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Fault in orbit: Constructing an Indian standard of care for satellite operators under Article III of the Liability Convention

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Abstract
Article III of the 1972 Liability Convention imposes fault-based liability when one space object damages another in outer space, yet the Convention does not define fault or prescribe an operational standard of care. Existing scholarship has persuasively identified this treaty gap; the contemporary Indian problem is more specific. India is expanding private space activity through IN-SPACe while simultaneously operating an increasingly sophisticated space-situational-awareness and collision-avoidance system. This paper argues that India should convert emerging technical practices into a licensing-based standard of care for Indian satellite operators. Drawing on Article III, Article VI of the Outer Space Treaty, UN long-term-sustainability guidelines, NASA conjunction-assessment practice, ISO/ESA debris standards, ISRO's 2025 Space Situational Awareness Report and India's authorisation framework, the paper proposes a five-part 'Orbital Reasonableness Test'. Fault should turn on trackability and data quality; receipt and evaluation of conjunction warnings; manoeuvrability and proportionate mitigation; operator-to-operator coordination; and compliance with debris, end-of-life and incident-record duties. The framework does not purport to rewrite the Liability Convention. It uses national authorisation and continuing supervision to define ex ante duties whose breach can later provide evidence of fault. India can therefore reduce international exposure while contributing operationally grounded state practice to the evolving law of orbital responsibility.

Keywords: Space law, Liability Convention; fault, satellite collision, conjunction assessment, In-Space, space situational awareness, Space traffic management

Introduction

The classic space treaties were negotiated when the principal actors were States and the number of active spacecrafts was small. The contemporary orbital environment is different: commercial constellations, small satellites and increasingly autonomous operations occupy congested orbital regimes, while collision warnings and avoidance manoeuvres have become routine features of responsible mission operations.

International law nevertheless retains a strikingly open-textured rule. Under Article III of the Convention on International Liability for Damage Caused by Space Objects 1972 [1], where damage is caused in outer space to a space object of one launching State by the space object of another, the latter is liable only if the damage is due to its fault or the fault of persons for whom it is responsible. The Convention neither defines 'fault' nor identifies the conduct expected of a reasonable satellite operator. [1]

Leading scholarship has already identified this doctrinal gap. Dennerley argues that the concept should be developed through general international law and standards of due diligence; more recent operational scholarship demonstrates that proving fault also depends on observability, data quality and the evidentiary record of conjunction events. [2] This paper therefore does not claim that undefined fault is a newly discovered problem. Its contribution is to construct an Indian operational standard of care capable of being implemented through IN-SPACe authorisation and continuing supervision.

Research Question and Method

The research question is: which operational duties should Indian satellite operators owe, ex ante, so that failure to comply can provide a coherent basis for determining fault after an orbital collision? The method is doctrinal, comparative and regulatory. It interprets the Liability Convention alongside the Outer Space Treaty, extracts behavioural expectations from international sustainability guidance and mature agency practice, and maps those expectations onto India's licensing and SSA institutions.

The paper's thesis is that Article III fault should be operationalised domestically as negligence-like failure to take reasonably available collision-prevention measures in light of information, capability, risk and coordination opportunities known or reasonably knowable to the operator. National rules cannot conclusively determine international liability, but they can create evidence of the standard expected from persons for whom India may be internationally responsible.

The International Legal Framework

The Liability Convention establishes a dual standard. Article II imposes absolute liability for damage caused on the surface of the Earth or to aircraft in flight; Article III uses fault for damage to another space object in outer space. The drafting choice reflects a compromise but leaves fault undefined. [3]

The Outer Space Treaty adds a separate responsibility architecture. Article VI makes States internationally responsible for national activities in outer space, including activities carried on by non-governmental entities, and requires authorisation and continuing supervision. For India, this means that private-sector growth does not eliminate the State's international interest in operational conduct. Domestic licensing becomes the mechanism through which India can translate broad treaty responsibility into concrete operator duties.

Article III's phrase 'fault of persons for whom [a State] is responsible' is especially important in the commercial era. Even where the precise international attribution analysis is contested, the launching State has strong incentives to supervise operators whose conduct can expose it to claims or diplomatic disputes.

1. From State Liability to Operator Conduct

The treaty claim is formally inter-State, but the conduct that generates orbital risk is increasingly undertaken by private operators. Article VI of the Outer Space Treaty is therefore important alongside the Liability Convention: States bear international responsibility for national activities by non-governmental entities and must authorise and continuously supervise them. For India, the practical consequence is that an Article III dispute may turn on operational decisions made inside a private mission-control room even though the international claim is asserted against a launching State. [9]

That structure creates a regulatory incentive to define expected operator behaviour before an accident occurs. If domestic authorisation merely requires general compliance with applicable law, the State may later struggle to show what level of care it reasonably expected from the operator. Licence conditions can narrow that uncertainty by specifying processes for conjunction screening, contactability, decision logging, manoeuvre coordination and end-of-life operations. They would not change the treaty's allocation of international responsibility, but they would improve the factual basis on which fault and any domestic recourse can be assessed.

Why Existing International Guidance Can Inform Fault

The absence of a binding universal traffic code does not mean there is no evidence of reasonable conduct. The UN Guidelines for the Long-term Sustainability of Outer Space Activities encourage States and operators to share orbital information, improve the accuracy of orbital data, perform conjunction assessment during controlled flight, develop pre-launch assessment and design and operate space objects sustainably. [4] These guidelines are formally non-binding, but they are relevant evidence of internationally endorsed safety expectations.

Technical standards add specificity. ISO 24113:2023 establishes top-level space-debris mitigation requirements. ESA's updated debris requirements now expressly address collision avoidance and space-traffic coordination, including data-sharing and manoeuvrability expectations for higher-risk missions.5 NASA's Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook likewise sets out practices on trackability, ephemeris generation, risk assessment, mitigation and coordination. [6]

No single document should automatically become the legal standard. A reasonable-care inquiry must remain sensitive to mission type, technical capability and risk. But convergence across these instruments can establish a persuasive baseline of expected operator behaviour.

1. Soft Law as Evidence of Care, Not Automatic Liability

International and technical standards should not be treated as though every deviation automatically constitutes treaty fault. Their legal relevance is evidentiary. Where a practice is widely used, technically feasible and directed to a known collision risk, it can help a decision-maker identify what a reasonable operator could have foreseen and done. Conversely, a novel mission may justify an equivalent safety method that departs from an established handbook while achieving the same risk-control objective.

This approach also avoids freezing technology. NASA's conjunction framework, UN long-term sustainability guidance, ISO standards and ESA requirements evolve at different speeds and apply to different institutional settings. Indian regulation should therefore incorporate them through performance-based duties and recognised technical baselines rather than copying every numerical threshold into primary law. IN-SPACe could update technical schedules or licence conditions as operational practice changes while preserving a stable legal duty of reasonable collision-risk management. [10]

India's Operational Context: Collision Avoidance Is Already Real

India's own practice makes the issue concrete. ISRO's Indian Space Situational Awareness Report for 2025 [7] states that more than 150,000 conjunction alerts issued for Indian Earth-orbiting satellites were analysed using operational flight-dynamics data. ISRO carried out 18 collision-avoidance manoeuvres for Earth-orbiting satellites in 2025—14 in LEO and four in GEO—and revised numerous routine manoeuvre plans to avoid post-manoeuvre close approaches. [7]

ISRO's System for Safe and Sustainable Space Operations Management (IS4OM) functions as the nodal entity for SSA and space-sustainability activity. India's public operator therefore already maintains institutional expertise capable of informing national standards for private operators. As commercial authorisations increase, the legal question is whether equivalent minimum safety duties should remain implicit or be incorporated into licensing conditions.

1. What Indian Operations Already Reveal about the Standard of Care

ISSAR-2025 shows that collision avoidance is not a binary choice between 'manoeuvre' and 'do nothing'. ISRO analysed more than 150,000 alerts, incorporated avoidance requirements into routine orbit-maintenance manoeuvres where feasible, and revised numerous planned manoeuvres because the manoeuvre itself could create a subsequent close approach. This operational record supports a legal standard centred on documented risk management rather than hindsight. Reasonableness may consist in changing timing, modifying an ordinary manoeuvre, coordinating with another operator, or deciding not to manoeuvre when uncertainty remains too high. [11]

The same evidence demonstrates why a regulator should care about institutional capability, not only the final command sent to a satellite. Safe operation requires staff who can interpret covariance and probability information, access to reliable orbit determination, escalation procedures, and authority to execute timely mitigation. For higher-risk Indian missions, IN-SPACe should therefore be able to examine whether the operator possesses an adequate conjunction-management system before launch and whether that capability is maintained during the mission.

The Limits of a Pure Treaty Interpretation Approach

A purely abstract interpretation of 'fault' cannot resolve the modern operational problem. A collision dispute will

require answers to factual questions: Was the spacecraft trackable? Did the operator receive a conjunction message? Was the warning reliable? Did the satellite have propulsion? Could it manoeuvre without creating a larger risk? Did both operators communicate? Were updated ephemerides shared? Were logs preserved?

Recent case-study scholarship makes the evidentiary point directly: small satellites, debris and incomplete observability can make it difficult to prove the chain of causation and breach of a duty of care. [8] The standard of care must therefore include information and recordkeeping duties, not merely a final obligation to manoeuvre.

1. Collision Typology Matters to Fault Analysis

Not all orbital collisions present the same negligence question. In an active-active encounter, both operators may possess tracking data and manoeuvre capability, making communication and coordinated decision-making central. In an active-debris encounter, only one object can respond, so the inquiry shifts toward the active operator's knowledge and reasonable mitigation options while questions concerning the debris object's historic creation and disposal remain separate. A collision involving an untrackable fragment may make event-specific avoidance impossible and place greater weight on upstream debris-prevention duties.

The test should therefore identify the encounter class before assessing breach. A legal rule that simply asks whether a manoeuvre occurred risks imposing impossible duties in debris encounters and under-regulating coordination failures between two capable spacecraft. Encounter classification also clarifies causation: the relevant omission may be failure to share an ephemeris, inability to receive warnings, a design choice to operate without recurrent manoeuvrability, or failure to mitigate after credible knowledge arose.

Proposed Orbital Reasonableness Test

India should incorporate into IN-SPACe authorisations a five-part Orbital Reasonableness Test. The test would operate ex ante as a compliance standard and ex post as evidence relevant to fault.

Element	Core duty	Fault indicators
1. Trackability and data quality	Maintain reasonable trackability; generate and update ephemeris/orbital information appropriate to mission risk; disclose material uncertainties.	Untrackable design without justification; stale or knowingly inaccurate orbital data; failure to communicate material uncertainty.
2. Conjunction assessment	Participate in recognised screening and promptly evaluate credible conjunction warnings.	Ignoring repeated high-quality warnings; absence of documented risk assessment; failure to obtain available data.
3. Capability and mitigation	Maintain manoeuvrability where proportionate to mission risk and use reasonable mitigation when collision probability crosses mission-specific action thresholds.	Failure to manoeuvre despite capability and serious risk; disabling propulsion without adequate alternative risk plan.
4. Coordination	Maintain reachable operator contacts and coordinate with counterpart operators where both can affect the encounter geometry.	Failure to respond; contradictory manoeuvres caused by lack of coordination; withholding useful ephemeris data without legitimate reason.
5. Lifecycle and records	Comply with debris/end-of-life requirements; preserve conjunction, decision and manoeuvre logs for post-event reconstruction.	Non-compliant disposal; failure to passivate; destruction or non-retention of material incident records.

Element One: Trackability and Data Quality

A satellite operator cannot reasonably respond to collision risk if the spacecraft cannot be accurately tracked or its orbit cannot be predicted with sufficient confidence. NASA best practice treats trackability and ephemeris generation as core parts of conjunction safety. For Indian licensing, the required standard should be risk-weighted: a small short-lived low-risk mission may justify a lower compliance burden than a large constellation operating persistently in a congested shell.

Fault should not arise merely because uncertainty exists. It should arise where the operator fails to take reasonably available steps to reduce avoidable uncertainty or fails to disclose uncertainty that materially affects another operator's risk assessment.

Element Two: Conjunction Warnings and Knowledge

Receipt of a credible conjunction warning transforms abstract risk into foreseeable risk. The legal significance of the warning should depend on its quality, predicted probability, uncertainty and time to closest approach. A single low-confidence alert should not automatically create a duty to manoeuvre. Repeated or improving warnings, however, can establish actual knowledge requiring documented evaluation.

The operator's duty should therefore be procedural before it is substantive: receive, assess, document and escalate. Failure to establish an operations process for credible warnings is easier to identify and regulate than hindsight-based assertions that a particular manoeuvre should have been performed.

1. Why a Single Collision-Probability Threshold Is Insufficient

A legal duty should not be triggered mechanically by one universal probability-of-collision number. Collision probability depends on the quality of orbital data, covariance, assumed object size and modelling choices; it can rise or fall sharply as additional observations arrive. A low numerical probability may still demand attention where uncertainty is large or the consequence of collision is exceptional, while a nominally high value may later reduce as encounter geometry becomes better known. The operator's duty should therefore respond to the quality and evolution of the warning, not a single snapshot. [12]

Numerical thresholds can nevertheless serve as presumptive operational triggers. ESA uses defined collision-risk thresholds in parts of its requirements for manoeuvrable spacecraft, while NASA employs a structured assessment-and-mitigation process. India could require each high-risk operator to adopt approved action thresholds and escalation

rules suited to its mission class. Failure to follow an approved process without documented justification would then be relevant to fault, while preserving discretion where rigid compliance would itself create greater risk. [13]

Element Three: Manoeuvrability and Proportionate Mitigation

A universal duty to manoeuvre would be unrealistic because some spacecraft is non-manoeuvrable, manoeuvres consume scarce fuel, and an uncoordinated manoeuvre can create new conjunctions. The standard should instead ask whether the operator had a reasonably available mitigation option proportionate to the predicted risk and mission capability.

Regulation should also address design. For high-risk or constellation missions, recurrent manoeuvrability may itself be a reasonable ex ante requirement. ESA's contemporary standards increasingly connect collision-risk classification with manoeuvre capability. India can adopt a similar risk-based approach without imposing identical technical architecture on every mission.

Element Four: Operator Coordination

Many conjunctions involve two active spacecraft. Fault analysis becomes difficult if each operator independently decides to manoeuvre. Licensing should therefore require registered operational contacts, response-time expectations and exchange of sufficiently precise manoeuvre intentions where coordination is necessary. The purpose is not to create an absolute 'right of way' rule, which international law currently lacks, but to make avoidable non-communication legally relevant.

1. Coordination Failures and Shared Responsibility

Active-active conjunctions also expose the weakness of treating one operator as the automatic 'primary' actor merely because a screening system labels one object primary and the other secondary. Those labels serve analytical convenience; they do not create legal right of way. Where both spacecraft can manoeuvre, reasonable care may require one operator to disclose a planned manoeuvre and the other to avoid taking an inconsistent action. The quality and timing of communication should therefore form part of the breach analysis for each operator separately.

The Liability Convention itself anticipates the possibility of shared fault. Article IV apportions the burden between launching States according to their respective fault where their space objects cause damage to a third State, and defaults to equal apportionment if the extent of fault cannot be established. Although Article IV addresses a specific multi-State configuration, its structure reinforces the broader point that orbital responsibility need not be all-or-nothing. A domestic standard should preserve the capacity to identify concurrent failures by multiple operators. [14]

Element Five: Lifecycle Compliance and Evidence Preservation

Collision responsibility does not begin minutes before closest approach. Poor disposal, failure to passivate and abandoned objects contribute to systemic risk. ISO, UN and ESA frameworks therefore treat end-of-life behaviour as part of space sustainability. Indian authorisations should similarly connect disposal duties to operational responsibility.

Evidence preservation is equally important. Because the international regime has almost no contested-collision jurisprudence, reliable logs may determine whether fault can be established at all. Operators should retain warning messages, covariance and ephemeris data used in decisions, internal risk assessments, communications with other operators and executed manoeuvre records for a prescribed period.

How the Test Should Interact with International Law

The Orbital Reasonableness Test would not bind another State's interpretation of Article III and should not be presented as unilateral amendment of the Liability Convention. Its legal value would arise in three ways. First, it would define contractual and regulatory obligations of Indian licensees. Second, breach would provide factual evidence that an operator failed to exercise reasonable care. Third, consistent Indian practice, especially if aligned with international standards, could contribute to the gradual consolidation of due-diligence expectations in space operations.

Conversely, compliance with the test should not operate as an absolute safe harbour. An operator may comply with minimum rules yet act unreasonably in an exceptional situation. The test should create a rebuttable evidentiary framework rather than mechanical immunity.

Evidentiary Presumptions and the Burden of Reconstruction

The proposed test is most useful if it structures evidence before an accident rather than merely supplying arguments afterwards. Compliance records should create a rebuttable inference that the operator maintained a reasonable safety system; a documented departure from an approved collision-risk procedure should correspondingly require explanation. Neither inference should be conclusive, because unusual encounter dynamics may justify deviation and formal compliance may still mask obviously unreasonable conduct.

Post-collision reconstruction will often depend on data held by the operators themselves. Indian authorisations should therefore impose preservation duties that activate upon serious conjunctions and not only after physical impact. If an operator fails without justification to preserve warnings, decision logs or manoeuvre records required by its licence, the decision-maker should be permitted to draw an adverse evidentiary inference. Such a rule aligns incentives before the event and reduces the risk that Article III's fault standard becomes practically unenforceable for want of records.

Private Operators, IN-SPACe and Continuing Supervision

The Indian Space Policy 2023 [5] and IN-SPACe authorisation architecture provide the institutional route for implementation. Article VI of the Outer Space Treaty makes continuing supervision especially relevant: authorisation cannot be a one-time entry permission if safe operations require ongoing SSA participation, reporting and end-of-life compliance.

IN-SPACe should therefore require mission-specific collision-risk plans at authorisation, periodic certification for higher-risk operators, notification of material loss of manoeuvrability, and serious-conjunction reporting. IS4OM expertise can support standards and information exchange

without necessarily becoming the adjudicator of operator liability.

Recommendations

- IN-SPACe should issue binding or licence-incorporated collision-avoidance and space-traffic coordination conditions applicable to Indian authorised satellite operators.
- Those conditions should adopt the five-part Orbital Reasonableness Test and scale obligations according to mission risk, orbit, constellation size and manoeuvrability.
- Operators should maintain registered 24/7 conjunction contacts and documented procedures for assessing credible warnings.
- High-risk and constellation missions should demonstrate adequate trackability, reliable ephemeris production and proportionate manoeuvrability before authorisation.
- Licences should impose incident-record preservation and serious-conjunction reporting duties to make later fault determination evidentially possible.
- Indian rules should expressly recognise UN LTS guidance, ISO 24113 and mature conjunction best practices as persuasive technical baselines while allowing equivalent safety demonstrations.
- Compliance should create a rebuttable presumption of reasonable operational care, not absolute immunity; grossly unreasonable conduct in a specific event should remain actionable.

Conclusion

Article III's undefined fault standard is often treated as a defect that only a new international space-traffic treaty can cure. That response is incomplete. International consensus may be slow, but national regulators already authorise and supervise the operators whose decisions create or mitigate collision risk. India can therefore make the existing treaty more workable by defining, in advance, what responsible operation requires from Indian licensees.

The proposed Orbital Reasonableness Test translates contemporary safety practice into legal duties without pretending that every conjunction has a simple answer. It focuses on the things an operator can reasonably control: data quality, attention to warnings, proportionate mitigation, coordination, lifecycle responsibility and records. By embedding those duties in authorisation and continuing supervision, India can reduce its own international exposure, improve private-sector predictability and contribute concrete State practice to the emerging law of space traffic responsibility.

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