

CHAPTER I

INTRODUCTION

A. Background

In recent years, human activities in outer space have accelerated at an unprecedented rate, with state agencies and private entities alike launching satellites and spacecraft to serve scientific, commercial, and defense purposes.¹ Since the launch of Sputnik 1 in 1957, many countries and now private companies have been sending satellites and spacecraft into orbit. These developments bring clear benefits in communication, navigation, science, and even defense. However, they also create a serious side effect: the build-up of space debris.²

Space debris refers to all non-functioning objects in orbit, such as old satellites, used rocket parts, and fragments from explosions or collisions.³ According to the European Space Agency, there are currently more than 36,000 pieces of debris larger than 10 cm being tracked, and millions of smaller pieces too tiny to monitor.⁴ Even small fragments can be very dangerous, since they move at speeds of up to 28,000 km/h and can severely damage active satellites or threaten astronauts in space.⁵

One of the biggest fears related to debris is the Kessler Syndrome, where collisions between objects produce new fragments that trigger even more collisions.⁶ This could make some orbital areas unusable for decades and put at

¹ OECD. 2023. "The Space Economy in Figures. Organisation for Economic Co-operation and Development". Accessed from <https://www.oecd.org/innovation/inno/space-forum/the-space-economy-in-figures-fa5494aa-en.htm>

² United Nations Office for Outer Space Affairs (UNOOSA). 2010. *Space Sustainability and Governance Reports* (Vienna: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/topics/space-debris.html>]

³ European Space Agency (ESA). 2023. *Space debris: The ESA approach* (Paris: European Space Agency). [https://www.esa.int/Safety_Security/Space_Debris/]

⁴ European Space Agency (ESA). 2025. *Annual Space Environment Report 2025 (ESA Publication BR-365)* (Paris: European Space Agency). [https://www.esa.int/Safety_Security/Space_Debris/]

⁵ European Space Agency (ESA). 2025. *Space Environment Statistics Report* (Paris: European Space Agency). [https://www.esa.int/Safety_Security/Space_Debris/]

⁶ Donald J. Kessler dan Burton G. Cour-Palais. 1978. *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*. *Journal of Geophysical Research: Space Physics*. Vol. 83, No. A6, pp. 2637-2646.

risk the future of space activities. Because of this, space debris is not only a technical issue but also a legal and environmental challenge for the whole world.⁷

The main legal framework for space is the United Nations Outer Space Treaty of 1967. The treaty sets out important principles, space must be used peacefully and for the benefit of all humanity, countries must avoid harmful contamination, and states are responsible for their activities in space.⁸ Article VI of the treaty makes states internationally responsible for both government and private activities, and Article VII makes states liable for any damage caused by their space objects.⁹

However, the treaty does not include specific rules on how to reduce or clean up space debris. Later, the Space Debris Mitigation Guidelines issued by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in 2010 gave recommendations on how to limit debris creation. But these guidelines are not binding, meaning countries and companies are not legally forced to follow them.¹⁰ This issue leads to the first research question of this thesis.

The second important issue is the growing role of private companies. SpaceX, for example, has become a leading space company through its Starlink satellite constellation. With thousands of satellites launched and regular rocket launches, the company has raised concerns about orbital crowding and debris creation¹¹. While SpaceX tries to follow safe deorbit practices, accidents and failures still happen.

A very clear example occurred in February 2025, when a Falcon 9 upper stage from a Starlink launch reentered Earth's atmosphere in an uncontrolled way. On the night of February 19, a fireball was seen crossing the skies of Western Europe, including the UK and Germany. The object was confirmed as a

⁷ United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (Vienna: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/topics/space-debris.html>], p. 1

⁸ United Nations. 1967. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty)* (New York: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html>], p. 4-5

⁹ *Ibid.*

¹⁰ United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (Vienna: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/topics/space-debris.html>], p. 2

¹¹ NDTV. 2026. "Starlink satellites falling to Earth raise fears of space junk chain reaction". Accessed from <https://www.ndtv.com/science/starlink-satellites-falling-to-earth-raise-fears-of-space-junk-chain-reaction-9457941>

Falcon 9 rocket stage (object ID 62878 / 2025-022Y), which failed to perform a planned controlled reentry. SpaceX later explained that a leak in the rocket's liquid oxygen system caused a failure in its attitude control, preventing the deorbit maneuver.¹²

Debris from the rocket was found on the ground in Poland. One piece landed at a company's property in Komorniki, and another was recovered in a forest in Wiry village, about 30 km away. Local authorities and the Polish Space Agency confirmed the recovery of these objects. Fortunately, no people were hurt, but the event highlighted the risks that uncontrolled debris poses to populated areas and the cross-border nature of such incidents.¹³ This incident links directly to the second research question.

According to current international space law, liability for damage lies with the launching state, not directly with the private company. This is stated in both the Outer Space Treaty and the 1972 Liability Convention.¹⁴ This means that if a SpaceX rocket causes damage, the United States as the launching state is legally responsible. However, experts argue that this framework does not fully reflect today's reality, where private companies are dominant actors.¹⁵ Simply holding states accountable may not be enough to encourage responsible behavior by corporations.

At the same time, lessons can be drawn from international environmental law. The Basel Convention of 1989 regulates hazardous waste and its movement across borders. It promotes principles such as state responsibility, transboundary harm prevention, and the polluter pays principle.¹⁶ Although it applies to waste on Earth, its principles can also be used as an analogy for space debris that falls

¹² Space.com. 2025. "SpaceX says its Falcon 9 rocket debris crash over Europe was caused by propellant leak". 26 February 2025. Accessed from <https://www.space.com/space-exploration/launches-spacecraft/fiery-falcon-9-rocket-debris-crash-over-europe-caused-by-propellant-leak-spacex-says>

¹³ Space.com. 2025. "SpaceX Falcon 9 rocket debris creates dramatic fireball over Europe, crashes in Poland". 20 February 2025. Accessed from <https://www.space.com/space-exploration/launches-spacecraft/spacex-falcon-9-rocket-debris-creates-dramatic-fireball-over-europe-crashes-in-poland>

¹⁴ United Nations. 1972. *Convention on International Liability for Damage Caused by Space Objects* (New York: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html>], p. 25

¹⁵ Fabio Tronchetti. 2013. "The Liability Convention: Time for Revision?". *Journal of Space Law*. Jackson: University of Mississippi School of Law.

¹⁶ United Nations. 1989. *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* (Geneva: United Nations Environment Programme). [<https://www.basel.int/>], pp. 11, 13, 75

back to Earth. In the Falcon 9 case, debris traveled across European airspace before landing in Poland, making it an issue of transboundary pollution similar to the problems addressed in the Basel Convention.

The difficulty is that space law does not yet have strong enforcement mechanisms. Environmental treaties often include reporting duties, compliance checks, and sometimes sanctions, but space law mostly relies on states' own regulations and goodwill. For example, the United States requires companies like SpaceX to follow debris mitigation standards through licensing by the Federal Communications Commission (FCC).¹⁷ Yet this does not solve the problem globally, since debris risks are international by nature.

The Falcon 9 fireball over Europe in February 2025 shows how real and urgent the problem has become. It illustrates the gaps in current law: there is no clear way to make private companies directly responsible, and no strong international system to enforce debris mitigation. This thesis therefore focuses on how the existing framework of the UN Outer Space Treaty can be used or improved for effective debris management, and whether principles from the Basel Convention can help in defining the responsibility of private actors like SpaceX when debris crosses borders and causes risks to people or the environment.

In general operation, the Basel Convention establishes a control system based on prior informed consent (PIC), requiring exporting states to notify and obtain approval from importing states before hazardous waste is moved. It also obliges states to ensure environmentally sound management (ESM), minimize waste generation, and prohibit exports to countries lacking capacity to manage such waste safely. In cases of illegal traffic, the Convention treats it as a criminal act, requiring states to impose national sanctions such as fines, penalties, or obligations to re-import and properly dispose of the waste.¹⁸

From this perspective, space debris that re-enters Earth and crosses borders can be analogized as transboundary hazardous waste. Although not

¹⁷ Federal Communications Commission (FCC). 2020. *Report and Order on Orbital Debris Mitigation Requirements*, Federal Communications Commission (Washington, D.C.: Federal Communications Commission). [<https://www.fcc.gov/document/fcc-adopts-new-rules-mitigate-orbital-debris>]

¹⁸ United Nations. 1989. *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* (Geneva: United Nations Environment Programme). [<https://www.basel.int/>]

formally classified under the Convention, debris poses comparable risks: physical injury, environmental contamination from residual fuel or materials, and damage to property. Under a Basel-inspired approach, the state connected to the debris-generating activity could be expected to ensure safe disposal, notify affected states, and bear the costs of recovery and remediation under the polluter-pays principle.

Furthermore, applying Basel's logic highlights the dangers of debris more clearly. Uncontrolled re-entry resembles unauthorized waste transfer, where affected states have no prior warning or consent. The absence of notification and control increases risks to public safety and environmental integrity. Therefore, viewing space debris through the Basel framework emphasizes the need for stricter monitoring, accountability, and possible sanction mechanisms in space law, particularly when private actors like SpaceX are involved in activities with transboundary consequences.

B. Problem Formulation

1. How can space debris mitigation be effectively implemented under the framework of the United Nations Outer Space Treaty?
2. How can private actors such as SpaceX be held responsible as a polluter for transboundary space debris under the principles of the UN Space Treaty and the Basel Convention?

C. Research Objectives and Benefits

The objectives of this research include:

1. To analyse how space debris mitigation can be effectively implemented within the framework of the United Nations Outer Space Treaty;
2. To assess the extent to which private entities, specifically SpaceX, can be held liable as transboundary polluters under international law;
3. To give acknowledgement, information, and insightful understanding regarding the issue of international space law and environmental responsibility in the context of global space debris management;
4. To give contribution to the development of international and national space law by providing a case-based analysis on the Falcon 9 debris

incident, offering more comprehensive data and perspective on the application of the UN Outer Space Treaty and the Basel Convention.

D. Research Originality

The authenticity of this research can be relied upon by the author, as the entire framework and analysis presented are derived directly from the author's own thinking and academic interpretation. This originality is further strengthened through the extensive use of supporting literature, including authoritative books, reputable legal journals, and relevant scholarly articles that improve the substance and depth of this study. While it is acknowledged that certain aspects of this paper may share thematic or conceptual similarities with previous research, the distinctions remain substantial and meaningful, as outlined below:

Table 1.1 Authenticity of Research 1

Author	Annisa Permata Sari Harahap	
Title	The Liability of SpaceX Company Towards the Space Debris Creation in the Perspective of International Law	
Category	Undergraduate Thesis	
Year	2025	
Institute	Faculty of Law, Universitas Diponegoro (Undip)	
Description	Previous Research	Research Plan
Issue and Problem	1. How is the liability of private space companies such as SpaceX regulated under the framework of international space law? 2. To what extent can the provisions of the Liability Convention and the Outer Space Treaty be applied to private companies that	1. How can space debris mitigation be effectively implemented under the framework of the United Nations Outer Space Treaty? 2. To what extent can SpaceX be held responsible as a

	cause or contribute to space debris? 3. What legal responsibilities fall upon the launching state in cases where private companies generate orbital debris?	polluter for transboundary space debris under the principles of the UN Space Treaty and the Basel Convention?
Research Method	Normative juridical method (doctrinal research)	Normative legal research
Result and Study	The author concludes that international law still places responsibility primarily on launching states, not directly on private companies. However, states must ensure that private entities comply with mitigation standards. The study recommends incorporating stricter national licensing requirements and clearer international enforcement measures.	

Table 1.2 Authenticity of Research 2

Author	Rieka Futri Tampubolon	
Title	Tanggung Jawab Negara Peluncur terkait Menanggulangi Sampah Luar Angkasa (Space Debris) di Tinjau dari Liability Convention 1972	
Category	Undergraduate Thesis	
Year	2022	
Institute	Universitas Jambi	
Description	Previous Research	Research Plan

Issue and Problem	1. Apakah negara peluncur dapat diminta pertanggungjawaban atas sampah ruang angkasa? 2. Bagaimana bentuk tanggung jawab negara peluncur yang dapat diterapkan terhadap kerugian yang disebabkan oleh benda-benda antariksa dalam Liability Convention?	1. How can space debris mitigation be effectively implemented under the framework of the United Nations Outer Space Treaty? 2. To what extent can SpaceX be held responsible as a polluter for transboundary space debris under the principles of the UN Space Treaty and the Basel Convention?
Research Method	Normative legal research	Normative legal research
Result and Study	The author concludes that launching states are internationally responsible for damage caused by space objects (cites Liability Convention articles). The Liability Convention provides the basis for state responsibility both in space and on Earth, but the Convention lacks clarity and firmness in several respects; the author suggests amendments or additional	

	provisions to improve legal certainty and handling of space debris.	
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Table 1.3 Authenticity of Research 3

Author	Ananda Multifani Sahara	
Title	Remediasi dan Mitigasi Sampah Ruang Angkasa Sebagai Bentuk Tanggung Jawab Negara Dalam Hukum Ruang Angkasa	
Category	Undergraduate Thesis	
Year	2023	
Institute	Universitas Brawijaya (UB)	
Description	Previous Research	Research Plan
Issue and Problem	1. Apakah remediasi dan mitigasi sampah ruang angkasa merupakan tanggung jawab negara peluncur? 2. Bagaimana urgensi pengaturan remediasi dan mitigasi sampah ruang angkasa sebagai tanggung jawab negara peluncur dalam hukum ruang angkasa?	1. How can space debris mitigation be effectively implemented under the framework of the United Nations Outer Space Treaty? 2. To what extent can SpaceX be held responsible as a polluter for transboundary space debris under the principles of the UN Space Treaty and the Basel Convention?
Research Method	Normative-legal research	Normative legal research
Result and Study	The author proposes The thesis found that space debris (sampah	

	ruang angkasa) is indeed the responsibility of the launching state (negara peluncur) based on Article 8 of the Outer Space Treaty. It also concluded that there is an urgent need for a binding international regulation specifically on remediation and mitigation of space debris, as current space law lacks detailed environmental-type provisions.	
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E. Theoretical Basis

1. State Responsibility and Due Diligence Theory

In international law, the concept of state responsibility is a fundamental principle. State Responsibility and the principle of due diligence form the theoretical foundation for regulating activities that may cause harm beyond national borders. A State must ensure that activities under its jurisdiction or control do not cause damage to other States or the environment. This principle was established in the Trail Smelter Arbitration (1941) and later reinforced through the Rio Declaration on Environment and Development (1992), particularly in Principles 2 and 15.^{19, 20}

The Outer Space Treaty (OST) 1967, especially Articles VI and IX, incorporates this principle into space law. Article VI declares that States bear international responsibility for both governmental and non-governmental activities in outer space, while Article IX requires States to conduct space activities with due regard to the corresponding interests of all other States Parties.²¹ This forms the legal basis for preventive

¹⁹ Permanent Court of Arbitration (PCA). 1941. *Trail Smelter Arbitration (United States v Canada)* (The Hague: Permanent Court of Arbitration).

²⁰ United Nations. 1992. *Rio Declaration on Environment and Development* (New York: United Nations). U.N. Doc. A/CONF.151/26 (Vol. I), pp. 1, 3

²¹ UN OST, *Op. Cit.*, p. 2

obligations, ensuring that States take reasonable measures to avoid harmful contamination and minimize the creation of space debris.

Under the due diligence theory, States are required not only to respond to damage but to actively prevent it. This aligns with the preventive and precautionary approaches used in environmental law, meaning that effective space debris mitigation depends on proactive legal and regulatory measures. Such measures include national licensing of private launches, compliance with debris mitigation guidelines, and participation in international cooperation frameworks such as those promoted by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

The theory of State Responsibility combined with the principle of due diligence provides the legal foundation for implementing effective space debris mitigation under the OST framework emphasizes that States must establish preventive mechanisms and exercise continuous supervision over all space activities, both governmental and non-governmental/private companies to protect the outer space environment from further degradation.

2. International Liability and Polluter Pays Theory

The second theoretical basis rests on the concepts of International Liability and the Polluter Pays Principle, which together explain how responsibility for transboundary environmental harm including space debris can be attributed and compensated. In international law, liability refers to the obligation of a State or an actor to make reparations for damage caused by its actions or those under its control, even if no wrongful act was intended.²²

Under Article VII of the Outer Space Treaty and the Convention on International Liability for Damage Caused by Space Objects, the launching State bears international liability for any damage caused by its space objects on Earth or in outer space.²³ This means that if a private

²² International Law Commission (ILC). 2001. *Articles on Responsibility of States for Internationally Wrongful Acts* (New York: United Nations).
[https://legal.un.org/ilc/texts/instruments/english/draft_articles/9_6_2001.pdf]

²³ Space.com, *Op. Cit.*, p. 3

company like SpaceX produces debris that damages other States' property or endangers human life, the United States as the launching State remains internationally responsible. However, the Liability Convention was drafted before the rise of private space companies, creating uncertainty about how direct corporate accountability fits into this framework.

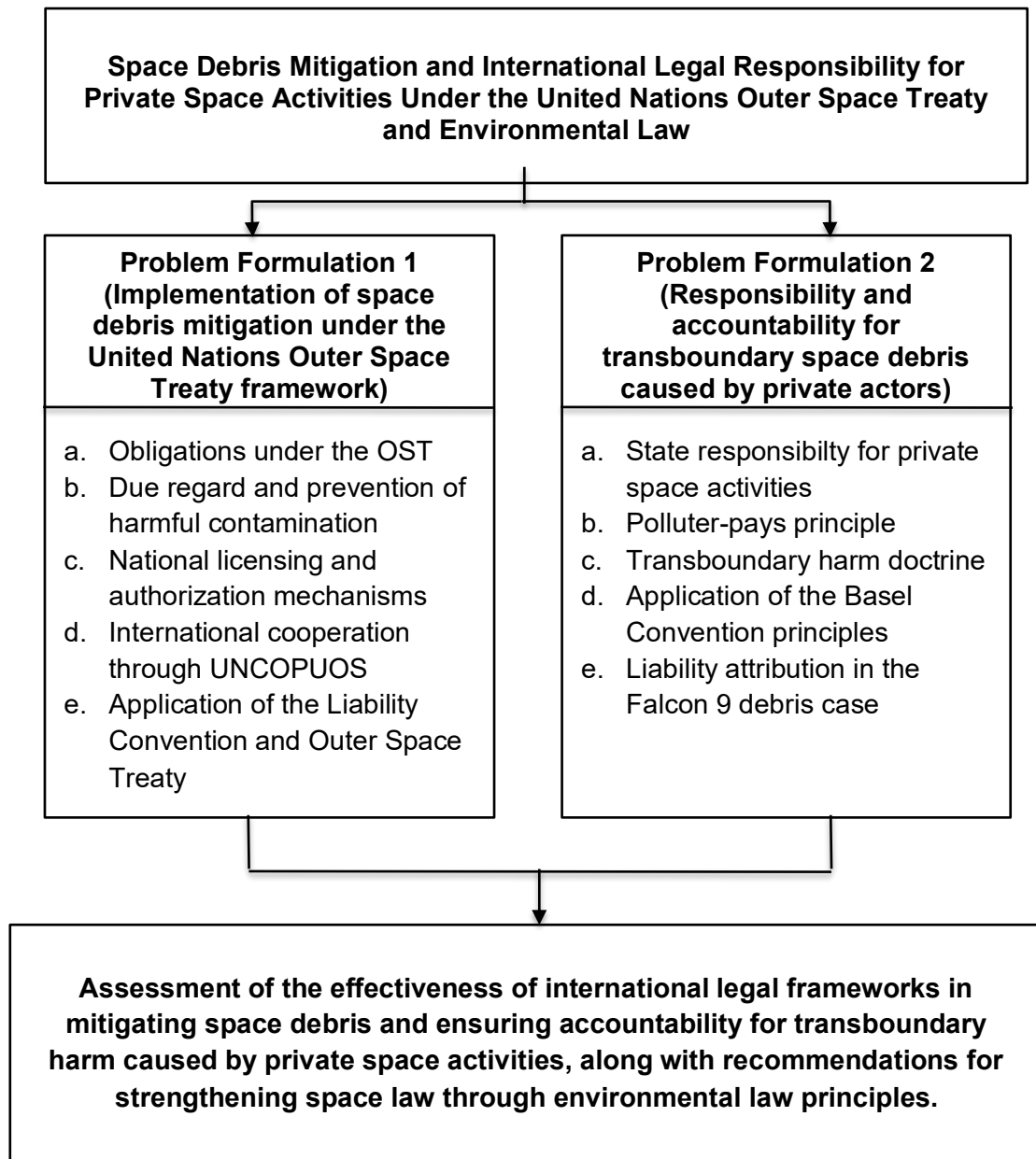
To fill this gap, the Polluter Pays Principle, introduced in Principle 16 of the Rio Declaration and reflected in the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, provides a complementary perspective. This principle asserts that those who produce pollution should bear the cost of managing it to prevent environmental harm.^{24, 25} By analogy, private companies engaged in space activities can be considered polluters responsible for orbital debris that crosses territorial or orbital boundaries.

Applying this theory to the Falcon 9 debris incident over Europe on February 2025 suggests that while international law places formal liability on the launching State, corporate actors like SpaceX could also be held secondarily accountable through domestic regulation or international environmental principles. Therefore, combining the International Liability Theory with the Polluter Pays Principle helps explain how both States and private entities can share responsibility for transboundary space debris, ensuring a fair and more comprehensive legal response.

²⁴ United Nations. 1992. *Rio Declaration on Environment and Development* (New York: United Nations). U.N. Doc. A/CONF.151/26 (Vol. I), p. 3

²⁵ UN Basel Convention, *Op. Cit.*, p. 5

F. Research Framework



G. Operational Definition

1. Liability

Legal responsibility of a launching State for damage caused by its space objects, including absolute liability for surface damage and fault-based

liability in space, as established under treaties like the Liability Convention.

2. SpaceX

SpaceX is a private aerospace company founded by Elon Musk that develops and launches rockets and spacecraft, providing commercial, governmental, and scientific space transportation services.

3. Space Debris

Non-functional, human-made objects in outer space, including defunct satellites, spent rocket stages, and fragments, which pose collision risks to operational spacecraft and contribute to the growing congestion of Earth's orbital environment.

4. Harmful Contamination

The introduction of biological, chemical, or particulate matter into space or celestial bodies that may adversely affect their environments or scientific integrity, prohibited under Article IX of the Outer Space Treaty.

5. Outer Space Treaty

The Outer Space Treaty is the foundational international agreement establishing principles for peaceful use of outer space, state responsibility, non-appropriation, and prevention of harmful contamination.

6. Basel Convention

The Basel Convention regulates the transboundary movement and disposal of hazardous wastes to protect human health and the environment, emphasizing prior informed consent and environmentally sound management.

7. Polluter-Pays Principle

An environmental law principle requiring that those who generate pollution bear the costs of managing and remedying its impacts, including prevention, control, and compensation for damage to the environment or public health.

CHAPTER II

RESEARCH METHOD

A. Research Type and Approach

The approach used as a method of research for this thesis is normative legal research. According to Kadarudin, normative legal research is one of the research methods that bases its analysis on current regulations and relevant legal matters. This process requires a systematic, structured research and comprehensive understanding from literature reading.²⁶

In this issue, the international legal framework will be used as the main analytical tool, particularly the United Nations Outer Space Treaty and the Convention on International Liability for Damage Caused by Space Objects. These two instruments establish the fundamental legal basis of responsibility and liability in outer space activities. The study also refers to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal as a comparative framework to analyse environmental responsibility, since it provides similar legal principles that could be extended to the management of orbital debris.

Relating to that, SpaceX, as a private space company registered under the jurisdiction of the United States, carries out its activities based on domestic regulations, such as the Commercial Space Launch Competitiveness Act and the licensing framework issued by the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA). These national laws represent the state's duty under Article VI of the Outer Space Treaty to supervise and authorize the activities of private entities in outer space.

The case study analysis involves examining specific international legal issues that arise from real incidents, such as the Falcon 9 debris or fireball event that occurred over Europe in February 2025, where fragments of a SpaceX rocket were observed re-entering the Earth's atmosphere. This case provides a factual background for analysing how international treaties and state responsibilities operate in practice. The analysis also includes

²⁶ Kadarudin. 2021. *Penelitian di Bidang Ilmu Hukum (Sebuah Pemahaman Awal)*. Makassar: Formaci, pp. 83-86

earlier precedents such as the COSMOS 954 (1978) satellite crash and the Iridium-Cosmos collision (2009) to compare how liability has been interpreted and applied in similar situations.^{27, 28}

This thesis adopts a doctrinal and analytical approach, meaning it interprets and analyses the legal texts, doctrines, and cases to form a structured understanding of how responsibility and liability are defined under international law. The doctrinal aspect examines what the current law provides, while the analytical aspect evaluates what the law should provide, considering modern developments in commercial space activities and the growing environmental threats from debris accumulation.

B. Types and Sources of Legal/Data Materials

In accordance with the research type and approach described earlier, this thesis utilizes two main types of data materials; primary sources and secondary sources. These sources are used to provide a comprehensive legal understanding and to interpret the international obligations applicable to space debris mitigation and liability under international law.

A. Primary Sources

The applicable law to be established in international law consists of primary and secondary sources. According to Article 38 of the Statute of the International Court of Justice, the sources that are considered primary include international conventions, international and domestic judicial decisions, and UN bodies' resolutions and recommendations. In relation to the current issue, the relevant primary sources include:

1. International Conventions

The main conventions applied in this thesis are the United Nations Outer Space Treaty (1967) and the Convention on International Liability for Damage Caused by Space Objects

²⁷ Government of Canada and Government of the Union of Soviet Socialist Republics. 1978. *COSMOS 954 Claims Settlement* (Ottawa/Moscow: Bilateral Claims Settlement Agreement).

²⁸ Government of the United States of America and Government of the Russian Federation. 2009. *Iridium 33 and Cosmos 2251 Collision Incident* (Low Earth Orbit: Accidental Satellite Collision Event).

(1972).^{29, 30} These conventions establish the basic principles of international space law, particularly concerning state responsibility, liability for damage, and the obligation to prevent harmful contamination of space and Earth's environment. Additionally, this research draws comparison from the Basel Convention (1989), which regulates transboundary movement and disposal of hazardous wastes on Earth.³¹

Although originally designed for terrestrial environmental protection, this convention is used by analogy to evaluate whether the same environmental principles such as the polluter-pays principle and transboundary harm prevention can be applied to orbital debris management. Other relevant conventions and international instruments used as primary materials include the Registration Convention (1975) and the Vienna Convention on the Law of Treaties (1969), which aid in the interpretation and legal validity of treaty provisions used in this research.^{32, 33}

2. International and/or Domestic Cases

In accordance with Article 38(c) of the ICJ Statute, past judicial decisions and state practice serve as a subsidiary means for the determination of rules of law. In this research, notable cases and incidents such as the COSMOS 954 (Canada v USSR) Settlement (1978) and the Iridium-Cosmos Collision (2009) are discussed to illustrate how the principles of liability and responsibility have been applied in practice.^{34, 35}

In addition, domestic legal frameworks such as the United States Commercial Space Launch Competitiveness Act

²⁹ UN OST, *Op. Cit.*, p. 2

³⁰ United Nations. 1972. *Convention on International Liability for Damage Caused by Space Objects* (New York: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html>]

³¹ Basel Convention, *Op. Cit.*, p. 5

³² United Nations. 1975. *Convention on Registration of Objects Launched into Outer Space* (New York: United Nations). [<https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html>]

³³ United Nations. 1969. *Vienna Convention on the Law of Treaties* (Vienna: United Nations). [https://legal.un.org/ilc/texts/instruments/english/conventions/1_1_1_969.pdf]

³⁴ COSMOS 954, *Op. Cit.*, p. 18

³⁵ Iridium-Cosmos, *Op. Cit.*, p. 18

(2015) and licensing requirements from the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA) are reviewed.^{36, 37} These illustrate how state supervision of private actors operates under Article VI of the Outer Space Treaty. Finally, the Falcon 9 February 2025 debris/fireball event over Europe serves as a current factual case study to analyse the potential application of international liability principles when debris from a privately launched object re-enters Earth's atmosphere, possibly affecting multiple states.

3. UN Bodies' Resolutions and Recommendations

UN resolutions and recommendations relevant to space safety and environmental protection are also used as primary legal references. These include the United Nations General Assembly Resolution 62/217 (2007) on International Cooperation in the Peaceful Uses of Outer Space, the UNOOSA Space Debris Mitigation Guidelines (2010), and the Guidelines for the Long-Term Sustainability of Outer Space Activities (2019).

These resolutions provide the interpretative context for understanding the duties of states to mitigate debris and cooperate internationally in preventing space environment degradation. The International Law Commission's Draft Articles on the Prevention of Transboundary Harm (2001) are also considered, as they reflect the customary obligation of states to prevent environmental harm beyond their jurisdiction principles that can analogically apply to space activities.

B. Secondary Sources

This source, also known as a subsidiary source, includes the teachings of highly qualified publicists and the writings of recognized

³⁶ United States Congress. 2015. *Commercial Space Launch Competitiveness Act* (Washington, D.C.: United States Congress). [<https://www.congress.gov/114/plaws/publ90/PLAW-114publ90.pdf>]

³⁷ Federal Communications Commission (FCC). 2023. *Orbital Debris Mitigation Rules* (Washington, D.C.: Federal Communications Commission). [<https://www.fcc.gov/document/fcc-updates-orbital-debris-mitigation-rules>]

international law experts as subsidiary means for determining applicable legal principles.

In this thesis, secondary sources consist of academic writings, research journals, conference papers, and reports that provide critical insights into the evolving scope of space law and environmental liability. Works by scholars such as Bin Cheng, Frans von der Dunk, and Fabio Tronchetti are particularly referenced to interpret state and private obligations in space activities. In addition, the author refers to institutional publications from UNOOSA, the European Space Agency (ESA), and NASA, which provide empirical and technical data regarding orbital debris. These materials help link legal reasoning with scientific facts, ensuring that the research conclusions remain grounded in both law and reality.

C. Methods of Collecting Data

The method of data collection used in this study is library and literature research, which focuses on collecting relevant secondary data derived from existing academic and institutional sources. This method aligns with the normative legal research approach, emphasizing textual and doctrinal analysis rather than empirical or field data.³⁸ Through extensive literature review, the author gathered international legal instruments, journal articles, reports, and online publications that discuss international responsibility for space activities, environmental protection principles, and state supervision over private entities.

The author also utilized online data sources such as UNOOSA, ESA Space Debris Office, and NASA Orbital Debris Program Office to obtain scientific background supporting the legal arguments. By reviewing both legal and technical materials, this study seeks to connect the legal framework with practical implications of debris mitigation, as reflected in the SpaceX Falcon 9 case. The literature collection process serves to ensure that all arguments and conclusions in this thesis are supported by credible, up-to-date, and authoritative data, both from international legal documents and from the most relevant academic writings in the field of international space law and environmental law.

³⁸ Kadarudin, *Op. Cit.*, p. 29

D. Analysis of Data

As a normative legal research, this thesis conducts its analysis primarily through legal interpretation and doctrinal examination of both primary and secondary sources. For the primary sources, the analysis focuses on interpreting the Outer Space Treaty, the Liability Convention, and the Basel Convention, especially regarding provisions that relate to state responsibility, liability for damage, and transboundary environmental obligations. These instruments are compared and analysed to determine how they collectively establish accountability for debris generated by space activities conducted by private entities under state authorization. For the secondary sources, the author analyses interpretations and commentaries by legal scholars and institutions to identify gaps, criticisms, and potential improvements in the existing legal system. Comparative analysis is also conducted between international space law and international environmental law to identify overlapping principles that can strengthen debris management, such as the polluter-pays principle and due diligence obligation.

The analysis method further involves qualitative reasoning, aiming to explain how the principles of international responsibility and liability can be extended to ensure that both states and private entities such as SpaceX are held accountable under international law for debris-related damage. The end goal of this analytical process is to present a coherent legal argument that supports stronger global governance and legal accountability for space debris mitigation, ensuring that the use of outer space remains safe, sustainable, and consistent with international law.