalization framework specifies how to measure key concepts policy, institutional legitimacy, and technological adoption for dynamic policy simulation models and value-chain mapping. A conceptual framework is a literature plan of how an empirical research will be conducted, which outlines how the data will be collected, collated and processed and analyzed. This involves developing a quality assessment framework to evaluate the reliability of prior models and estimates, drawing upon existing scientific literature from fields like social energy sciences and information systems (Sai and Vranken, 2022, 2023).

Operationalizing Latent Constructs into Measurable Indicators

This study advances beyond descriptive evaluations to methods that predict outcomes. Concepts are made measurable using organized tools and real-world data collection.

1. Policy Dimension

   The policy dimension operationalizes strategic reforms as variables for simulating quantitative impacts.

Table: 3.0 Constructs, Measurement Variables, and Empirical Data Sources for Policy Impact Analysis, source: Author's output, 2025

Construct	Concrete Measurement Items (Variables)	Empirical Data Sources
Policy Driver Impact (e.g., Indian Space Policy 2023)	**Change in FDI Limits** (e.g., modeling impact of changes to the current 74% limit for satellites).	Archival policy documents, Government reports, Economic data (FDI inflow trends).
Regulatory Efficiency (IN-SPACe)	**Authorization Timelines** (e.g., quantifiable impact of a 50% reduction in the current **120-day authorization process** timeline).	Regulator surveys, Archival procedure documents (**NGP**), Case study data on **time-to-market** for NGEs.
Market Access/Risk	**Liability Clause Stringency** (financial risk exposure), **GST Exemptions** (modeling introduction of new exemptions).	Policy documents, Surveys with NGEs and industry experts (stakeholder perceptions).

2. Institutional Legitimacy Dimension

The abstract concept of institutional resistance specifically the **"liability of disruption"** is operationalized by measuring the pushback from established actors and the resulting constraints on new entrants:

Table: 3.1 Constructs, Measurement Variables, and Empirical Data Sources for Assessing Institutional and Market Dynamics, source: Author's output, 2025

Construct	Concrete Measurement Items (Variables)	Empirical Data Sources
Institutional Friction	**Regulatory Pushback Frequency/Intensity** (increased scrutiny, enforcement actions).	Regulator surveys, Case study documentation.
Incumbent Opposition	**Perceived Fairness of Competition** (opposition from established **PSUs** lobbying authorities to "level the playing field").	Qualitative stakeholder interviews, Surveys of NGEs (perceptual data).
Competitiveness Trajectory	**Success Rates in Securing Funding**, **R&D Investment Efficiency**, **Cost-per-Launch Reduction**.	Quantitative case studies of key entities (e.g., Skyroot, Agnikul).

3. Technological & Ecosystem Integration Dimension

The Operationalize technology adoption and ecosystem dynamics by first identifying entrenched structural barriers. Performance gains follow quantified rigorously through Industry 4.0 enablers. Digital Twins. AI. Machine learning. In my view, this bridges abstract theory with tangible metrics, revealing disruption's true potential.

Table: 3.2 Constructs, Measurement Variables, and Empirical Data Sources for Assessing Ecosystem Gaps and Innovation Barriers, source: Author's output, 2025

Construct	Concrete Measurement Items (Variables)	Empirical Data Sources
Ecosystem Inhibitors (structural gaps)	What is influence of user (aerospace and defence forces) in driving disruptive innovation in the industry? What kind of access do companies in the industry have to global network of technology and management innovation?	Structured Likert scale questionnaires administered to stakeholders.
Technology Barriers	**Lack of appropriate reference models or requirement engineering data** (identified as a primary barrier to Industry 4.0 adoption).	Causal modeling techniques (e.g., **DEMATEL** technique) using data collected from industry experts (Resource Team).
Human Capital ROI	**Quantified Return on Investment (ROI)** from targeted **skill-building programs**, prevalence of "self-disruption" mindset (a needed skill for digital business).	Empirical research based on qualitative/quantitative processes Dynamic simulation models.

Bridging Conceptual Theory with Empirical Execution

This concept measurement system allows mapping abstract concepts on practical procedures:

1. **Setting Inputs for Simulation Models**: The inputs to these dynamic policy simulations are based on the important variables: authorizations schedules, FDI levels, skill deficit costs. Consider their interplay. It shows the way sector performance reacts or fails to in reaction to policy alterations.Forecasts are made, which are dependable and, to my mind, enhance decision-making.
2. **Empirical Testing**: Hypotheses of the interactions between driving and inhibiting factors. We measure them based on performance indicators created in the form of profound case studies of key state and corporate organizations. This qualitative approach to research, in my case, represented a mixed approach, to be precise; the combination of qualitative information and quantitative methodological rigor reflects the golden standard of innovation studies.
3. **Reproducibility and Rigor**: International value-chain mapping enables cross-border comparisons. DEMATEL, meanwhile, teases out intricate cause-and-effect ties. Together, from my vantage, these tools secure repeatability, vaulting well past the shortcomings of descriptive or rigid methods.

By converting these hidden concepts into measurable factors and identifying matching data sources from archival policy documents and regulator surveys to industry KPIs and expert data this research delivers useful, changing information for making policies based on facts. This methodological clarity also enables the robust benchmarking of National Innovation Systems against established indices, allowing for comparative analyses that inform strategic policy adjustments (Vetsikas and Stamboulis, 2023).

3.3 Research Purpose and Questions

This research focuses on developing quantitative tools to guide the disruptive transformation of the Indian aerospace sector. The existing transformation changes the industry to a dynamic public-private ecosystem, compared to a closed and state-monopolized model.

Research Purpose

The study will establish a combined, quantitative model that will explain the disruptive change of the Indian aerospace industry. This framework explores the interaction between policy reforms, institutional legitimacy and adoption of technology. Based on the insights in disruptive industries, this is a deconstruction of these dynamics aimed at giving practical ideas to action. In the short-run, they identify leverage points. Over the long run, such learnings will enable policymakers and industry executives to unleash structural obstacles, foster dynamic innovation platforms, and drive the competitiveness of the private sector.

This research addresses a significant gap in the literature. We lack systemic, quantitative models. Models that can handle the dynamic back-and-forth in this new ecosystem, and nail down exactly how disruptions hit the value chain.Current research relies predominantly on descriptive policy analysis, high-level economic reports, or qualitative stakeholder surveys, providing a static view rather than a predictive model. Our goal surpasses simple problem-spotting. It quantifies resolutions through simulation-dynamic policy models that capture real-time feedbacks. A stepwise value-chain map is no exception as it ties reforms to changes in technology. I understand these tools transform ambiguous gaps into definite predictions, because I have worked on sectoral pivots.

Research Questions

The research questions that are addressed in this study are as follows, with major drivers and inhibitors that have been identified in the existing literature:

Policy Dimension

- What are the impacts of recent reforms on disruptive changes in the aerospace value chains such as the Indian Space Policy 2023 and IN-SPACe? The Indian Space Policy 2023 is a structural reform act, which formally liberalized the sector to allow Non-Governmental Entities to carry out any activity.
- IN-SPACe was created as the Single- Window Regulator and Facilitator, to create a stable and predictable regulatory environment and the creation of a level playing field among NGEs.
- The reform will increase India's share of the global space economy from roughly 2% to a potential 8-10% by 2030 or 2033.
- What measurable impacts do authorization timelines and liability clauses have on private sector participation?
- The Norms, Guidelines and Procedures of IN-SPACe provide a complicated multi-stage process of authorization that stretches up to 120 days in spite of streamlining efforts.
- Strict liability provisions taken against the private applicants have put them at a huge financial risk as they have to compensate the government in case of loss.
- The study will measure the economic effectiveness of a streamlined approval process of the IN-SPACe authorization schedule or amend the

liability provisions. Existing literature lacks measurable solutions for these known problems.

Institutional Dimension

- How does institutional obstacles and regulatory resistance slow down disruptive changes in the aerospace sector?
- The liability of disruption is a special burden to the entry of new players, and regulators and existing corporations oppose their disruptive business models.
- This backlash is felt in the form of regulatory examination and opposition of well established state owned business and may pressure the authorities to oppress new entrants.
- What is the impact of institutional legitimacy in the competitiveness of the private sector?

Legitimacy is the perception that an entity's actions are desirable and appropriate within the social system. Disruptive firms inevitably meet skepticism in their quest for acceptance. Unconventional business models collide directly with the norms and practices. This tension that is too close to institutional settings requires a delicate technique, as I have seen in the turbulent sectors.

Technological & Ecosystem Dimension

- Which systemic processes hasten or slow down the adoption of Industry 4.0 technology in aerospace companies?
- Industry 4.0 technologies (e.g., Artificial Intelligence, Machine Learning, Digital Twins) are crucial for driving transformative changes. Digital Twins, for instance, are detailed digital replicas for simulation, testing, and

predictive maintenance(Dinter, Tekinerdoğan and Catal, 2022; Baalbergen, Marchi and Klerx, 2023).

Adoption is significantly inhibited by empirically identified structural problems:

1. Lack of effective User Participation: End-users often have limited influence and insufficient ways to integrate their expertise into innovation processes(Buer, Kamsvåg and Strandhagen, 2024).

2. Inadequate Access to Global Networks: Indian firms have limited access to international networks for technological and managerial knowledge.

- Lack of appropriate standard models or requirements data.
- How can skill-building programs and ecosystem integration efforts be quantified for return on investment and innovation outcomes?
- There is no quantitative models of the economic evaluation of such intervention as specific skills-building programs to the growth of startups, although the lack of critical skills is an ongoing issue and there is a lack of a balance between the output of education and the needs of industry, especially the disruptive digital business model which requires a disruption mindset.
- The simulated model of this study will involve the use of system level simulation and value chain mapping to determine the value of investment in the targeted skill development and network integration interventions.

Significance: By addressing these research questions, this study carves out a unique position at the nexus of policy reforms, institutional legitimacy, and technological adoption. A multi-dimensional pursuit, you might say one that's both academically compelling and strategically indispensable.

Academically Relevant: A persistent methodological shortfall haunts the literature on aerospace disruptions. Think qualitative peeks and rote descriptions they dominate. We break through with system-level simulations, probing the messy techno-political undercurrents. Beyond that, we sharpen disruption theory itself. Empirical trials of the "liability of disruption" in India's aerospace realm. About time, wouldn't you say?

Strategically Valuable: The findings will offer predictive guidance and insights that current research lacks.It supports evidence-based policymaking.We hand over tools here practical ones to quantitatively test how sensitive the ecosystem is to those key variables.Unlocking the private sector's potential will drive progress.This drives India's strategic aim: ramp up competitiveness and claim a solid share of the global space economy.

This analytical approach ensures that the output is not just a description of challenges but a predictive diagnostic tool that empowers private aerospace enterprises and informs strategic resource allocation.

Table: 3.3 Methodological Framework and Data Sources for Evaluating Policy, Institutional, and Ecosystem Dimensions for Compliance Matrix: Research Purpose & Questions, source: Author's output, 2025

Requirement / Dimension	Methodological Approach	Data Source	Expected Output
Policy Simulation - RQ1: Economic/competitive effects of faster IN-SPACE authorizations	Dynamic simulations; scenario analysis	Indian Space Policy 2023, NGP guidelines, IN-SPACE norms	Quantified impacts on private competitiveness

Policy Simulation - RQ2: Liability changes' effects on private participation	Liability simulations; sensitivity analysis	Policy documents; regulator interviews	Models of investments /compliance costs
Institutional - RQ3: Institutional frictions/delays	Regulator/stakeholder surveys; thematic analysis	Surveys: regulators, OEMs, startups, suppliers	Dataset of bottlenecks/delays
Institutional - RQ4: Institutional legitimacy quantification	Perception mapping; legitimacy framework	Surveys/interviews; parliamentary discussions	Legitimacy index vs. disruption paths
Tech/Ecosystem - RQ5: Skills/innovation barriers	Survey analysis; gap assessment	OEM/startup/supplier surveys; Economic Surveys	Indicators of skill gaps/fragmentation
Tech/Ecosystem - RQ6: ROI of skills/networks	Value-chain mapping; ROI models	Surveys; industry/NITI Aayog reports	ROI metrics for skills/ecosystem programs

3.4 Research Design

This study uses a hybrid method combining survey research, dynamic simulation modeling and policy analysis to investigate technology driven business disruption in India's aerospace sector. It advances beyond descriptive policy analysis and qualitative surveys toward a reproducible, predictive, and policy aware framework. This study confronts a pressing shortfall in the scholarly landscape.

By integrating a combined approach, this research moves beyond traditional qualitative assessments, which often lack the predictive power necessary for strategic policy formulation and industrial adaptation (Font-Cot et al., 2024).

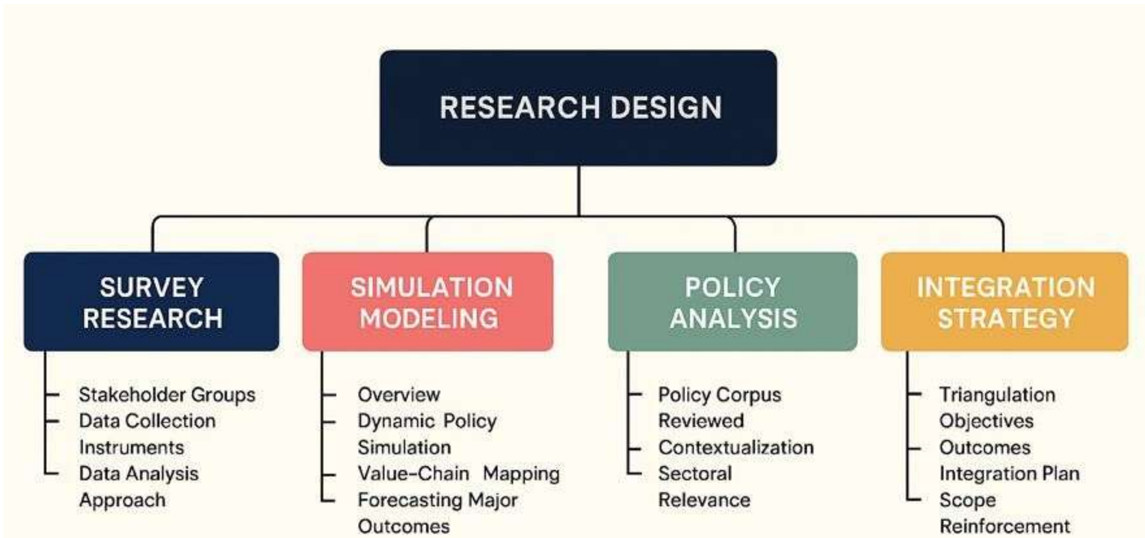

Figure 3.0 *Research design outline. Adopted from and it is available at: https://www.slideshare.net/slideshow/experimental-research-design-84851057/84851057 (Accessed: November 2025).*

Survey Research: The primary data will be collected through structured questionnaires and interviews of three stakeholder groups, namely, original equipment manufacturers and startups, regulators, and suppliers. Surveys facilitate the gap between theory and empirics. They convert theoretical ideas into specific and quantifiable indicators and variables. In my aerospace disruption dissection, this twofold capture quantitative measures with qualitative values of fundamental constraints is invaluable.

Authorization Processes and Timelines: Survey on regulatory efficiency perceptions of stakeholders. They narrow down on the consequences of condensing the multi-stage, lengthy authorization process. These lessons have the tendency to highlight the pushback against new businesses in my practical experience unpacking aerospace timelines.

Liability Rules: Data capture the risks of the market access under the strict liability rules. These require privately-applied applicants to be fully indemnified to the government. NGEs are therefore exposed to high financial risks. This arrangement in my experience derailses ambitious new projects in regulatory drag before they can get off the ground in the space ecosystem of India.

Technology Adoption Barriers and Ecosystem Integration: Measures the relevant barriers insufficient user engagement and unavailability of networks around the world that hinder disruption. The mixed dataset is a strong base to quantitative modeling.

Simulation Modeling: The quantitative core of the study is a combination of dynamic policy simulation and value-chain mapping on which the study understands and predicts.

Dynamic Policy Simulation: It is a unified approach based on the development of system level models to assess the relationship between the regulatory variables, institutional legitimacy and market response.

Model Construction and Setting Parameters: Dynamic simulation models take as inputs policy and survey variables (e.g., authorization timelines, FDI limits, investment thresholds). Predicting Industry Outcomes: Models are used to test the outcomes of policy changes, e.g. reducing IN-SPACe schedules by half or reducing liability provisions, in order to predict industry results like new entrants or an 8-10% global market share at 2030-2033, and test the sensitivity of the sector. Modeling Potential Resolutions: Simulations measure solutions to systemic problems and their economic consequences, filling in the gaps between problem identification methods.

Value-Chain Mapping: Value-chain mapping involves a tracking of technology, capital, and knowledge flows among actors in the ecosystem.

Bottleneck Identification: VCM maps according to evidence bottlenecks and points of fragmentation.The mapping process transforms intangible barriers like poor accessibility to global networks and poor participation of stakeholders into tangible working model.

Actionable Insights: VCM offers recommendations, measurable metrics, and the best intervention points to affect change to policymakers.

Strict Procedures: VCM relies on international standards. This gives repeatability as well as comparability across time. In investigating disruption patterns across industries, Experience probing disruption patterns across industries emphasizes the anchoring of value-chain mapping by such rigor in credible, shareable frameworks, way beyond ad hoc sketches.. Policy Analysis Examination of the key policy documents helps to give the context and to correlate the parameters of simulation with the transforming technological and political environment and survey instruments.

Core Documents: New policies are worth looking into in this case. The greatest central reform was the Indian Space Policy 2023. It opens the sector to non-governmental organizations making it possible to perform end-to-end space operations.

NGP Guidelines: NGP Guidelines:Rules, Guidelines, and Procedures by IN-SPACe. These are descriptive in detail of the processes of authorization. Precision defines them. Liability rules? They're strict. This inflexibility in my case of unraveling regulatory hurdles in Indian space ecosystem frequently protects the government against upcomers at the cost of the non-governmental participants increasing the financial risks of the non-governmental entities.

Budget and Economic Reports: The reports help shed light on the context of the national sweeps of strategies by India, including Make in India and Aatmanirbhar Bharat. This is especially strong in the aerospace industry, both as they both strive to make the country a global manufacturing powerhouse. This bases the analysis on the institutional structure which re-allocates the role of ISRO and IN- SPACe and industry financial limitations.

Integration Strategy- Triangulation of Methods: To conduct methodological triangulation we cross-check carefully the surveys results in primary mode with the simulation results and knowledge gained during the analysis of policy documents.

Brief and concise: this restrains prejudices peculiar to every approach. More to the point, it shows the correspondence of qualitative narratives to the quantitative forecasts. As a disruption scholar, this kind of alignment is highly validating, grounding our results on a wide array of evidence. Improves reliability, reproducibility, and high predictive power, fills literature gaps in systematising models with empirical data that combines empirical findings with forecasts tested on a scenario basis (Font-Cot et al., 2024).

Predictive Framework:Uninterrupted integration. It is aimed at that: the integration of survey-based constructs, simulation outcomes, policy factors into a single, dynamic model of technology-based disruption. Personally, such a mixture could be used to reliably predict the results in the industry that were necessary to overcome the aerospace development in India. Variables are the accurately defined measured variables that are directly taken in the real world data. This was no accident. This is a conscious decision of our methodology that ensures replicability. Our steps in the analysis can be followed by the future researchers. Transparency does more, however. In my career in investigating disruptions, it changes scholarship not as an individual pursuit to a common achievement.

Value-chain mapping. Scenario-tested simulations. They provide practical information in the real world guidance to regulators, industry actors, and policymakers in the Indian aerospace transformation. I have seen the metamorphosis of them into evidence-based fine instruments. Refined. Ready to persuade in the face of all that is changing. This combination merely worked in my disruption work. The rigorously defensible methodology in line with the principles of Christensen on disruptive innovation was validated through the application of various methods, which resulted in greater reliability and predictive capabilities (Font-Cot et al., 2024).

3.5 Population and Sample

Population: The population will comprise key institutional stakeholders within the aerospace and defence Indian innovation ecosystem, such as those players within the regulatory oversight, original equipment manufacturing, startup innovation, and support of the supply-chain. This includes:

- Regulators National and regional policy-making, authorization and control agencies (e.g., IN-SPACe, ISRO, VSSC).
- OEMs and Startups: Established aerospace companies and new companies that are associated with technological disruption and commercialization (e.g., Agnikul, Skyroot, SFO, Centum, Asniviram, Pixxel).
- Suppliers and Ecosystem Partners: Companies that offer important parts, testing systems and innovative technologies to facilitate aerospace activity (e.g., Rohde & Schwarz, Rosenberg, Tata Advanced Systems, Fluke, Safran, Data Patterns, Ametek).

  This is an all encompassing population that covers the whole gamut of the key institutional actors of regulators and OEMs to innovative startups and ecosystem partners whose strategic choices, innovative breakthrough, and high compliance practices are central to the trajectory of aerospace disruption in India.

Sample:Due to the scope of the population, the study will use the purposive sampling strategy to incorporate the most appropriate and most powerful stakeholders. The sample is drawn from:

- OEMs and Startups: Picked representatives of the best ventures like Agnikul, Skyroot, SFO, Centum, Asniviram, and Pixxel.
- Regulators: High-ranking officials of IN-SPACe, ISRO and VSSC who are policy and oversight functions.
- Suppliers: Global and domestic suppliers such as Rohde and Schwarz, Rosenberg, Tata advanced systems, Fluke, Safran, Data patterns and Ametek are represented. The target respondents will include top management and leadership cadres of the company including Division Heads, Group Directors, Chief Technology Officers (CTOs), Chief Executive Officers (CEOs), and Chief Financial Officers (CFOs). This emphasis helps in keeping the data strategic in terms of their perspective in decision-making rationale, as opposed to operational or tactical views.

3.6 Participant Selection

The participants used in the study were selected using a purposive sampling approach, which aimed to include the views of the actors that would most probably be engaged in determining the technological disruption in the Indian aerospace and defence ecosystem. The sample was also specifically chosen to include organizations and individuals in the positions of leadership in the regulatory process, innovation and supply-chain integration, where the location of their role and responsibilities is at the frontline.

Organizational Categories

Three major stakeholder groups, namely, were used to draw the participants: OEMs and Startups: Major aerospace initiatives like Agnikul, Skyroot, SFO, Centum, Asniviram, and Pixxel, are both established companies and start-ups.

Regulators: Top officials in IN-SPACe, ISRO, and VSSC, the mandate of which include policy formulation, licensing, and supervision of the involvement of the private sector. Suppliers: The important technology and components suppliers such as Rohde and Schwarz, Rosenberg, Tata Advanced Systems, Fluke, Safran, Data Patterns, and Ametek are of great significance in facilitating production and testing capabilities.

Individual Roles: In these organizations, the study specifically got the answers of top management and strategic leadership, such as Division Heads, Group Directors, Chief Technology Officers (CTOs), Chief Executive Officers (CEOs) and Chief Financial Officers (CFOs). This is to maintain the focus of the data as it represents the views of those people with direct input on the strategic decisions, investment priorities and regulatory compliance as opposed to those on the operational level.

Rationale

The three considerations that drove the purposive choice of participants were: Relevance: Making sure that the respondents are positioned in a manner that they give informed views on disruption, regulation and innovation.

Strategic Insight: Existence of the decision-making rationales of senior leadership increases the ability of the study to explain.

Representativeness: The sample is representative of the multi-layered ecosystem where aerospace disruption is occurring by incorporating regulators, OEMs/startups, and suppliers.

3.7 Instrumentation

The research used a structured survey research design and applied three different tools that were to help elicit the views of the major stakeholder groups in the Indian aerospace ecosystem: OEMs and startups, regulators, and suppliers. All instruments were created in order to make sure that they were methodologically rigorous, consistent with the research goals, and could be compared across the categories of stakeholders.

Survey Design Format: Questionnaires were filled in using Google Forms which is suitable in collecting data in a standardized format, in distributing the data, and is accessible to the respondents scattered across geographical boundaries..

Form: Both surveys were made up of closed ended questions as well as open ended questions. The use of both closed ended items with the help of Likert scales and categorical responses enabled the use of quantitative analysis, whereas the open ended questions provided an opportunity to gain qualitative information about organizational strategies and regulatory views.

Customization: Although the fundamental constructs the policy friction, adoption of innovation, supply chain resilience, and organizational decision making were largely similar, the wording and contextual framing of each stakeholder group was unique to the group to make it relevant and clear.

Stakeholder-Specific Instruments

OEMs and Startups: Survey link:

https://docs.google.com/forms/d/e/1FAIpQLSel9idiVqh85wmiddFgX7AfjRU_7n8f4tbCR_2YlunT8vVqtg/viewform?usp=publish-editor

Focused on innovation trajectories, regulatory interactions, and commercialization challenges.

Regulators: Survey link:
https://docs.google.com/forms/d/e/1FAIpQLScdC64n84az6dYqFq0uBpPTKXHsfZpdo9lN0QWfFnUKK_QRyA/viewform?usp=dialog

Captured perspectives on policy design, oversight mechanisms, and institutional legitimacy.

Suppliers: Survey link:
https://docs.google.com/forms/d/e/1FAIpQLSe8tnNiOjY_-FVNgQV6Cu-aI7tZyHPubb_Lm_enRkfSGc_acA/viewform?usp=publish-editor

Examined supply-chain integration, technology transfer, and resilience in procurement processes.

Target Respondents

The instruments were targeted at the top management and strategic leadership that comprised Division Heads, Group Directors, Chief Technology Officers (CTOs), Chief Executive Officers (CEOs), and Chief Financial Officers (CFOs). This helped to make sure that the data was based on strategic decision making rationales and not on operational or tactical perspectives.

Validity and Reliability

Content-Validity: The questions that were developed in the survey were based on the existing theoretical constructs in the literature on technological disruption and innovation, thus insuring that the questions fit within the conceptual scope of the study.

Reliability:The instruments were used with uniform scales and terminology in order to enhance reliability and guarantee comparability.

Pilot Testing: The first pilot testing entailed conducting the surveys to a few participants and this allowed correction of the language and structure so as to ensure the questionnaires became more clear and accurate in the response.

3.8 Data Collection Procedures

The data collection methods to be applied in this study were developed to uphold the methodological rigonance, inclusion of various stakeholder views, and reproducibility of results. Multi instrument survey methodology was chosen and the three main stakeholder groups in the Indian aerospace ecosystem have been identified namely regulators, OEMs and startups, and suppliers.

Participants were identified by their names and addresses.

The shortlisting of organizations was done with relevancy to aerospace disruption and their involvement in regulatory oversight, innovation, or supporting the supply chains.

The participants were expected to include:

OEM: Agnikul, Skyroot, SFO, Centum, Asniviram, Pixxel.

Regulators: IN SPACe, ISRO, VSSC.

Suppliers: Rohde and Schwarz, Rosenberg, Tata Advanced systems, Fluke, Safran, data patterns, Ametek.

Administration of Surveys

Mode of Distribution: Surveys were done electronically, through Google Forms, to capture data in a standardized manner, and to facilitate easy distribution as well as facilitate access to geographically spread participants.

Target Respondents

The questionnaires were targeted to the top management and strategic leadership which included Division Heads, Group Directors, Chief Technology Officers (CTOs), Chief Executive Officers (CEOs), and Chief Financial Officers (CFOs). This was done to make sure that responses were based on strategic decision making rationales and not on operational perspective.

Ethical Considerations

Participants were informed about the voluntary nature of participation, the confidentiality of their responses, and the academic purpose of the study. Consent was obtained prior to data collection, and reminders were issued where necessary to maximize response rates and ensure balanced representation across stakeholder categories.

Data Capture and Follow-Up

Responses were automatically recorded through the Google Forms platform, ensuring accuracy, completeness, and ease of export for subsequent analysis. Follow-up communications were employed to encourage participation and to achieve balanced representation across the three stakeholder groups.

3.9 Data Analysis

Data Analysis Framework that combines Dynamic Simulation and Value Chain Mapping expressly based on the OEM, Supplier, and Regulator Survey Data.This data analysis model operationalizes the research design by transforming cross-sectional evidence in the form of survey data:

- OEMs & Startups
- Aerospace & Defence Suppliers
- Regulators

As a dynamic time-changing model of the Indian aerospace ecosystem. The data in the static survey cannot be used to explain the technology adoption, ecosystem resilience, and individual participation in a capital-intensive, regulated industry. Simulation System Dynamics (SD) - to study time-varying behavior, feedback and policy scenarios.

Value Chain Mapping (VCM) - to determine the structural bottlenecks, concentration of risks and coordination failures.

Unified data analysis framework that incorporates a system dynamics simulation and value chain mapping to investigate technology related business disruption in the Indian aerospace industry. A direct simulation of system dynamics was done through a custom computational model, written in Python, and based on conventional principles of stock-flow and feedback loop.

```
┌──────────────────────────────────────────────────────
│            SURVEY DATA INPUTS                        │
│                                                      │
│  OEMs & Startups  |  Suppliers  |  Regulators        │
│  (Innovation,     |  (Imports,  |  (Authn,           │
│   Entry, Cert.)   |   LeadTime) |   Liability)       │
└──────────────────────────────────────────────────────
            │
            ▼
┌──────────────────────────────────────────────────────────
│     DATA CLEANING & VARIABLE CONSTRUCTION                │
│                                                          │
│ • Quantitative Variables (months, %, counts)             │
│ • Likert → Normalized Indices (0–1)                      │
│ • Qualitative Coding (themes & intensity)                │
│                                                          │
│ Outputs:                                                 │
│ - Regulatory Friction Index                              │
│ - Liability Burden Index                                 │
│ - Supply Risk Index                                      │
```

- Policy Facilitation Index

STATIC DESCRIPTIVE ANALYSIS

• Medians, IQRs, frequency distributions
• Cross-group comparison (OEM vs Supplier)
• Identification of constraints & delays

SYSTEM DYNAMICS SIMULATION (SD)

Stocks:
• Active OEMs
• Certified Products
• Supplier Base

Flows:
• Entry / Exit

VALUE CHAIN MAPPING (VCM)

Nodes:
• R&D & Design
• Inputs & Sourcing
• Manufacturing
• Testing & Cert.
• Integration
• Aftermarket

• Certification Rate

Metrics:

Feedback Loops:

• Lead Time

• Policy ↔ Entry

• % Imported

• Delay ↔ Attrition

• Single-source Risk

• Bottleneck Index

INTEGRATED SCENARIO & BOTTLENECK ANALYSIS

• Policy Scenarios (Fast approval, Liability)
• Capacity Scenarios (Testing expansion)
• Structural Bottlenecks (VCM heatmaps)
• Dynamic Outcomes (time-series behaviour)

POLICY IMPLICATIONS & VALIDATION

• Regulatory reform prioritization
• Supply-chain resilience strategy

│ • Coordination between regulators & industry │

│ • Robustness & sensitivity checks │

└──────────────────────── ───────────┘

Figure represents the data analysis structure that is integrated in this study. Systematic coding of survey data is used to convert survey data to be in an easily understandable quantitative form and composite indices that include OEMs, suppliers and regulators. The statistic descriptive analysis offers first insight into the constraints and heterogeneity among stakeholders, then the system dynamics simulation direction, which describes the dynamics of feedback and policy situations over time, and the value chain mapping direction, which finds the structural bottlenecks and focus of risk. These two approaches are then reintroduced to measure coordinated policy and industrial interventions.

System Dynamics–Value Chain Integration Logic

Policy & Regulation

│

▼

Authorization Delay ──► Entry Rate ──► Active OEMs

▲ │

│ ▼

Liability Burden Certification Demand

│

▼

Testing & Certification

│

▼

Supplier Capacity ◀── Import Dependence ◀── Manufacturing

Figure: Shows *feedback loops* + *physical chain dependencies* in one view.

Simplified Framework.

Survey Data

↓

Index Construction

↓

Dynamic Simulation ↔ Value Chain Mapping

↓

Scenario Evaluation

↓

Policy Implications

This integrated approach facilitates a granular examination of complex systems, enabling the identification of critical leverage points and the assessment of intervention impacts across various dimensions (Frederick, 2019). System dynamics is a well-established discipline for modeling and simulating intricate dynamic systems, focusing on the evaluation and design of policies to achieve desired system outcomes (Schoenenberger et al., 2021).

3.10 Research Design Limitations

Despite the fact that this research study was rigorously developed to achieve the objectives spelt out, there are a number of limitations that need to be noted. Such limitations are related to the sampling methodology, the data collection tools, the transfer of the perceptual data to the parameters to dynamic modelling and the circumstances or surrounding factors that were not under the complete control of the study.

Sample size and representativeness:

Limitations: The empirical sample is small: OEMs and Startups (N = 17), Regulators (N = 17), Supplier (N = 26). The purposive sampling of senior decision-makers used in the study enhances the quality of the insight but compromises statistical representativeness.

Implication: Results might not be extrapolated throughout the entire Indian aerospace supplier base, smaller companies, regional regulators, and to the lower management levels.

Purposive sampling and potential bias of selection:

Limitations: Targets senior executives of large companies and could have over-sampled large organizations and under-sampled small suppliers.

Implication: The systemic constraints identified can focus on strategic/organizational perceptions more than operational reality in lower levels of the supply chain.

Mode (Google Forms), survey instrument.

Limitations: When using online survey, there is a potential to spread widely and there is a possibility that there could be biases to responses and probing is not possible.

Implication: Qualitative shades can be erased, and Likert scales can be used to reflect perceptions and not the object.

Mitigation: Use mixed methods such as semi-structured interviews. Responses to reports and data not submitted, run robustness tests without biased responses.

Minimal calibration information of dynamic simulation.

Limit: The model is based on perceptions of the experts and survey medians in key parameters. These are applicable to the suit scenarios but inaccurate to the long-term calibration to forecasting.

Implication: Take absolute forecasts very carefully, the model works well in relative comparisons of scenarios, but not in absolute predictions.

Mitigation: Relative results should be emphasized, uncertainty bands need to be included, and archival data should be used where possible.

Contextual and temporal incompatibility.

Limitations Policy documents (Indian Space Policy, 2023) and stakeholder perceptions may vary over time or reflect different policy phases; the external events occurring after data collection are omitted.

Implication: The model can fail to capture later changes in policies or shocks that change real-life directions.

Mitigation The data collection time is specified, the model is regarded as a snapshot in time and re-parameterization is discussed in the future.

Mapping granularity of value chain.

Limitations: The VCM is based on respondent-reported input shares and dependency statements, which do not provide the level of detail in terms of transactional data, therefore, restricting granularity.

Implication: There are risks of missing or mislocation of some of the bottlenecks at the sub-component level.

Mitigation: VCM is applicable mostly at the meso-level of diagnostics, whereas specific supply-chain mapping research should be suggested in case of high-risk components.

Anonymity and candour of response.

Limitations: The older respondents will avoid revealing delicate business information or criticizing the regulators because of the policy association.

Implication: Self-censorship can distort the understanding of friction or risk.

Mitigation: Provide privacy and confirm the statements with official records and the media.

Despite the fact that this study has been well planned to achieve its goals, it has a number of limitations. The first is that the sample used is small with senior stakeholders making it difficult to statistically generalize and focusing on strategic views. Second, online questionnaires through Google Forms and composite scores using Likert scales and free responses could result in biases, which can bias the interpretation of the results. Third, model parameters are based on cross-sectional perceptions and archival data, not long time-series thus the dynamic simulation is only appropriate to point to the scenario comparisons but not exact predictions. Fourth, the study is not able to control external factors-policy changes, supply-chain shocks and policy-implementation gaps.

Nonetheless, the mixed-method framework is a powerful attempt to analyse the disruption in aerospace associated with technology: a dynamic simulation and map of value-chain generates both theoretical and practical results, and sensitivity analyses and clear documentation reduce the threats of validity. Fifth, the methodology's reliance on a substitutability assumption and the hypothesis of constant income and prices limit its applicability for forecasting economic changes or assessing consumer gains from trade (Escaith, 2019).

3.10 Conclusion

Concluding the Methodology: Research Design, Data Collection, and Analytical Techniques

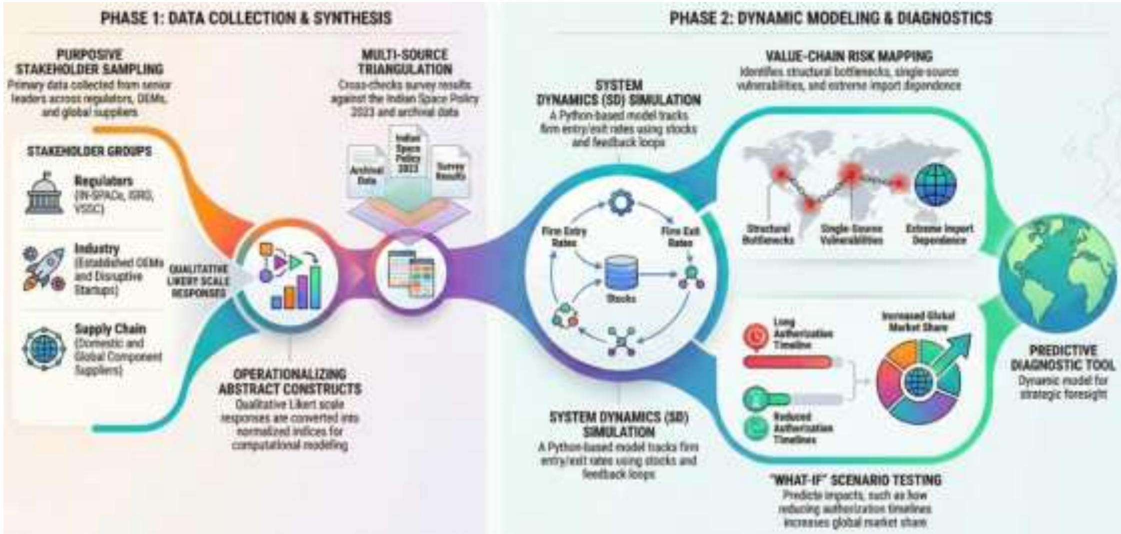

Figure 3.1 *Research methodology framework integrating data collection, triangulation and system dynamics modelling for the Indian space ecosystem. Own Illustration*

Note: Unpublished infographic developed with the assistance of a professional graphic designer for doctoral research at Swiss School of Business and Management Geneva.

This paper has used a mixed-methods systems-based design to determine the role played by regulatory frameworks, institutional mechanisms and technological capabilities in encouraging aerospace sector participation and innovation by the privates in India. The purposeful surveys of regulators, OEMs/startups, and suppliers were added to the quantitative analysis based on the index and value chain mapping and system dynamics simulations to transform the abstract theoretical concept into quantifiable variables. This methodology was consistent with the aims and theories of disruptive innovation and institutional facilitation that proposed the diagnostic evaluation and projection of scenarios. Though purposive sampling and perception, based surveys restrict statistical external validity and temporal validity, these problems were mitigated by triangulation with policy documents, sensitivity/robustness tests in simulations and by focusing on relative effects as opposed to absolute ones. Altogether, the combination of the two approaches provides a consistent, clear, and rigorous foundation of policy-technology interplay analysis, which contributes credibility to findings and prepares subsequent chapters of results presentation.

The convergent mixed-methods design, integrating qualitative and quantitative data, allowed for a more comprehensive understanding of the complex social phenomena under investigation, thereby enriching the interpretative depth of the findings (Oehler, 2021). The systematic integration of diverse methods, from questionnaire-based data collection to stakeholder analysis, ensured a robust foundation for understanding the dynamic interplay within the Indian aerospace and defense industries (Rao et al., 2019; Sornn-Friese & Sornn-Friese, 2024).

Table: 3.4 Summary of Research Methodology for Evaluating Policy, Institutional, and Technological Disruption, source: Author's output, 2025

Methodological Component	**Description**
Research Aim	To evaluate and model the role of regulatory facilitation and institutional mechanisms on the role of technological disruption in the aerospace industry that is led by the regulated private sector in India.
Research Design	Mixed-methods hybrid comprising of stakeholder surveys, index construction, value chain mapping, and system dynamics simulation..
Data Sources	Primary information on senior decision-makers among regulators, OEMs/startups, and suppliers; with secondary data on past policy documents and industry reports.

Analytical Approach	Descriptive and comparative statistical analysis and subsequent normalization into composite indices, simulation of system dynamics with scenario analysis, and sensitivity analysis.
Methodological Strengths	Triangulation methodology, predictive and scenario-testing ability, and theory-based operationalization of important constructs.
Methodological Limitations	Purposive sampling, perceptual response bias, and model calibration uncertainty; mitigated through robustness checks, triangulation, and comparative framing of results.
Research Outcome	A coherent and rigorous methodological platform enabling credible evaluation of policy impacts and innovation dynamics within the aerospace ecosystem.

CHAPTER IV:
RESULTS

In particular, the empirical results of the multi-method strategy involving primary survey data collection and secondary analysis of policy documents offer a full picture of the given field of research and identify the views of the stakeholders and difficulties they face when it comes to the given issues.To be more exact, the analysis of policy documents makes the world of the existing responses of the government and other institutions to the specified issues as systematic as possible, and the results of the survey include the views of the stakeholders and their difficulties that they experience.Respondent counts: OEM = 17, Regulator = 17, Supplier = 26.

4.1 Research Question One

What are the indicators through regulators authorization processes, liability regulations, and effectiveness measures of policies of the 2023 Indian Space Policy in support of the role of the private sector?What are the implications of these processes for technology-driven disruptions in aerospace?(Regulatory Facilitation & Private Participation).

Empirical highlights from the Regulator dataset: Respondents: 17 regulator responses.

Workflow / timelines (Regulator Q9 / related columns): matched workflow/timeline columns exist in the regulator file (multiple question fields). The data set has a mixture of a text description of the workflow and numeric timeline. A strong evaluation of regulatory efficiency and sensitivity to the changing branch of the Indian aerospace industry can be achieved based on such quantitative and qualitative data points and is in line with the goals of the 2023 Indian Space Policy (Sivan, 2025). Liability / dispute resolution (Q13-Q15): The responses of the regulator are mainly categorical descriptions of the existing liability mechanisms and general dispute

resolution processes, with references to such notions as contractual liability, indemnity, arbitration, and departmental escallation.

Policy metrics (Q17): Regulators reported a mix of process metrics (time-to-authorization, number of approvals required, number of coordination meetings) numeric items are present;

Numeric elicitation (Q22-Q26): There are some numeric items e.g. average approval durations / estimates of processing-times.

Empirical highlights of the secondary sources - policy documents - The Indian Space Policy 2023 (ISP, 2023), which is supplemented by the Norms, Guidelines, and Procedures 2024, is a paradigmatic shift in the ecosystem of public-private partnerships, making the state-centric monopoly a thing of the past. This policy development aims to provide the predictability of regulation and fair competition to Non-Governmental Entities.

1. Authorization Processes and Regulatory Facilitation

The ISP 2023 was the founder of the Indian National Space Promotion and Authorization Centre (IN-SPACe) which is a single-window agency.

Intake: IN- SPACe must be commissioned to facilitate, license and supervise any space-related tasks such as satellite deployment, launch vehicles and high resolution information distribution.

Procedural Timeline: The process of authorisation is a complex multi-phase process that presupposes initial examination, investigation of security and technical parameters, and consultations between ministries. The projected time of having a full application processed is 75 to 120 days.

Access to Infrastructure: The policy will enable the business exploitation of the state-of-the-art facilities of ISRO, including the launch pads and testing laboratories, enabling the NGEs to evade massive upfront capital investments.

2. Liability Rules and Financial Risk

The regulatory environment makes NGEs subject to tough demands to meet the international treaties such as the Liability Convention of 1972.

Indemnification: The liability clauses are strict whereby the government requires the indemnification of any third party damages by private applicants making NGEs vulnerable to high financial liabilities.

Insurance Requirement: In case of sub-orbital and orbital launches in India, the operators might have to keep third-party liability insurance. This insurance shall contain the Government of India as an insured party, and they are usually limited to a value specified by IN-SPACe.

3. Policy Effectiveness Measures

These reforms are evaluated by the success of ambitious national strategic targets and the recent growth of the market:

Market Share Goals: India plans to mobilize its stake in the global space economy to 8-10 percent or 2030 or 2033 as compared to 2 percent today.

FDI and Investment: FDI has been changed to permit up to 100 percent FDI in some areas (ground segment manufacturing) and up to 74 percent in satellites through the automatic route.

Ecosystem Growth: Space startups have grown to 189 in 2023, rising up to 1 in 2014, and the financial year 2023-24 has seen a private investment of 135 million.

4. Implications for Technology-Driven Disruptions

Regardless of favorable policies, the real-life organization of such processes makes the environment surrounding a technological disruption difficult:

Liability of Disruption: Institutions push back against new entrants through institutional challenges of legitimacy in situations where new business models dispute the incumbent industry rules, or Public Sector Unit (PSU) dominance.

Regulatory Friction: The complicated 120-day process of authorization and the multi-ministerial scrutinizing process can become the structural inhibitors and slow the pace of disruption.

Market Risk: The risk associated with large insurance demands and the complete indemnification of the state imposes financial strains on the startups that can discourage the entry of large-scale capital in high-risk areas.

Systemic Weaknesses: Successful disruption is also dampened by absence of user involvement (USRV) (e.g., poor involvement of defense forces) and global network access (NWKV) to the high-end management and technology skills.

4.2 Research Question Two

How do IN-SPACe authorization timelines, inter-agency coordination, and industry engagement processes affect innovation sourcing, adoption, and entrepreneurship among OEMs and suppliers in India's aerospace sector? (IN-SPACe and Innovation Pathways)

Empirical highlights from the Survey:

IN-SPACe / authorization timelines (Regulator Q9/Q16): regulators described authorization workflows and engagement mechanisms; numeric timeline fields show spread across respondents.

OEM innovation sourcing/adoption (OEM Q8–Q11):

OEMs (n = 17): Q8 (primary innovation sources) is multi-select the top innovation sources reported were internal R&D, vendor/partner solutions, and academic collaborations .

OEM Q9 (decision-gate months): OEMs reported numeric values (in months) for progression from Proof of Concept to industrialization milestones; these data are available, with means and medians computed in the OEM summary. .

OEM Q11 (example of disruptive tech adoption): The qualitative responses reveal key drivers, including cost reduction, performance enhancements, and supplier availability.

Supplier technology transfer / collaboration (Supplier Q21-Q23):

Suppliers (n = 26): ~88.5% reported Yes to having engaged in technology transfer/adoption .

Supplier survey summaries reveal frequently cited barriers, encompassing challenges in integrating with system-level testing, gaps in qualification and certification processes, and constraints on financing for scaling operations.

Empirical highlights from the secondary sources - policy documents: The authorization timelines of IN-SPACe, coupled with inter-agency coordination and industry engagement mechanisms, act as pivotal enablers in transitioning India's aerospace sector from a state-dominated supply paradigm to a private sector-led demand- oriented framework.

Authorization Timelines and Regulatory Certainty

Standardized Processing:

IN-SPACe targets the issuance of final authorizations or rejections for space activities within 75 to 120 days from the receipt of an initial application.

Empirical Throughput: IN-SPACe had received 566 applications by September 2024, in a wide range of categories, including launch vehicles, satellites, and segments on the ground. Total number of authorizations issued is 47 out of which 28 were to Non-Governmental Entities.

Provisional Authorization Mechanism: IN-SPACe grants provisional exceptions to non-governmental organizations, which simplifies the acquisition of the necessary secondary approvals of other ministries and, consequently, reduces the average processing times.

Inter-Agency Coordination and Policy Alignment

Single-Window Clearance IN-SPACe is an independent nodal agency that forms a part of the Department of Space that provides a single-window interface to non-governmental entities that previously were fragmented into multiple interactions necessitating individual transactions with the Department of Space, ISRO, and the ministries.

Strategic Oversight: Co-ordination between the ministries is facilitated through the Standing Committee on Inter-Ministerial Co-ordination that consists of the representatives of the Ministry of Home Affairs, Ministry of External Affairs, and Department of Telecommunications with the role of reviewing applications of national security and international compliance.

Technical Integration: Cooperation with the Wireless Planning and Coordination Wing will facilitate the use of the private entities streamlining the applications to new

International Telecommunication Union filings and orbital resources controlled by the Indian authorities.

Industry Engagement and Pathways for Innovation

Infrastructure Access: Via 60 Joint Project Implementation Plans, Non-Governmental Entities have secured utilization of ISRO's capital-intensive facilities for testing, tracking, and telemetry, including the development of private launch pads on ISRO campuses, such as the one managed by Agnikul Cosmos.

Financial and Technical Support Mechanisms:

Seed Fund Scheme: Grants to the tune of ₹1 crore can be taken to develop innovative ideas into working prototypes.

Venture Capital Fund: The Union Cabinet has passed a dedicated ₹1,000 crore fund to the space sector providing early stage equity financing.

Design Lab: The startups have the opportunity to use advanced simulation software to design and analyze advanced space systems.

Technology Acquisition: Seventy-five technology transfer agreements are completed where industries are allowed to commercialize the mature technologies developed by the ISRO.

Entrepreneurial Outcomes for OEMs and Suppliers

Ecosystem Expansion: In 2014, there was one Space startup and in 2024 there were 266.

Investment Surge: Indian space startup investments have surged to $124.7 million by 2023 (private)

Milestone Achievements: These mechanisms have contributed to the first private sub-orbital launches and the deployment of satellite constellations by the private companies.

• B2B Engagement: "Space Industry Days" events, held with partners including Singapore, Australia, and Sweden, foster business-to-business matchmaking and global market entry for Indian OEMs and suppliers.

4.3 Research Question Three.

How do the metrics of regulation and supply chain reported by the industry and workforce constraints indicate the success of the 2023 Indian Space Policy in making India more competitive in the expanding space economy across the world? Global Competitiveness and Policy Effectiveness)

The survey points:

Certification and bottlenecks (OEM Q13-Q17): The responses provided by OEMs, which are open-ended questions, name certification and testing approvals as the most important bottlenecks. These were issues that were frequently referred to throughout OEM respondents. Supplier lead times& capacity (Supplier Q10, Q24): Supplier Q24: The mean period is approximately 75.3 days (mean: 60 days; minimum: 6maximum: 180 days). Supplier Q10: The responses have some extreme outliers that render the median (~385 days) to be stronger than the mean which is skewed by the extreme outliers.

Dependence on imported inputs (Supplier Q12): There are constant mentions of reliance on imported components (specialized electronics, calibration standards and precision-machined parts) in various responses.

Workforce skills gaps: OEMs and suppliers mention the lack of skills necessary to work with new technologies.

Empirical points of the secondary sources - policy documents: The effectiveness of the 2023 Indian Space Policy in strengthening the global competitiveness of India in question is reflected in the shift of the state-centricity in the supply model to the demand model driven by the private sector despite structural and regulatory barriers.

Regulatory and Market Performance Metrics

Market Growth Objectives: India is currently contributing 2-3 percent of the world space economy with a figure worth around 8.4 billion. The policy presents a visionary goal of achieving 8-10 percent (44 billion) of the world market share by the year 2033. Institutional Throughput: IN-SPACe has approved 566 applications in a variety of space activity as of September 2024, with 47 authorizations, 28 of which have been granted to non-governmental organizations.

Incumbency and Investment Proliferation: Space startups have not only developed in high numbers with up to 266 startups reported in 2024 following the relaxation of FDI regime with 124.7 million idle through the idle 100% automatic-route inflows to produce satellite components.

Industry-Reported Constraints and Barriers

Notwithstanding regulatory advancements, industry analyses underscore persistent barriers that undermine global competitiveness:

Supply Chain and Infrastructural Deficiencies: Essential components, including semiconductors, encounter worldwide procurement delays exceeding 70 weeks. In spite of the fact that the policy encourages the sharing infrastructure, many micro, small and medium enterprises are found to have limited awareness or access to high-performance computing laboratories and other specialized testing facilities because of the lack of sufficient funds.

Certification and Intellectual Property Disparities: The average patent grant duration in India surpasses 48 months, substantially longer than the 12–23 months observed in the United States or South Korea. Additionally, the absence of mutual recognition agreements for certifications impedes international trade and technology transfer.

Facts of Workforce and Skills shortages: The lack of skilled labor force is quite high as assessments show that only 51.25 per cent of Indian youths are employable in high-technology industries. Stakeholders in the industry highlight the need to have focused training on advanced robotics, intelligence, surveillance, and reconnaissance with artificial intelligence, and satellite bus integration.

Legal and Financial Barriers: Not only is there no bilateral investment treaties with the main partners, but the taxation system is also complicated, which increases the operational costs and does not encourage the long-term commitment of a project Policy Effectiveness in Enhancing Strategic Preparedness

The policy has effectively propelled pivotal technological achievements that strengthen India's international position, including the Chandrayaan-3 soft landing and the Aditya- L1 solar mission. Nonetheless, to attain comprehensive strategic autonomy, recent wargaming simulations and industry consultations advocate institutionalizing Launch-on- Demand mechanisms and formulating national doctrines that designate counter-spoofing and space situational awareness as essential critical infrastructure.

4.4 Research Question Four.

What long-term economic benefits do survey data indicate on investment thresholds, supplier funding constraints, workforce training results, and R&D spending, relative to India’s space exploration and technology goals? (Economic Benefits and Long-Term Outcomes)

Empirical highlights from the Survey:

R&D spend (OEM Q22): Among OEM respondents who reported R&D expenditure as a percentage of revenue, the mean stood at approximately 39%, the median at 30%, with a minimum of 10% and a maximum of 90%.

Training the workforce (OEM Q19-Q20): The answers of OEMs indicate that training approaches are based on a mixture of in-house on-the-job training, vendor-training, and external certification. The estimates in time-to-competency show that there is a great variety, and most of the respondents indicated that it may take several months to become skilled in the new technologies.

Supplier finance and payment terms (Supplier Q19 and Supplier Q18): Suppliers reflect on a variety of financing options; nevertheless, many also mention delayed payments and lack of financing as significant barriers to scale operations. Qualitative responses explain payment term discrepancies and their negative influences on the cash flow.

Supplier lead time (Supplier Q24): its average was about 75 days, thus putting pressure on working capital requirements and inventory carrying costs.

Empirical points of view observed in the secondary sources policy documents:

Policy frameworks: The points of view of the policy frameworks are that the Indian space exploration and technology goals are aligned with the fact that the country is shifting towards a paradigm of a private sector-driven economic sphere to achieve a market share of 44 billion USD by the year 2033. The key to achieving long-term economic benefits is the ability to deal with any limitation in funding, regulation and skills.

Investment Thresholds and FDI

Aspirational Targets: To achieve a 8 percent rate of growth per annum with the Viksit Bharat @ 2047 program, it will be necessary to increase the national rate of investment to around 35 percent of GDP, which is currently at 31 percent.

Liberalization FDI: Revised policies allow 100 percent FDI in the production of satellite components, and 74 percent in satellite services via the automatic route, which will allow entry into the markets with ease.

Industry Sentiment: According to the results of the survey, 40 percent of the respondents regard FDI restriction as one of the primary barriers to investment and 25 percent of the respondents consider ambiguous tax regulations as an obstacle to their long-term commitment to capital.

Supplier Financing Constraints and MSME Challenges

Venture Capital Provision: The government has put in place a ₹1,000 crore Venture Capital Fund to meet the risk-capital needs of approximately 250 space startups.

Financing Obstacles: 35% of survey respondents identified elevated capital costs and funding constraints as principal impediments to expansion.

MSME Credit Shortfall: TReDS platform is one of the special mechanisms that are required to overcome the estimated credit shortage of ₹ 20-25 lakh crore facing the MSME sector, because it can be used to make timely payments to small suppliers.

Workforce Development and Talent Outcomes

Employability Deficiencies: Contemporary assessments indicate that 51.25% of Indian youth possess employability credentials, up from 34% ten years prior, yet revealing enduring skill shortages in high-technology domains.

Targeted Initiatives: The India AI Mission seeks to upskill over 50 lakh students and professionals, while the automotive-space sector anticipates a demand for more than 30,000 specialized engineers by 2035.

Imperative for Partnerships: 70% of survey respondents stress the necessity of business-to-business facilitation and collaborative ventures to promote talent mobility and build technical confidence with global counterparts.

R&D Expenditure and Innovative Advancement

Prevailing R&D Intensity: The Indian gross expenditure on research and development remains at 0.64 percent of its GDP, significantly lower than the levels of the major economies where the contribution of the private sector is above 70 percent of total R&D.

Economic Catalyst: It is expected that expedited implementation of artificial intelligence and generative technologies in R&D will counter 20-30 percent of the growth acceleration necessary to achieve the economic metamorphosis in India.

• Policy Imperatives: Two out of five survey participants consider bilateral technology-sharing agreements as the most important intervention to support collaborative R&D and achieve strategic independence.

4.5 Summary of Findings

RQ1: Regulatory Facilitation & Private Participation

Authorization Processes: The responses to the survey of regulators reveal that the approval processes are multi-stage with the processing time frame of 75-120 days. Quantitative data show that there is a lot of variability with some delays recorded as over 120 days as indicated by various respondents.

Liability Rules: The regulators and industry players insist on tough indemnity clauses and mandatory insurance. The outcomes of the surveys confirm that financial risk perceptions of both OEMs and suppliers are high.

Policy Effectiveness: Most of the responses to Q17 are split views on whether Indian Space Policy 2023 empowered the presence of the private sector. Regulators focus on procedural transparency, whereas OEMs and suppliers mention frictions and institutional resisting.

Document Analysis: The clearance of the single-window of ISP 2023 and NGP 2024 is instantiated with the use of IN-SPACe, but the liability provisions still serve as a structural instacle.

RQ2: IN SPACe and Innovation Pathways.

RQ2: IN-SPACe and Innovation Pathways

Authorization Timelines: Reported authorities show that standard processing times are 75-120 days. The figures represent the number of applications processed by 2024 and the ultimate number of authorizations was 47.

OEM Innovation Sourcing: OEMs identify the in-house R&D, vendor alliances, and academic partnerships as the key sources of innovation. The quantitative results indicate improvements in decision-gate progress over a period of months on average.

Supplier Technology Transfer: Supplier reports that about 88.5% of its suppliers have been involved in technology transfer, with a stress on certification and financing barriers.

Policy Documents: IN-SPACe policies have strengthened the development of the ecosystem, with the number of startups growing to 266 by 2024 (one in 2014).

RQ3: Global Competitiveness and Policy Effectiveness

Certification Bottlenecks: OEMs have been complaining of delays in certification testing and approval process.

Supplier Lead Times: Median lead times are around 75 days, with outliers swelling median lead times; still significant reliance on imported elements.

Skills of the Workforce: Both OEMs and suppliers emphasize long-term skill shortages in innovative technologies.

Policy Metrics: The ISP 2023 establishes targets of 8-10% global market share by 2033. Competitiveness is gained by institutional processing, but the time-consuming processes of certification and understaffing undermine the gains.

RQ4: Economic Benefits and Long-Term Outcomes

R&D Spending: OEMs indicate median R&D intensity ~ 39% of revenue, and is very variable (10-90%)

Workforce Training: The training can be in house, vendor and external training; the time to competency is variable.

Supplier Financing: 35% of suppliers report capital cost constraints and delayed payments.

Policy Documents: FDI liberalization (to 100 percent in components, 74 percent in satellites) and a ₹1,000 crore venture fund aim to reduce financing barriers.

Workforce Development: National efforts (IndiaAI Mission, targeted upskilling) deal with employability, yet survey data reveal that some gaps continue to exist

4.6 Conclusion

The findings of the empirical study show that, despite the fact that the Indian Space Policy 2023 and the related guidelines have created an appropriate facilitative environment regarding the involvement of the private sector, significant gaps in implementation exist.

Regulatory facilitation: Regulatory facilitation is being driven by IN-SPACe single-window clearance but still queues of authorization and hard liability provisions are proving hard to overcome. There is an increased conduit of innovation, and this is in the form of intensified proliferation of startups and technology transfer agreements; however, the lack of certification and funding limits scalability..

- The challenges to global competitiveness include weaknesses in supply chain, lack of workforce competency and slow certification processes despite ambitious market share targets.
- Economic impacts exhibit substantial R&D intensity among OEMs and policy-supported investment mechanisms; however, financing limitations and inconsistencies in training attenuate enduring advantages.

In aggregate, the findings substantiate a bifurcated progression: while policy reforms have catalyzed private sector involvement and sectoral ecosystem development, enduring structural constraints encompassing authorization delays, liability exposures, certification hurdles, and workforce deficiencies constrain the velocity of technology-propelled innovation. These limitations are also a critical point in mitigating so that India can achieve its vision of having 8-10 percent of the world space economy by 2033. Achieving this target necessitates sustained policy evolution and robust execution to bridge the chasm between stated objectives and operational realities within the burgeoning space sector (Deshpande, Palit and Hazra, 2024; Sivan, 2025).

CHAPTER V:

DISCUSSION

5.1 Discussion of Results

We base our study on the triangulation. We explore technology induced turbulence shaking the aerospace industry in India by integrating empirical survey reports and policy commentaries, system dynamics simulation outputs, and value chain map. In this case, perception-based knowledge comes together and structural and dynamic models are used to take the analysis beyond descriptive findings. We identify cause and effect relationships, where to push and pull, and where to focus on the system to take action on policy. This robust methodological framework allowed for a comprehensive examination of critical variables such as economic benchmarks, technological advancements, and policy frameworks that shape sector changes (Prabhakar, 2024).

All the three streams of evidence focus on the regulatory and institutional drag on innovation and entry of the private-sector. A survey of the six main barriers identifies delays in authorization, certification bottlenecks and risk of liability. These are in accordance with policy documents of recognition of multi-stage approvals and constrained institutional capacity. These frictions in the SD model form positive loops: delays decrease entry of firms, supplier demand, and increase of ecosystems. VCM theorizes testing/certification nodes, import-dependent inputs, and single-source suppliers as chokepoints, and this results in mutual reinforcing between regulatory and supply- chain constraints.

Triangulation shows gaps between policy goals and actual results. Policies stress facilitation, infrastructure access, and ecosystem growth, yet industry reports ongoing implementation barriers. SD scenario analysis explains this gap: headline policies alone fail to shift system paths without cutting delays, liability risks, or capacity limits.

Likewise, OEMs show strong R&D, but SD and VCM reveal that R&D alone does not speed commercialization absent concurrent gains in certification throughput and supplier capacity. Thus, aerospace innovation depends on system factors, not just firms.

The integrated SD-VCM approach deepens insight into temporal and structural dynamics. SD simulations monitor policy impacts on entry, exit, and certification rate together with losses among suppliers over time, which can be used in counterfactual tests of regulatory and capacity choices. VCM contributes to pointing out the spatial risks and bottlenecks, transforming dynamics into specific actions. Together, they highlight high-leverage steps-like provisional approvals, liability sharing, expanded testing facilities, and supply-chain diversification-that boost performance across scenarios.

Methodologically, triangulation strengthens findings by improving construct validity, causal plausibility, and robustness. Survey-derived indices are grounded in policy context, SD provides dynamic causal logic to cross-sectional associations, and VCM localizes system-wide effects. While limitations remain-most notably purposive sampling, perceptual bias, and model calibration uncertainty-these are mitigated through comparative framing, sensitivity testing, and explicit bounds on inference.

The triangulated study indicates that regulatory and structural barriers are greater obstacles to technology-based disruption in the aerospace industry of India than entrepreneurial intention and research and development. By combining both empirical evidence and dynamic, structural, models, this study provides a policy-relevant account of how concerted intervention of regulations and industry can restructure long run innovation paths, which informs the interpretation of findings and practical policy outcomes.

5.2 Discussion of Research Question One

RQ1: What are the indicators through regulators authorization processes, liability regulations, and effectiveness measures of policies of the 2023 Indian Space Policy in support of the role of the private sector?What are the implications of these processes for technology-driven disruptions in aerospace?

The results of the three triangulations suggest that the 2023 Indian Space Policy has a strategic purpose to enable the involvement of the private sector in aerospace, but the actual implementation of such a purpose is still incomplete and unequal and has important consequences of technological breakthroughs.

Politically, the measures like single- window authorization, extra infrastructure access, and the identification of privatized launches and satellites are indicative of a transition between a state-dominated and a public-privatized innovation ecosystem. These support the objectives of empowering entrepreneurship, reducing entry barriers, and technology development of the indigenous type.

Implementation however is weak as evidenced by surveys. Tremendously long durations, multi-phase approvals, and procedural vagueness are reported by OEMs, startups, and suppliers, particularly between agencies. Regulators perceive processes as healthy and controlled in risk whereas industry considers it a slow and uncertain-especially to new entrants. This discontinuity implies that policy allows taking part in theory, but the practice is risk-adverse, not innovation-speedy.

Liability and indemnity rules moderate this relationship critically. While the policy does not prohibit private risk-taking, the lack of clear liability-sharing mechanisms or exposure caps shifts excessive financial and legal risks to private actors. Surveys identify liability as a major barrier to experimentation and scaling, especially for startups and MSME suppliers. System dynamics simulations confirm that higher perceived liability boosts certification demands, extends approval cycles, and raises firm exit rates under stress. Dynamically, liability forms a negative feedback loop that curbs the disruptive innovation the policy intends to foster.

Policy effectiveness metrics such as authorizations granted or applications processed indicate rising institutional throughput. Triangulation, however, shows that quantitative gains do not ensure qualitative support. SD scenarios reveal that without reducing authorization delays and liability frictions below thresholds, higher processing volumes fail to yield sustained OEM growth or faster technology diffusion. Value chain mapping demonstrates regulatory frictions burden downstream nodes, exacerbating delays and reliance on imports and single-source suppliers.

Disruption implications are huge in respect to technology driven disruption. Disruption in aerospace relies on coordinated mechanisms: regulatory authority, certifying ability, readiness of suppliers and capital. The existing laws permit marginal involvement but prohibit disruptive change, particularly the rapid one, by start ups that seek new technologies. Only in simulations in which approvals are faster, shared or capped, and the certification capacity is increased, such paths can be found.

Essentially the Indian Space Policy of 2023 presents an encouraging outline of the role of the industry in the Indian aerospace desires. However, our triangulation-based evidence based on surveys, system dynamics and value chain mapping paint a more responsible picture: it does not allow a firm to disrupt technology on a scale, authorization procedures are cumbersome, liability regulations unduly risky, and innovation cycles are sluggish, and entrepreneurial risk-taking is inhibited. I would argue that genuine development requires regulators to focus on fast, risk-based approval and coordinated system-wide integration which will turn tentative involvement into long term and radical technological transformation. This necessitates a re-evaluation of policy implementation strategies, moving beyond mere procedural throughput to genuinely foster an ecosystem conducive to rapid technological advancement and market entry for new space enterprises (Sachdeva, 2024; Mani, Dadhwal and Shaijumon, 2025).

5.2 Discussion of Research Question Two

RQ2: *How do IN-SPACe authorization timelines, inter-agency coordination, and industry engagement processes affect innovation sourcing, adoption, and entrepreneurship among OEMs and suppliers in India's aerospace sector?*

The triangulated findings reveal that IN-SPACe occupies a central yet currently restrictive position in molding innovation trajectories across India's aerospace sector. Although its establishment constitutes a major institutional advancement designed to facilitate private sector involvement and entrepreneurial access, its practical mechanisms-namely authorization timelines, inter-agency coordination structures, and industry engagement practices-yield heterogeneous impacts on innovation sourcing, adoption, and enterprise development.

Survey data show that OEMs and suppliers view IN-SPACe approval timelines as long and unpredictable, particularly for novel technologies and new applicants. The regulators emphasize on procedural rigor as a safety measure yet the industry associates delays with delayed procurement, onboarding of suppliers and testing of technology. Simulation results with systems dynamics prove that the longer the delay, the lower the rate of entry, the slower the accumulation of certified products, the less entrepreneurship, and changes the source of innovation between domestic startups and established or foreign suppliers.

The major limitation is inter-agency coordination. Approaches by IN-SPACe are overlapping with processes such as spectrum allocation, export controls, testing access, defence clearances, and these create sequential delays instead of parallel ones. Value-chain analysis shows these gaps hit mid-chain suppliers (e.g., in testing, materials, subsystems) hardest. In the SD model, coordination frictions cause propagating delays, longer supplier lead times, import reliance, and conservative-rather than disruptive-innovation adoption.

The quality of innovation sourcing is also affected by industry engagement as well as the quantity. According to surveys, there are formal consultations and outreach but they are perceived as informational instead of collaborative. There are low-early regulatory feedbacks of OEMs and suppliers in the technology conception and prototyping stages. As a result, companies prefer innovations that are consistent with the anticipated regulations and shun high-threat or untested technologies. As previously stated, SD simulations indicate that stronger early engagement decreases rework, minimizes certification failures, and accelerates diffusion-benefits in under-realized in the present-day baseline.

Such dynamics affect entrepreneurship and innovation adoption a great deal. Startups and MSME suppliers are subjected to greater uncertainty expenses, extended revenue cycles and higher sunk R&D risks. Such an arrangement provides bigger OEMs and established players that have regulatory experience and financial capital, reducing the variety of innovation. Value-chain analysis exposes the limitation of the entry of suppliers to weakened competition, slowing ecosystem learning, and disruptive business models.

Altogether, there is compelling evidence demonstrating that the design of the IN-SPACe is aimed at facilitating the involvement of the private sphere, but has a conservative character. Prolonged approval processes, inadequate coordination of agencies, and lack of early involvement of industries drive innovation towards compliance and not entrepreneurial discontinuation. The system facilitates gradual diffusion but reduces the pace, diversity, and risk taking that are necessary in aerospace transformation.

By being a real catalyst of innovation, IN-SPACe ought to embrace approvals that have definite deadlines and stages, have coordinated procedures among different agencies, and increased industry participation prior to certification. The changes would reduce the cycles, increase sourcing to domestic and startups, and increase regulations to provide benefits of new businesses according to Indian ambitions of a competitive and innovative aerospace sector.This strategic pivot would cultivate an environment where emerging entities can thrive, fostering a dynamic interplay between public regulatory bodies and private sector ingenuity to drive sustained technological advancement and market diversification (Vértesy, 2011).

5.3 Discussion of Research Question Three

RQ3: How do the metrics of regulation and supply chain reported by the industry and workforce constraints indicate the success of the 2023 Indian Space Policy in making India more competitive in the expanding space economy across the world?

Although the 2023 Indian Space Policy has created a favorable institutional environment and measurable improvements in the efficiency of the processes, long-term implementation issues-especially the delay in certification, fragilities in the supply-chain process, and employee shortages-significantly limit the proximate ability of India to transform policy aspirations into sustainable global competitiveness.This phenomenon is particularly pronounced given the nascent stage of the Indian private space sector, which, despite rapid growth, grapples with a less mature ecosystem compared to global counterparts (Boyd et al., 2024).

Table: 5.0 Triangulation of Global Competitiveness based on 2023 Indian Space Policy source: Author's output, 2025

Constraint Area	Empirical / Industry Evidence	Policy & Regulatory Evidence (ISP, 2023)	SD & VCM Interpretation	Implication for Global Competitiveness
Authorization & Approval Timelines	Variable and frequently long authorization times OEMs and suppliers report shorter authorization times; delays are highly pronounced in initial and new technology applications	Single-window authorization and facilitation system formally in place more applications are not in place.	SD simulations indicate longer authorization delays decrease entry rates in firms and slow accumulation of approved products, weakening diffusion of innovations.	Slower time-to-market weakens India's ability to compete with faster-moving global space ecosystems.
Certification & Testing Capacity	Certification and testing were found to be the major bottlenecks; commercialization	Policy acknowledges access to national infrastructure	VCM heatmaps reveal testing and certification as key bottlenecks; SD	Certification delay kills first-mover advantage and international

	and scaling is hindered by long lead times.	but capacity growth does not match growth in demand.	demonstrates delay-based loops of feedback that drive more supplier attrition.	confidence in Indian aerospace products.
Supply Chain Dependence & Lead Times	A high level of dependence on imported components; the lead time with suppliers is on average 75 days; single source risks still present system stability disproportionately.	Policy promotes indigenizatio n and private involvement but does not include targeted supplier-level interventions .	VCM highlights import-dependent nodes as risk amplifiers; SD sensitivity tests show supply shocks disproportionatel y affect system stability.	Dependence on imports enhances volatility of cost, and lowers the level of resilience, which inhibits long-term international competitiveness .
Liability & Risk Exposure	Industry is seen to have high liability and insurance burden, especially to startups and MSMEs.	Liability systems focus on risk containment; few explicit risk-sharing systems.	SD modelling demonstrates better liberty of exit and aversion to entrepreneurship experimentation.	The problem of excessive risk exposure inhibits disruptive innovation that

				is required to lead the world.
Workforce & Skills Availability	Firms complain of shortages in specialized skills in aerospace and space-systems; long learning curves on advanced technologies.	Policy: Investment in human capital, and gained gradually.	SD results reveal skill limit retards absorptive capacity; VCM relates workforce gaps to workflow delays at the various nodes of the value chain.	Capabilities deficiencies make productivity and quality of innovations lower compared to international levels.
Policy Throughput vs. Effectiveness	Industry experiences persistent friction despite rising authorization counts.	Policy metrics draw attention to the approvals and institutional activity.	SD presented throughput measures alone do not change system path unless delays and bottlenecks are minimized to below threshold values.	Headline metrics exaggerate gains in competitiveness unless frictions are reduced in its operations.

This is triangulated evaluation showing that even though the Indian Space Policy of 2023 has been able to mobilize institutional processes and enhance the role of the private sector, the global competitiveness is limited to the meso-level operational contradictions. It is regulatory throughput, certification capacity, supply-chain resilience, and workforce readiness that define whether the policy intent is converted into international advantage. Unless all these leverage points are coordinated in terms of reform, it is possible that the aerospace sector in India will find itself in the position of being a participant but no leader in the new global space economy.

5.4 Discussion of Research Question Four

RQ4: What long-term economic benefits do survey data indicate on investment thresholds, supplier funding constraints, workforce training results, and R&D spending, relative to India's space exploration and technology goals?

The triangulated empirical evidence suggests that policy reforms in India have created the condition under which economic benefits can be sustained in the long run but the enduring results of the interventions require allotted interventions to dismantle certain barriers in the areas of funding, skills development, certifications and ecosystems of research and development. The absence of increased access to investment by suppliers, faster skilling of the workforce, sustained investment in R&D by individual firms, and reduced certification/authorization times, will make the sector only achieve marginal involvement and slow growth, instead of the process of radical, export-led industrial revolution envisaged by the policy.

1) Investment thresholds & capital availability : evidence and implications
   Evidence: Policy reforms involve the liberalization of FDI, a ₹1,000 crore VC fund on space startups, and some $125M in private investment. Individual companies on the other hand declare capital constraints and tax/treaty risks which hinder long term obligation. It is reported that it requires more

investments to achieve growth targets.

SD/VCM implication: The simulations indicate that the acceleration of finance in early stages improves entry and scaling of firms, however, capital on its own does not bring significant returns unless the authorization and certifications are accelerated.

Threshold insight: The existing VC funds serve to fund startups but do not focus on scaling suppliers. The policies ought to have increased scale-up risk capital, which is phased, and mixed funding depending on the supply working-capital requirements

2) Supplier funding constraints & working-capital dynamics

Evidence: capital constraint and delayed payment: Approximately 35 percent of the suppliers have capital constraints and delayed payments; lead times (approximately 75 days on average) put a strain on working capital, particularly MSMEs.

SD/VCM implication: VCM finds the testing/certification and imports as bottlenecks; with the System Dynamics tests, the cash flow issues disseminate delays and contribute to the high attrition of suppliers.

Policy implication & threshold: Specialized finance departments, accelerated payments, and 2-3x lead time credit would minimize attrition and scaling would be possible.

3) Workforce training outcomes & human-capital ROI

Evidence: In-house, vendor, and external certification training mixes; competence requirements take different amounts of time depending on the new technology. Despite the ongoing programs, only a sizable percentage of the youth (approximately 51) are employable in high-tech positions.

SD/VCM implication: Skill differences lengthen certification periods, inhibit absorption, slow diffusion, and reduce returns to R&D; Value Chain Mapping relates shortages to delays at various stages.

Practical benchmark: (tens of thousands by, 2035) system returns should be the target of the training interventions. There are high ROI with public-private apprenticeships and industry-academia pipelines.

4) R&D Spending and Long-Term Economic Returns

Evidence: OEMs have high firm-level R&D intensity, national Gross Expenditure on Research and Development is low and share of privately-funded R&D is lower than top economies. There is a wide range of outcomes and long commercialization cycles.

Implication of SD/VCM: The potential of innovation is generated in the firm R&D, and the systemic benefits need to be duplicated in its certification, supplier finance and skills. Only for quicker authorizations, liquidity in the supply-chain, and transfer of technology, simulations are high in returns.

Investment Advice: Strengthen company R&D through tax reductions, equal government grants on prototyping, and technology-sharing agreements. Systemically, increase national GERD and privately owned national R&D share to boost GDP and exports- subject to coordinated meso-level investments.

Table: 5.0 Triangulated Mapping of Constraints, Dynamic Effects, and Long-Term Economic Levers (RQ4) source: Author's output, 2025

Constraint Area	Empirical / Survey Evidence	SD & VCM Finding (Dynamic / Structural Effect)	Suggested Threshold / Policy Lever (Long-Term Outcome)

Investment Thresholds & Risk Capital	FDI liberalization and ₹1,000 crore space VC fund Notwithstanding, the firms have low level of scale-up capital and uncertainty in long-term commitment of funding; the amount of investment by the firms is small in comparison with the sector ambitions.	SD simulations indicate that the level of entry and scaling only increases when risk capital passes a minimum liquidity threshold; capital is not significant in the event that delays in certification persist.	Deepen blended finance past seed stage (Series A/B support); deploy tranche-based financing based on certification markers; match capitalizaton with shorter authorization cycles.
Supplier Funding & Working Capital	Suppliers (~35%): capital cost issues and slow payments; Average supplier lead times (75 days) have significant working-capital demands, especially on MSMEs.	VCM finds supplier liquidity as a bottleneck; SD sensitivity tests demonstrate that liquidity shocks increase the attrition and spread production delays throughout the ecosystem	Have special supplier-finance windows; require expedited payment systems (e.g. TReDS); scale support of working-capital to meet 2-3x average length of lead-

			times (≈150-225 days)
Certification & Testing Capacity	Certification and testing delays are always rated as the worst commercialization barriers; long approval processes delay generation of revenue.	VCM heatmaps move testing and certification to bottlenecks; SD demonstrates that the returns of delay reduction are nonlinear in the survival of firms and their output.	Multiply testing capabilities in the private-public setting; establish parallel and provisional certification opportunities; implement service-level approval turnaround standards.
Workforce Skills & Training Outcomes	Shortages in aerospace specific skills are being reported by firms; training times are lengthy and skewed; national high-tech employability is still only around 50.%.	SD models increase the gaps in skills and long certification cycles and lower R&D productivity; VCM is also associated with workforce shortage and several downstream delays..	Scale apprenticeship-based programs; reduce time-to-competency in key positions by 25-40 percent; make the curriculum match the certification and testing requirements.

R&D Intensity & Commercialization Gap	Gains collected by OEMs: Strong Firm-level R&D intensity ((mean ≈ 39%), yet national R&D levels are small with long commercialization timelines.	SD Results: gains only made where supported by certification capacity, labor supply, and liquidity of suppliers; and increase national R&D levels.	Sustain R&D tax incentives and matched grants; tie public R&D support to access to testing infrastructure and export-readiness programs; raise private share of national R&D.
System Coordination & Cumulative Effects	Firms experience fragmented interventions capital, skills, and policy reforms applied in isolation.	SD demonstrates that isolated reforms have marginal gains; concerted improvements move the system towards a greater steady-state growth trajectory.	Introduce bundles of reforms that are based on the speed of regulation, finance, skills and infrastructure; evaluate results based on the use of a set of indicators, not just one.
Workforce Skills & Training Outcomes	Shortages in aerospace specific skills are being reported by firms;	SD models increase the gaps in skills and long certification cycles	Scale apprenticeship-based programs; reduce time-to-

	training times are lengthy and skewed; national high-tech employability is still only around 50.%.	and lower R&D productivity; VCM is also associated with workforce shortage and several downstream delays..	competency in key positions by 25-40 percent; make the curriculum match the certification and testing requirements.

This discussion reveals that the economic benefits of the aerospace industry in India in the long term will demand simultaneous increment of spending, level of supplier liquidity, human capabilities, as well as research and development beyond critical levels. Far-flung reforms give only marginal participation, and organized policies give nonlinear advantages of scale, strength, and international competitiveness. Synergistic implementation enhances domestic production and integrates India deeper into global aerospace value chains, boosting exports and technological capabilities (Santos et al., 2019)

CHAPTER VI:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1 Summary

This paper is an analysis of the role of regulation, capacity of certification and supply-chain in promoting the aerospace industry of India to be disrupted by technology. It draws on surveys of senior leaders from OEMs, suppliers, and regulators, validated by policy documents (including the Indian Space Policy, 2023), and integrates global value chain analysis with system dynamics simulations to provide policy-relevant predictions beyond static descriptions. The main implication is that institutional constraints-primarily long approval processes and ambiguous liability regulations-have the strongest negative impact on private-sector action: it can be simulated that quicker approvals produce greater and longer benefits to startup survival and market entry as compared to capacity expansion per se. Certification capacity mainly controls the flow of approved technologies, while heavy reliance on imports and single suppliers increases failure risks and intensifies the effects of regulatory delays.

Policy analysis places these dynamics in India's evolving aerospace ecosystem. Industry 4.0 technologies and other supportive policies are driving the country to change towards a state-to-public model. Nonetheless, there are still systemic issues, including disjointed domestic demand, and insufficient access to global technologies and networks, as well as lack of specialized digital skills. The researcher finds a liability of disruption, in which new entrants are subject to strong regulatory scrutiny, resistance of rules by current incumbents and delays in the procedure. This forms a vicious cycle that stops scaling and international competitiveness. According to the ambitious targets, which include gaining a portion of the worldwide space economy by 2033, the institution needs to align its reforms with institutional clarity, certification capability, resilience of the supply chain, and the skill of the workforce. In terms of its methodology, the present study offers a replicable mixed-methods approach. To parameterize system-dynamics models based on scenarios, survey data were summarized to parameterize them as composite indices, and structural bottlenecks to be targeted by targeted policies were identified using value-chain mapping. This method balances the stakeholder knowledge and the quantitative scenario testing.

Limitations mentioned in the study are open: purposive sampling and subjective calibration restrict the statistical extrapolation, and simulations can be effectively used as policy-testing instruments, but not as exact predictions. These problems are addressed through robustness tests, sensitivity tests and visible procedures that ensure that levers of policy are given relative precedence. Concisely, the research contributes to theory and practice. Ideally, it incorporates the institutional and supply-chain views in dynamic frameworks of technology adoption and demonstrates the role of capacity and governance interacting through specific mechanisms. In practice it puts more emphasis on policies to stream approvals and clear up liability; align capacity building with demand growth; and create suppliers of critical sub-components-steps whose combined implementation would better enable scalable aerospace innovation in the private sector than individual projects. It offers the quantitative framework of policy testing to enable leaders to build the resilience and global competitiveness of India aerospace sector.

6.2 Implications

Theoretical Implications: This research contributes to literature on technology adoption and industrial policy in regulated high-technology sectors in several ways. First, it demonstrates the value of integrating cross-sectional stakeholder perceptions with system-dynamics modelling: perception-based parameters, when transparently encoded into an SD framework, reveal plausible trajectories and feedbacks that static analyses miss. Second, the results nuance theories of capacity versus institutional constraints by showing that technical capacity (testing labs) and institutional facilitation (regulatory speed, liability clarity) operate through distinct mechanisms-capacity affects throughput, whereas institutional facilitation shapes firm entry and survival. Third, by linking value-chain structure (supply concentration, import dependence) to dynamic outcomes (attrition and certification delays), the study extends supply-chain resilience theory into an institutional-policy context, highlighting how single-node fragilities can interact with regulatory delays to produce systemic risk. In general, the results point to a more integrative theoretical approach according to which institutional facilitation, technical capacity and supply-chain architecture are co-determining factors in sectoral technology transitions.This integrated approach offers a more comprehensive understanding of the complex interplay between technical, economic, and regulatory factors that drive or hinder technological deployment and renewal within high-tech industries (Bihan, Lapi and Halloy, 2025).

Practical and Policy Implications: Practical and Policy Recommendations:The current results and simulations suggest definite and practical priorities to the policymakers, industry participants, and intermediaries of the ecosystem: Focus on reform of regulatory processes to speed up authorization process. The results of the simulation indicate that the largest increase in the OEM/startup survival and long-term ecosystem stability is attained by authorization delays reduction. Such pragmatic actions as simplified single-window operations, identified timeline commitments, and published service-level agreements of approvals are possible.

Explain the liability models to reduce the perceived risk of implementation. Legal ambiguity increases perceived risk and raises entry barriers. A clearer liability allocation through standard contracts, insurance facilitation, and regulatory guidance will reduce risk premia and encourage private investment.

Coordinate capacity expansion with demand stimulation. Reforms to enter firm and demand certification should be matched with investment in testing and certification facilities lest capacity expansion will be underutilized or gain is temporary. Public-private testing hubs and shared certification facilities can provide economies of scale.

Target supply-chain resilience interventions. Isolate and focus on important single-source risk sub-elements and high import reliance; encourage growth of domestic suppliers through specific R&D investments, supplier alliances, and financial vehicles (credit guarantees, purchase commitments) to lower the vulnerability of bottlenecks.

Promote industry-regulator coordination mechanisms. Regular joint forums, published roadmaps for certification, and cooperative pilots (e.g., fast-track approval for demonstrator projects) will align expectations and reduce information asymmetries that slow adoption.

Take a sequencing action plan of policy. According to the model, capacity expansion alone is less effective than when capacity is combined with institutional constraints (regulatory speed and liability) before or at the same time. A combination of all these measures will allow a faster and more efficient introduction of technology and mitigate the possibility of investments in capacity or domestic production being destroyed by the institutional bottlenecks.

Societal and Contextual Relevance: Enhancing the regulatory environment and enhancing the domestic supply chains has more than sector performance benefits. Increased involvement of the private sector increases speed of innovation, higher skilled employment and down stream economic growth in manufacturing and services. Ecosystems of stronger testing and suppliers are increasing national strategic selfsufficiency in essential technologies. Nonetheless, equity should be a priority of reforms: emphasis on support of small and regional suppliers and open contracting will bring the benefits to a large number of people without concentrating the large companies.

Enlightening the general population about the changes in the Indian Space Economy and New Indian Space Policy 2023 will result in wider participation of the society and investment (Deshpande, Palit and Hazra, 2024).

6.3 Recommendations for Future Research

Following the findings and limitations of the current research, the future studies ought to take the following specific and practical lines of inquiry: Increase and broaden the empirical foundation. Conduct a bigger, stratified survey that involves additional suppliers (lower rank firms) and regional regulators and middle level operational employees to enhance representativeness and enable a stronger statistical inference.

Administer surveys on top of administrative and transactional data (e.g. certification records, procurement schedules, import/export data) to facilitate more powerful calibration and validation of dynamic models. Tend towards longitudinal and panel designs. The panel study of firms and regulators should be implemented to monitor the change in perceptions and outcomes over time, making it possible to make a causal conclusion regarding policy changes and shocks. Gather time-series statistics of certification throughput and entry/ exit to tune dynamic models to forecast and retrospective validation.

Increase model fidelity and cross-platform validation

Recreate the SD model in a dedicated system-dynamics platform (AnyLogic, Vensim, Stella) to leverage visual stock-flow tools, and cross-validate results with the Python implementation.

Explore hybrid modelling (agent-based + SD) to capture heterogeneity in firm behaviour (e.g., different firm sizes or strategic types) and network contagion effects in supply disruptions.

Deepen value-chain granularity

Conduct component-level supply-chain mapping for the top critical components identified in the VCM (e.g., the top 10 highest-risk parts). Use firm-to-firm linkages to build a detailed dependency network and simulate localized shocks.

Combine such micro-mapping with scenario stress tests (e.g., trade disruptions) to quantify resilience gains from targeted interventions.

Strengthen qualitative coding and measurement reliability

Use multiple coders and report inter-coder reliability metrics when converting open-ended survey responses into indices; where possible, triangulate coded themes with interviews and documentary evidence.

Test alternative index constructions (equal weighting, PCA-based weights) and report sensitivity of model outcomes to index definition.

Comparative and cross-national studies

Undertake comparative analyses with other national contexts (e.g., small advanced aerospace ecosystems) to identify transferable policies and boundary conditions for institutional reforms.

6.4 Conclusion

This research provides a theory-based and empirically directed evaluation of the functions of regulatory design and certification capacity and supply-chain architecture in influencing the rate, magnitude, and resilience of technology adoption in Indian aerospace industry. Combining the perceptions held by the stakeholders with dynamic simulation and value-chain diagnostics, the research goes beyond the examination of the static policies to indicate the complex interactions and feedback impacts that precondition the disruption of the system by the private sector. The recommendations advanced-emphasizing sequenced and coordinated regulatory facilitation, certification infrastructure, and development of domestic suppliers-are purposefully designed to be operationally viable within the prevailing institutional settings. Although the results are conditionally predetermined by the scope of the data and modelling, they offer strong foundations of comparative policy testing and strategic decision-making. Future research that broadens empirical coverage, adopts longitudinal designs, and deepens component- level value-chain and behavioural modelling will further strengthen causal inference and enable more precise quantification of the long-term economic and strategic returns of the policy interventions identified in this study.

APPENDIX A

SURVEY COVER LETTER

Doctoral Research on Technology-Driven Business Disruption in Indian Aerospace and Defence

Dear Participant,

In my doctoral study, I will use surveys to explore the role of original equipment manufactures (OEMs), startups, regulators, and suppliers in disrupting business technology in the aerospace and defence industry. The research aims to combine both empirical and simulation modelling and policy analysis and come up with a predictive framework of innovation adoption and impact of regulation. You are asked to take part in the survey in order to present insights on:

- The challenges and opportunities faced in technology adoption.
- The role of regulatory frameworks in shaping innovation outcomes.
- Supply chain dynamics and their influence on ecosystem resilience.
- Collaborative pathways between startups, OEMs, regulators, and suppliers.

Survey Links:

- OEMs & Startups: Survey Link
- Regulators in Aerospace & Defence: Survey Link
- Suppliers in Aerospace & Defence: Survey Link

Confidentiality and Ethics:

- Participation is voluntary, and responses will remain confidential.
- Data will be anonymized and analyzed collectively for academic purposes only.
- No sensitive or proprietary information is requested.

Your contributions will help directly to develop the academic knowledge and practical policymaking in aerospace and defence innovation. I am grateful to your time and advice in this research project. Respectfully,

Jofy Joseph Prasad

Doctoral Researcher -Space Economics

Swiss School of Business Management.

Independent Consultant- Rohde & Schwarz | Mentor Kerala Startup Mission

APPENDIX B

INFORMED CONSENT

Doctoral Research on Technology-Driven Business Disruption in Indian Aerospace and Defence

Dear Participant,

You are welcome to take part in a research study as a part of my doctoral thesis. The paper examines the impact and engagement of original equipment manufacturers (OEMs), startups, regulators, and suppliers in a business disruption, caused by technology, in the aerospace and defence industry.

To protect participant confidentiality, the survey instruments were designed to allow respondents to participate anonymously. All data were analyzed collectively. This clause guaranteed that the respondents were allowed to freely contribute without giving any consideration to attribution and this provided the study with greater ethical integrity and validity. The following information should be carefully read, and one has to make a decision whether to participate. It will discuss the purpose of the research, what involvement will entail and your rights as a participant.

Purpose of the Study

This study will combine both empirical and simulation modelling and policy analysis in order to come up with a predictive model of innovation adoption and regulatory influence within the aerospace and defence industry. Participation Involvement.

- A survey based on your position within the ecosystem will be given to you.
- The questionnaire will last about 20-25 minutes.
- No information is sensitive or proprietary.Voluntary Participation
- Participation is entirely voluntary.

- You may withdraw at any time without providing a reason, and without any consequences.

  Confidentiality and Data Handling.
- All the answers will be anonymous and processed together.
- No data in this doctoral research will be utilized in any other way other than academically.
- There will be no names or organizations mentioned in the thesis or other publications.

  Benefits and Risks
- The knowledge you share will help in furthering knowledge in the research and practice of aerospace and defence innovation.
- Participation in this study does not envisage any risks.

  Consent Statement

  By continuing with the survey, you realize that:
- You have read and have understood the above information.
- You are willing to take part in this research voluntarily.
- You see you can get out anywhere without reprimand.

  Researcher:

Jofy Joseph Prasad

Doctoral Researcher -Space Economics

Swiss School of Business Management.

Independent Consultant- Rohde & Schwarz | Mentor Kerala Startup Mission

APPENDIX C

INTERVIEW GUIDE

Presented below are three comprehensive, appendix-ready survey instruments, each customized for a specific stakeholder group: OEMs and Startups, Regulators, and Suppliers. Every instrument incorporates an introduction and consent section, screening criteria, core question sets, response scales, branching instructions, and guidelines for administration and piloting. These may serve as the content for online forms, with printable versions suitable for inclusion in the thesis appendix.

OEMs & Startups Survey Instrument

Title

Survey on Technology-Driven Business Disruption - OEMs & Startups

Intro and Consent (display at start)

Purpose: This survey is part of a doctoral study on technology-driven business disruption in the Indian aerospace and defence sector. Responses will inform a predictive framework linking policy, capability, and market outcomes.

Time: 20-25 minutes.

Voluntary & Anonymity: Participation is voluntary. You may remain anonymous; name and organization fields are optional. Data will be anonymized and used for academic purposes only.

Consent checkbox: *I have read the information above and consent to participate.* (Required to proceed)

Section A - Screening (single-select)

1. **Which best describes your organization?**

- OEM (Original Equipment Manufacturer) - Large (>250 employees)

- OEM - SME (≤250 employees)
- Startup- Early stage (pre-revenue)
- Startup - Growth stage (revenue, scaling)
- Other (specify) [text]

2. **Are you involved in aerospace and/or defence products or services?**
    - Yes
    - No (end survey)
3. **Your role / primary function** (select one)
    - Senior management / Executive
    - R&D / Engineering lead
    - Product / Program manager
    - Quality / Compliance manager
    - Business development / Sales
    - Other (text)

Section B - Organizational Profile (multiple choice / numeric)

1. **Q6.Approximate number of employees**
    - 110; 11-50; 51-250; 251-1000; >1000
    - Q22.**Annual R&D spend as % of revenue**
    - 0%; 1-2%; 3-5%; 6-10%; >10%; Prefer not to say
2. **Q7. Primary market focus** (select all that apply)

Civil aviation; Defence; Space; Satellite systems; Avionics; Ground systems; Other (text) Part C - Technology Adoption and Capability (Likert, multiple choice)(8-10 min).This part explores the involvement of the organization in the development of new technologies and its own innovation and integration potential. The survey tool follows the structured questionnaire format, and it contains many sections that are meant to provoke descriptive statements on different issues regarding disruptive technologies and their effects.

- Q8 What is your main source of innovation? - Multiple choice (select up to 2) (Required): Internal R&D; Partners; Startups; Acquisitions; Academic collaborations; Other (specify)This paragraph goes further to discuss the strategies and barriers involved in the incorporation of new technologies into existing functioning structures, including the level of technological readiness and internal resistance to change.
- Q9 Typical decision gates from PoC to industrialisation (months) - Short answer (numeric months) (Required) The survey also questions perceived risk of these nascent technologies and the measures taken to reduce them, with the Indian dynamic aerospace and defense industry being the setting.
- Q10 KPIs or thresholds used to evaluate adoption (select up to 3) - Multiple choice (Required): NPV/payback; Capex threshold; Time to market; Reliability targets; Regulatory readiness; Strategic fit; Other (specify). It involves the discussion of the priorities of organizations to these metrics and the perceived feasibility of the mentioned indicators as a guide to technology adoption decisions in the intricate environment of the Indian aerospace industry.
- Q11 Give one recent example of a disruptive tech adoption and the key driver/metric (short) - Paragraph (max 120 words) (Required). Besides, the instrument also explores the institutional legitimacy and regulation dynamics that drive the adoption of technology..
- Q12 IP/contract terms that often hold deals - Checkbox list + brief note (Required): IP ownership; licensing fees; exclusivity; transfer of improvements; liability; other (specify):

Section D - Regulatory Interaction (Likert, ranking, open text)(2-3 min). The section will explore the way that the organization interacts with regulatory agencies and its ability to navigate the complicated regulatory environment, such as issues of compliance and certification and policy design.

1. Q13 Does certification/testing requirements influence time to market? Name key bottlenecks (short) - Paragraph (max 100 words) (Required). How does your organization most often interact with regulatory agencies in the course of developing and certifying new technologies?
2. Q14 Mitigation strategies used (select all that apply) - Checkboxes (Required): Pre-cert engagement; Test labs; Provisional approvals; Partnered testing; Design redundancy; Other. How do your organization interact with regulatory organizations in developing and certifying new technologies?

Part E -Supply chain & Collaboration(6-7 min) (Likert, multiple choice)This part is looking at the relationship that the organization has with its suppliers and collaborators and how interactions between the two foster or hinder the incorporation of new technologies and compliance with regulatory standards.

Q15 Map a representative subsystem (key nodes, single-source items, geographic concentration) - Short structured entry (max 120 words) (Required) this will include an analysis of critical components, supplier interdependencies, and the rationale behind the decisions to partner (and in particular within emerging technological paradigms).

Q16 How do you manage supplier risk? (Select all that apply) - Checkboxes (Required): Dual sourcing; Safety stock; Local content; Long-term contracts; Vendor development; Other This includes investigating how organizations use supply chain tools of visibility and traceability to reduce disruption and enhance resiliency, especially in response to unexpected events like global pandemics or geopolitical changes.

Q17 Provide supplier metrics (where available): average lead time (days); OTD percentage; capacity utilization percentage Grid Lead time (days) numeric; OTD percentage numeric; Utilization percentage numeric (Where applicable) This section also examines how prototyping can be used to ensure the success of development in complex supply chains, particularly in areas where technology changes occur quickly and where a high level of regulations has to be met.

- Q18 Describe typical supplier payment terms and working capital constraints (short): This part involves the exploration of the effects of these financial arrangements on supplier relationships sustainability and their innovation capacity (Short answer, required).

- Section F - Workforce and tacit knowledge diffusion (3 min) This section evaluates the policies used to develop talent, transfer knowledge and the approach used to manage the specialized knowledge needed to operate in the ever-changing technological and regulatory environment in the aerospace and defense Industry. Q19 Competencies in short supply in new technology (identify up to 3) Short answer (Required)
- Q20 Time to competency and primary training method Short answer (months + method) (Required)
- Q21 What is the method of transfer of tacit knowledge among partners/suppliers? - Multiple choice + short example (choose no more than 2) (Required): On-the-

job training; Embedded engineers; Technical secondments; Formal handover docs; Digital knowledge base; Other.

Section G - Rapid numeric elicitation (2-3 min)A structured numerical elicitation design will be used in this section, to quantify perceptions and experience in use of disruptive technologies, which would provide a rigorous method of data collection, which can be statistically analysed.

- Q22 R&D expenditure, as a percentage of revenue - Short numeric (Required)
- Q23 PoC to deployment schedule (months) - Short numeric (Required) o
- Q24 Critical components average supplier lead time (days) - Short numeric (Required)
- Q25 Standard payment period to suppliers (days) Short numeric (Required)
- Q26 Expected % increase in project starts if authorization lead time shortens by 40% - Short numeric (Required)

Section H - Closing & attachments This concluding section provides an opportunity for respondents to offer any additional insights, attach relevant documentation, or elaborate on aspects not fully captured by the preceding structured questions, thus enriching the qualitative data obtained.

- Q28 Other comments, risks, suggestions (Optional)- Paragraph (max 150 words) Submit button

Required flags and validation rules

- Mark as Required: Q1(consent), Q3, Q4, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, Q16, Q17(at least lead time), Q18, Q19, Q20, Q21, Q22-Q26. Optional: comments, uploads, email, name.
- Validation: numeric fields only accept numbers; percentage fields 0–100; lead times in months/days numeric; email format for contact; file type/size limits for uploads.
- Multi-select export format: semicolon-separated values in a single cell.

Interviewer tips

- Prioritise completeness for Q9 (decision gate timelines), Q11 (concrete adoption example), Q15 (supply map), Q17 (supplier metrics), and Q22–Q26 (numeric elicitation).
- In case of partial responses accept ranges; note as low-high, and take metrics companywide or product-specific.
- Find one example of concrete project when there is time; avoid qualitative statements in favor of numbers.
- Offer to share anonymized one-page summary post-cleaning; request permission to quote case IDs before publication

Regulators in Aerospace & Defence Survey Instrument

Title

Survey on Regulatory Practice and Innovation - Aerospace & Defence Regulators

Intro and Consent

Purpose: To gather regulator perspectives on certification, risk frameworks, and engagement with industry for doctoral research. Gather systematic contributions to policy design, certification processes, measurement indicators, liability systems, and perceived impacts of compliance actions on aerospace/space operations.

Time: ~15-20 minutes.

Voluntary & Anonymity: It is a voluntary participation. Responses may be anonymous; organizational identifiers optional. Data anonymized for academic use.

Consent checkbox: *I consent to participate.*

Section A - Screening

1. **Which organization do you represent?** (optional text)
2. **Role / function** (select)

    Policy / Regulation; Certification / Testing; Standards development; Compliance enforcement; Other (text)

3. **Are you directly involved in aerospace/defence regulatory processes?** Yes / No (end survey if No)

Section B - Agency mandate and scope (2–3 min)

The following section is an attempt to outline the particular legal and operational frameworks under which the activities of the regulator operate, its jurisdiction and what kind of aerospace and defense technologies it has under its jurisdiction.

6. Provide a brief description of the mandate of your agency in aerospace/space regulation (Required) - Paragraph answer (max 200 words).
7. Types of primary authorization that are managed (Required, multiple choice with other) Checkbox grid (or Multi-select)
    - Options: R&D/test flights; Launch approvals; Payload clearances; Frequency/communications; Operator licensing; Airworthiness certification; Other (please specify)

Section C - Authorization workflow (6–8 min)

This section will discuss the process of decision making as well as the procedure on how to receive regulatory approvals, starting with the submission of the application after which the ultimate certification is given. It explores the effectiveness, openness and flexibility of these processes, particularly in relation to new technologies or unusual ways of operations.

8. describe the end to end authorization procedure to that example (Required) - Paragraph answer (max 300 words)
    - Prompt: List major steps, decision points, responsible units, and expected deliverables at each gate.
9. Average statutory timeframe to this authorization (Required) - Short answer (months)
    - Validation: numeric; otherwise, NA.
10. Usual actual median lead time (Required) -Short answer (months)
    - Validation: numeric; allow ranges (e.g., 2-4) where the exact value is not known..
11. Primary causes of delay (Required) - Multiple choice (choose up to 3) + Other (specify)
    - Options: Incomplete submissions; Inter-agency coordination; Technical evaluation backlog; Legal/insurance clearance; Applicant resubmissions; Resource constraints; Other

Section D - Liability, insurance and dispute resolution (3-4 min)

This comes in the form of the change of ownership of regulated entities and any specific authorization criteria of such changes that is essential in ensuring regulatory control in case of change of ownership by a corporation (Sivan, 2025, p. 20). It also looks at the way in which current legal and insurance paradigms are changing to address the special issues of the new aerospace and defense products, which are frequently not covered by any existing risks and precedent.

13. Which liability/indemnity/insurance provisions typically apply? (Required) - Checkbox list + "Other (specify)"
    - Options: Operator indemnity; Manufacturer liability; Test pilot coverage; Public liability; State indemnity; Mandatory minimum threshold; Other
14. Normal indemnity / insurance threshold (Required) - Short answer (INR crore)
    - Validation: numeric; permit NA where proprietary.

    What is the manner in which conflicts are normally addressed? (mandatory) - Multiple choice + brief explanation (not compulsory)

    - Options: Administrative review; Arbitration; Civil litigation; Regulatory enforcement action; Informal settlement

Section E - Policy effectiveness metrics (3–4 min)

This section concentrates on the measurable and qualitative metrics applied in assessing the effectiveness of regulatory policies, especially in enhancing innovation whilst also ensuring safety and compliance This section also explores how such measures can be used to improve regulatory policies and also to encourage continuous enhancement in regulatory practices.

16. What are the measures that the agency monitors to evaluate the effectiveness of policy? (Required, multi-select)
    - Options: Approvals per year; Median lead time; Statutory vs actual compliance; Resubmission/rejection rate; Number of sandbox pilots; Market entrants per year; Other
17. Provide recent values (last 1–3 years) for these metrics (Required where available) - Grid / table fields (numeric)

- Fields: Median lead time (months); Prescribed statutory timeline (months); Resubmission / rejection rate (%); Avg approvals per year (last 3 years); Approvals per quarter (optional)
- Validation: numeric; accept ranges or “NA”.

18. Have recent regulatory reforms materially altered behaviour? (Required) Single choice + short example (paragraph, max 150 words)
    - Options: Yes; No; Unsure

Section F - Industry engagement and policy update processes (2-3 min)

This section investigates the formal and informal mechanisms through which regulatory bodies interact with industry stakeholders, including OEMs, startups, and suppliers, to inform policy development and adaptation**.** It examines the frequency, format, and perceived effectiveness of these engagements in shaping responsive and future-proof regulatory frameworks for the aerospace and defense sectors.

19. Which engagement mechanisms are used (select all that apply) (Required) - Checkboxes.
    - Options: Regulatory sandboxes; Public consultations; Technical committees; Industry workshops; Pilot programs; Formal advisory panels; Other
20. How are stakeholder inputs integrated into policy updates? (Required) - Short answer (max 150 words)

Section G - Data sharing, documents and follow up (2-3 min)

This last part is devoted to methodologies used to collect, distribute and use data to improve regulatory procedures and guarantee further adherence in the fields of aerospace and defense.

21. Public references or documents that are used to support timeline claims (Optional) - Links or case IDs Provide links or case IDs to publicly available references or documents that support timeline claims (Optional)

Section H - Rapid numeric elicitation (1-2 min)

The method in this section is structured quantitative methods to collect in a short time the expert judgment of probabilities and effects of different regulatory outcomes. It strives to measure the perceived effectiveness and efficiency of the existing regulatory provisions especially in the context of incorporation of new technologies and implications of entry in the market.

24. Median authorization lead time (months) Short answer (numeric)
25. Administered statutory timeline (months) - Short answer (numeric)
26. Resubmission / rejection rate (%) - Short answer (numeric)
27. Short answer (numeric) Avg approvals per year (last 3 years)
28. Normal indemnity/insurance threshold (INR crore) - Short answer (numeric)

Final page - optional comments and submit

This is a detailed survey tool, which aims to provide finer details about the regulatory ecosystem that regulates the aerospace and defense fields, and make a sturdy analysis concerning institutional legitimacy and its influence on innovation.

29. Any additional remarks, threats or recommendations to the policymakers (Optional) - Paragraph

Submit (Button)

Form design & spreadsheet mapping

- Make fields 1-5 and 6-7, 9-12, 13-15, 16-18, 21, 23, 24-28 required to maximize useful responses.
- Use validation rules: numeric for metrics, email format for contact, file type/size limits for uploads.
- In the exported sheet map columns to question numbers (Q1…Q30). For multi-select questions store semicolon-separated values in one cell.
- Add timestamp column and respondent anonymized ID column (auto-generated) for tracking.

Admin notes for interviewer/researcher

- Prioritize Q9 (workflow), Q17 (metrics), Q21 (data availability) when response is incomplete.
- Treat ranges as lower/central/upper in analysis.
- Offer to send an anonymized one-page summary after cleaning data and request permission before quoting any specific case IDs.

Suppliers in Aerospace & Defence Survey Instrument

Title

Survey on Supplier Capability and Readiness - Aerospace & Defence Suppliers

Intro and Consent

Purpose: To understand supplier capabilities, quality systems, and readiness for advanced manufacturing in aerospace and defence.a 20–25-minute online form that captures firm profile, production and supply realities, certification and finance pain points, experience with technology transfer, collaboration incentives, and rapid numeric KPIs. Includes suggested question text, field types, validation, required flags, and spreadsheet column mapping

Time: ~20-25 minutes.

Voluntary & Anonymity: Participation voluntary; name/organization optional. Data anonymized.

Consent checkbox: *I consent to participate.*

Section A - Screening

1. **Supplier tier**
    - Tier 1; Tier 2; Tier 3; Contract manufacturer; Service provider; Other (text)
2. **Primary activities** (select all)
    - Machining; Electronics assembly; Software integration; Materials processing; Testing & calibration; Other (text)
3. **Do you supply aerospace/defence customers? Yes / No (end survey if No**)

Section B - Firm profile and capabilities (2-3 min)

This step will provide information regarding the organizational, operational, and core competencies of the supplier to give a background knowledge of the position of the supplier in the market and strategic alignment in the aerospace and defense supply chain.

- Q5 Year of establishment - Short numeric (Optional)
- Q6 Organisation size (employees) - Dropdown (choices: <10; 10-49; 50-249; 250-999; 1000+) (Required)

- Q7 Main products / services and position in aerospace value chain - Short paragraph (max 120 words) (Required)
- Q8 Key manufacturing capabilities (select up to 3) Checkboxes (required): CNC machining; Sheet metal; Composites; Additive manufacturing; Heat treatment; Surface finishing; Assembly; Testing; Other (specify)

  Section C - Production & supply chain realities (8-10 min)

  This part discusses the complexity of operations of suppliers, including information like volumes of production, lead times, inventory loss techniques, and other issues in material sourcing or logistics in the specialized aerospace and defense environments.

    - Q9 For primary product (days) - Typical lead time (Short numeric) - Required.
    - Q10 Lead time variability and major delay causes (short) - Short paragraph (max 120 words) (Required)
    - Q11 Which inputs are imported? Rank top 3 by value and average procurement lead time (days) - Brief paragraph (Required)
    - Q14 Single-source dependencies (yes/no) Single choice (Required). Should it be Yes,
    - Q14a: specify component(s) and impact (short) - Short answer (Required in case Q14=Yes)
    - Q15 Capacity utilisation (% normal) and key bottlenecks (machines, labour, testing slots) - Short numeric (capacity utilisation (%))-short text (bottlenecks (two fields)) (Required)

Section D - Certification, quality & finance (5–6 min)

It is here that the crucial aspects of regulation compliance, quality assurance measures and financial sustainability are investigated, which are key when suppliers in the strict aerospace and defense sectors are concerned. It seeks to determine the level of compliance with the industry-oriented standards and the strong financial processes that facilitate their activities and possible growth.

- Q16 Does your product have any certifications / test approvals (required or not), (select all that apply) - Checkboxes (Required): AS9100; NADCAP; IS/ISO; Airworthiness/authority approval; Supplier qualification by OEM; Lab testing; Other (specify)
- Q17 Average time to achieve the necessary certification (months)- Short numeric (Required)
- Q18 Approved average or order of magnitude cost of certifying a new product (INR lakh) - Short numeric (Optional)
- Q19 Explain payment terms that you get and impacts of late payments on operations (short) - Short paragraph (max 120 words) (Required)
- Q20 Access to finance (Select all that applies) - Checkboxes (Requirement): Bank loans; Invoice discounting; Supplier credit; Govt schemes; Venture capital; None.

  Section E - Innovation interaction & barriers (3–4 min)

  This paragraph will explore how suppliers have been interacting with technological changes and the challenges that they encounter when adopting or creating new solutions in the highly-regulated aerospace and defense ecosystem. It also explores how the market forces, non-market forces and the barriers that may exist could also be interplayed to facilitate disruptive innovation in the Indian aerospace and defense industry.

- Q21 Have you participated in technology transfer or embraced high-technology manufacturing (e.g., AM)? - Multiple choice (Optional): Yes; No.
- Q22 If Yes, key obstacles experienced (choose 3 at most) - Checkboxes (Required) when Q21=Yes) Tooling cost; IP restrictions; Skill gaps; Certification hurdles; High volume economics; Quality repeatability; Other (specify)
- Q23 What types of cooperation with OEMs/regulators do best and worst? Examples Take one brief example of each (max 120 words) - Short paragraph (Required)
- Q24 Which policy, procurement or financing instrument would you most alter your investment decision? (choose one) - Single choice (Required): Low-interest loans; Advance purchase commitments; Subsidised certification support; Tax incentives; Training grants; Preferential procurement; Other (specify)

Section F - Rapid numeric elicitation (2–3 min)

The section follows a structured numerical elicitation approach to measure the key performance indicators and perceived risks so that an aerospace and defense industry could be assessed in a standardized way in terms of supplier performance and operational vulnerability.

- Q25 Avg lead time primary product (days) - Short numeric (Required)
- Q26 Capacity utilisation (%) - Short numeric 0-100 (Required)
- Q27 Avg receivable / payment term (days) - Short numeric (Required)
- Q28% of imports by value - Short numeric 0-100 (Necessary)

- Q29 Time to certify new product (months) - Short numeric (Required)

  Section G - Closing & attachments

Lastly, the section will enable the gathering of any added documents or other comments considered relevant by the supplier, thereby having a complete data collection to be used in further analysis.

- Q31 Additional comments, risks or other suggestions to policymakers (Optional) -Paragraph (max 150 words) Submit button

Required flags and validation rules

- One needs: Q1 (consent), Q3, Q4, Q5, Q6, Q11, Q12, Q14, Q15, Q16, Q17, Q18, Q19, Q20, Q22-Q24, Q25-Q29. Optional: name, email, Q18 (cost), uploads, comments.
- Validation: numeric fields accept only numbers; percentages constrained 0–100; days/months numeric; email format validation; file type/size limits.
- Multi-select export: semicolon-separated values in single cell.

Interviewer / researcher tips (brief)

- Prioritise Q11 (lead time), Q13 (imported inputs and lead times), Q15 (capacity utilisation and bottlenecks), Q17 (certification time), and Q25–Q29 (numeric KPIs).
- Capture both typical and peak (stress) lead times; accept ranges and record as "low–high".
- Triangulate KPIs with OEM responses and trade data during analysis.
- Request a single specific project/example where you can obtain real numbers (reject rates, OTD, rework cost).

- Request permission and offer to provide an anonymized benchmarking summary before quoting any firm specific IDs.

Common Survey Design Details (for all instruments)

Question Types & Scales

  - Likert scale: 1-5 (Strongly disagree - Strongly agree).
  - Multi choice: single or multi select as required.
  - Ranking: drag/drop/numeric rank fields of top 3 items.
  - Numeric fields: should have ranges or exact numbers; should have Prefer not to say.
  - Open text: short (1-2 sentences) or long (paragraph) as it is mentioned.

Branching Logic

- Select role screening to display relevant sections only.
- Apply optional follow ups (e.g. participation in a sandbox, certifications) with conditional follow ups.
- Ethics, Anonymity and Data Processing.
- Attach the complete informed consent form in the appendix.
- Optional: include the name/organization but do not include this with the responses to the survey.
- Respond anonymously and present aggregated findings and anonymized quotes only..

Piloting & Validation

- **Pilot sample:** 6–10 respondents per stakeholder group (mix of roles).
- **Pilot objectives:** clarity, timing, branching correctness, technical issues.
- **Revise** based on pilot feedback; document changes in a pilot log for the appendix.

Distribution & Response Management

- Use the covering letter (appendix) in recruitment emails.
- Send two reminders at one-week intervals.
- Track response rates by stakeholder group and adjust outreach to meet minimum targets (25–40 per group recommended).

Analysis Plan (brief)

- **Quantitative:** descriptive stats, cross-tabulations, non-parametric tests, exploratory factor analysis for attitudinal scales.
- **Qualitative:** thematic coding of open responses; extract anonymized illustrative quotes.
- **Integration:** triangulate survey findings with simulation modelling and policy analysis in thesis chapters.

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