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Euro Composites' Strategic Dilemma: Balancing Sustainability within Supply Chains in the Context of Space Mining

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Abstract:

The growing potential of space mining presents a unique challenge for Euro-Composites, a leader in advanced composite materials. This case study examines the company's critical decision regarding an ambitious European Space Agency proposal: either fast-track production to seize a vast market opportunity or prioritize long-term sustainability commitments. The analysis explores Euro-Composites' project-driven supply chain, the challenges of incorporating sustainable practices, and its alignment with international sustainability objectives, including the United Nations Sustainable Development Goals. The case invites reflection on Euro-Composites' strategic direction in the rapidly evolving New Space economy by exploring operational trade-offs and future industry implications.

Keywords: New Space, Space Mining, Sustainable Supply Chain Management, Triple Bottom Line, Sustainable Development Goals, Business Strategy, Resources

Abbreviations:

EC	Euro-Composites S.A.
ESA	European Space Agency
SC	Supply Chain
LSA	Luxembourg Space Agency
LSRI	Luxembourg Space Resource Initiative
NEA	Near-Earth Asteroid
ISRU	In-Situ Resource Utilization
SDG	Sustainable Development Goal
SSCM	Sustainable Supply Chain Management
CSR	Corporate Social Responsibility
TBL	Triple Bottom Line

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Time-critical ESA proposal sparks high-level meeting at Euro-Composites

At 9 am on a routine Monday morning, Christoph Herrmann, head of sales for defense and space at Euro-Composites S.A. (EC) in Luxembourg, was sitting at his desk when an email with the subject line "Urgent" appeared on his screen. It was sent from a European Space Agency (ESA) colleague, and Herrmann's curiosity grew as he opened it. The email contained a high-stakes proposal that could transform EC's future in the New Space industry. The proposal invited EC to supply critical components for an ambitious ESA mission aimed at a rare, resource-rich celestial object passing close to Earth. A mission that could set new standards in space mining and securing this contract would establish EC as a leader in composite manufacturing for space mining and unlock significant opportunities.

As EC has limited time to respond due to the proposal's tight delivery timeline, Herrmann arranged an emergency meeting with senior management at 10 am, recognizing the importance of the proposal. The people involved included CEO Rolf Alter, Head of Production for Space Technology Erik Markestein, and Christoph Herrmann. "We have an extraordinary proposal from ESA," Herrmann started, "but the delivery timeline is tighter than anything we've faced." During the debate, it became evident that the leadership team had different perspectives on approaching this opportunity. The tight schedule and required delivery speed might endanger EC's commitment to sustainable practices throughout its supply chain (SC), compromising long-term sustainability and profitability. To fully grasp the implications of the ESA proposal, it is essential to understand EC's role in the advanced composite material industry and its legacy of innovation.

Pioneering advanced composite materials since the 1980s

Renowned for its expertise in advanced composite materials, EC has built its success on decades of innovation and technical precision. Now, the ESA proposal tests its ability to maintain sustainability while meeting the urgent demands of a transformative opportunity. Founded in

1985, the company has grown into a global leader in advanced composite materials, with headquarters in Echternach (Luxembourg) and production facilities in Luxembourg, Germany, and the United States (Appendix 1). As a global player in high-performance composite products, EC serves customers worldwide from its three state-of-the-art production sites. Continuous innovation and growth have established its position in the industry, driven by advanced technologies and strong customer relationships. The company's commitment to innovation is reflected in its history of filing numerous patents, with 24 patents listed in Luxembourg's government records (Le Gouvernement du Grand-Duché de Luxembourg 2024). While some patents have expired, others remain active, demonstrating an ongoing commitment to advancing composite technologies. Alongside its innovative efforts, EC employs over 1,000 people and aims to expand its workforce by 750 and invest €150 million to modernize its production by 2030 (Schwadorf 2021).

While specializing in lightweight honeycomb composite materials and ready-to-assemble structures, EC services various industries, including space, defense, aviation, and rail. Initially, materials such as fiberglass, Kevlar®, Nomex®, and aluminum are chosen for manufacturing and transformed into honeycomb structures (Appendix 2). These are then infused with resin, cured under high temperatures and pressure (Appendix 3), and subsequently customized with features such as bolt inserts or heat pipes for temperature management. In general, these high-performance materials enhance strength-to-weight ratios, which are crucial for fuel efficiency, performance, and are integral to EC's success in demanding sectors like space. Launched in 2013, EC delivered crucial aluminum and carbon fiber-reinforced panels for ESA's PROBA-V satellite that monitors Earth's vegetation and its changes (Euro-Composites Group 2019). These lightweight materials reduced the satellite's net mass while meeting the durability standards required for space operations. Trusted by industry leaders such as Airbus and Boeing, EC has gained its reputation as a reliable supplier of high-performance materials among government agencies and private companies (Euro-Composites Group 2024). Its competitive edge lies in advanced expertise in honeycomb structures paired with dedicated production facilities, including one of Europe's largest cleanrooms (Appendix 4), ensuring the precision required for mission-critical space applications. With a foundation of technological innovation and precision, EC is well-positioned to thrive in the New Space sector, and it is also benefiting from Luxembourg's strategic support for space resource development.

Luxembourg is shaping the future in space resource support

As a leader in this growing sector, Luxembourg has become a global pioneer in developing space resources. A revolutionary change in the public and private administration of space resources was introduced and led by the Luxembourg Space Agency's (LSA) launch of the Luxembourg Space Resources Initiative (LSRI) in 2016 (LSA 2019a). By providing financial incentives, legislative clarity, and international cooperation, the LSRI seeks to establish Luxembourg as a central hub for resource extraction and space exploration (LSA 2019b). A key component of the LSRI is Luxembourg's Law of July 20, 2017, making the Grand Duchy the first European country to create legal certainty in this field by permitting private enterprises to assert ownership of harvested space resources (Foust 2017). By reducing legal ambiguity, this law provides companies with a solid foundation for space exploration. This legal framework gives enterprises based in Luxembourg unambiguous ownership rights and ensures compliance with international treaties (LSA 2019c).

In addition to this strong legal foundation, Luxembourg backs its ambitions with significant financial support to foster innovation and attract businesses in the space sector. This includes the Space Research Program and venture capital platforms such as Orbital Ventures, which both encourage public-private partnerships, fund innovation and draw businesses to the country (Deloitte 2020). Given Luxembourg's sophisticated space infrastructure, the country has become an essential destination for startups and large firms such as EC (LSA 2024). With Luxembourg establishing itself as a leader in the New Space economy, ESA's proposal draws attention to the increasing opportunities and challenges businesses face in this emerging industrial revolution.

The rise of a new industry offering vast opportunities

Given the space industry's rapid expansion and development, ESA's proposal comes at a crucial time for EC. As Acket-Goemaere et al. (2024) advocate, "the space industry is standing at an inflection point," comparable to the early stages of the internet. In this New Space era, private companies are taking the lead in space exploration and commercialization, areas once dominated by government agencies. This shift has accelerated infrastructure development, satellite deployment, and exploration worldwide. By taking advantage of their flexibility, private businesses have increased access to space, cut expenses, and opened up new technological possibilities (Bland, Brukardt, and Swartz 2022). Addressing global issues like resource depletion, environmental monitoring, and communication coverage is another goal of the New Space actions. In the context of growing commercialization and competition, the private sector is influencing space operations using partnerships with international organizations and governments (Murray 2023).

The rapid expansion of New Space has raised serious issues regarding sustainability, especially resource management, reducing the negative environmental impact, and guaranteeing the long-term viability of space activities while presenting the potential for innovation and exploration. Private companies are adopting certain practices to counteract orbital debris and reduce environmental impacts (Donou-Adonsou 2024). To address these challenges, they are developing reusable launch vehicles, designing satellites and rockets with end-of-life disposal in mind, and exploring cleaner propulsion methods (Wilson and Vasile 2023). Space mining offers a promising solution to resource scarcity and future space exploration as sustainability consciousness increases.

Unlocking resources beyond Earth through space mining

Space mining offers a promising opportunity to secure critical resources beyond Earth, addressing growing demands while reducing pressure on terrestrial ecosystems. This new area presents a viable method to extract necessary elements, which could lessen our reliance on mining activities on Earth. Recent technological advancements and shifts in the global economy have fueled a growing interest in the field. Additionally, the urgent need for sustainable alternatives to meet the demands of high-tech industries and space exploration has further accelerated this trend (Hein, Matheson, and Fries 2020).

The idea of extracting resources from space dates back to the mid-20th century, when the space race and early lunar and planetary missions inspired the exploration of life beyond Earth (MacDonald 2014). By highlighting the feasibility of traveling to the Moon and back, the Apollo missions laid a crucial foundation for future efforts to extract resources from space (Crawford 2015). The once speculative idea of mining asteroids has become a realistic objective due to ongoing advancements in robotics and propulsion technology, especially concerning near-Earth asteroids (NEAs).

Due to their accessibility and potential resource wealth, these asteroids orbiting near Earth are rich in minerals and, thus, an ideal target for space mining (Appendix 5). With estimates indicating that the minerals found in NEAs might be worth trillions of dollars, NEAs have enormous economic potential, attracting substantial interest and investment from public and private organizations (Aziz 2015). In addition to addressing Earth's resource shortages, the wealth of vital materials, such as rare metals and water, in NEAs could also support future space missions (Raja 2023). Offering significant advantages for space exploration, NEAs play a crucial role for in-situ resource utilization (ISRU), a method that involves extracting and directly using materials on-site rather than relying on transportation from Earth. As a key innovation, ISRU enables missions to cut logistical costs, improve sustainability, and reduce the environmental impact of transporting large amounts of resources over long distances. By producing vital resources like hydrogen and oxygen, ISRU supports longer-duration missions and provides rocket propellant and life support for astronauts (Kornuta et al. 2019).

This on-site use of resources can make space missions more cost-effective and ecologically sustainable by decreasing dependency on Earth's resources (Hein, Saidani, and Tollu 2018). The development of ISRU technologies is essential for achieving a sustainable human presence in space, as it lays the foundation for deep-space missions while aligning with the space industry's sustainability goals (Gumulya, Zea, and Kaksonen 2022). Space mining presents an opportunity to support Sustainable Development Goal (SDG) 12 (Responsible Consumption and Production), specifically Target 12.2, which emphasizes sustainable management and effective use of natural resources by unlocking the vast reserves of NEAs (United Nations 2015). EC can promote responsible resource consumption for upcoming space missions and high-demand sectors on Earth by reducing dependency on Earth-based resources. The ambitious ESA proposal, combined with the opportunities and complexities of space mining, highlights the importance of understanding EC's SC and its ability to meet the expectations of this evolving market. Balancing innovation and sustainability is crucial, particularly as EC evaluates the potential impact of its SC operations on long-term objectives.

Examining SC readiness through risk management

To evaluate EC's readiness for addressing the sustainability and operational demands of the ESA proposal, Christoph Herrmann analyzed EC's highly specialized and project-driven SC environment. Herrmann's analysis highlighted that EC's operations predominantly focus on manufacturing products tailored to specific customer requirements, where adherence to detailed and exact specifications is essential. This emphasis on meeting exact customer demands drives most aspects of the SC, reinforcing the reliance on proven materials and methods extensively tested and validated to ensure consistency and reliability. While this project-driven nature ensures the consistent delivery of high-quality products, it limits flexibility, particularly in innovation and sustainability integration. To gain deeper insights and assess the SC readiness, Herrmann initiated interviews with employees across key departments: production, procurement, environmental management, compliance/quality control, and R&D. Achieving a sustainable and resilient SC requires evaluating critical aspects such as risk management, transparency, strategic alignment, and the integration of sustainability into corporate culture.

As Christoph Herrmann began investigating EC's SC readiness, he started by discussing risks with the procurement and compliance teams. These conversations underscored the challenges posed by EC's reliance on materials like titanium, primarily imported from Russia, a key supplier for the space sector. A senior procurement manager noted, "Our reliance on Russian titanium poses significant geopolitical risks, particularly given the ongoing conflict." This dependency exposes EC to SC disruptions and resource shortages (European Union 2022). Flexible procurement strategies and regular supplier audits are used to mitigate these risks and ensure compliance with international standards. Compliance officers explained that certifications from suppliers, particularly in regions like China, are carefully evaluated through detailed audits to address potential compliance concerns. However, the efficacy of these audits has been limited in recent years due to pandemic-induced travel restrictions, which disrupted traditional on-site due diligence and quality checks. These constraints, as one compliance officer noted, "highlight the increasing need for robust and adaptive compliance strategies to mitigate risks in a dynamic environment."

Environmental risks were raised in discussions with the environmental management team, who pointed to emissions from solvents like isopropanol as a key concern. They emphasized ongoing efforts to modernize production processes and implement waste reduction strategies, such as using compacting equipment to lower transport emissions of waste. Meanwhile, R&D engineers expressed frustration with the limited availability and high cost of certified sustainable materials, noting that “client requirements for proven materials almost always limit the adoption of innovative alternatives.” These discussions highlighted the tension between maintaining operational reliability and addressing emerging sustainability challenges within the SC.

Visibility and accountability in the SC remain a challenge

As Herrmann delved further into the SC readiness, he turned his attention to transparency and talked to several employees about the visibility of supplier operations. Procurement managers highlighted the strength of EC’s relationships with first-tier suppliers, with one manager stating, “our trust in immediate suppliers ensures the quality of raw materials and compliance with our standards.” Production and compliance officers emphasized, “our close collaboration with these suppliers ensures alignment on technical requirements and quality control.” This direct engagement ensures the quality and traceability of raw materials, a critical element of EC’s SC. However, these discussions also revealed a significant gap in visibility beyond first-tier suppliers. A compliance officer noted, “We trust our main suppliers, but we lack insight into their upstream operations, particularly regarding environmental and social impacts.” This limited visibility restricts EC’s ability to fully monitor or influence sub-suppliers’ practices, especially in labor norms and environmental standards. Herrmann observed that EC’s reliance on immediate suppliers to enforce compliance reduces its direct engagement with sub-suppliers, creating a blind spot in achieving deeper sustainability goals.

Herrmann’s discussions with procurement and compliance teams revealed that EC’s SC configuration emphasizes direct collaboration with immediate suppliers to ensure efficiency and quality control. However, these efforts face challenges in extending sustainability practices, where visibility and influence are more limited. While this strategy prioritizes efficiency and quality through direct relationships with immediate suppliers, it hides sustainable practices further upstream. This challenge is consistent with findings by Koberg and Longoni (2019), who emphasize the importance of integrating long-term partnerships with reputable suppliers to enhance transparency and align sustainability efforts across all levels of the SC. Certifications like ISO 14001 and 9001 reinforce sustainable practices within EC's production environment. However, compliance officers admitted that gaps remain when working with smaller, non-certified suppliers. "Some materials come from suppliers that don't hold official certifications, making it difficult to verify their sustainability," one officer explained. This lack of oversight risks undermining EC's broader sustainability commitments.

Herrmann concluded that EC must strengthen its transparency efforts across the extended SC to address these issues. Potential solutions discussed during the interviews included adopting third-party certifications, leveraging technology-enabled traceability tools, and building long-term partnerships with trusted suppliers. These steps would enhance visibility while ensuring that EC's SC aligns with its sustainability and operational objectives.

Strategy and culture for sustainable SC development

While Christoph Herrmann evaluated EC's SC strategy, he noticed a predominant focus on immediate operational demands rather than a proactive integration of sustainability goals. Interviews with R&D and environmental management teams highlighted a growing emphasis on sustainable innovations. An R&D engineer noted, "Lightweight designs and recyclable materials are key research areas, but lengthy certification processes and stringent client requirements often limit their practical application." The engineer further elaborated that such constraints often delay innovation, requiring extensive testing to meet EC's strict standards while addressing client specifications. This creates a challenge in balancing operational reliability with integrating sustainable practices into the SC. Procurement managers also pointed to ongoing efforts to diversify the supplier base by including more certified suppliers and exploring local sourcing solutions to minimize transportation emissions. Despite these initiatives, sustainability projects remain largely compliance-driven rather than proactive, reflecting EC's cautious approach to innovation.

Herrmann observed that EC's strategy includes promising long-term ambitions to enhance sustainability within its SC. Key initiatives include implementing renewable energy sources like photovoltaics and improving waste management systems to meet EU sustainability reporting standards. These efforts underline EC's commitment to addressing future challenges, yet their implementation is constrained by the reliance on proven materials and established qualification processes. While these practices ensure operational stability, they also limit flexibility and slow the integration of ecologically friendly alternatives. Environmental management employees emphasized EC's long-term ambitions, including implementing renewable energy sources like photovoltaics. They also highlighted efforts to improve waste management systems to meet EU sustainability reporting standards, showcasing EC's commitment to future sustainability. However, these efforts face significant challenges, reflecting the tension between maintaining operational reliability and advancing innovative practices. Overcoming these systemic barriers will require a proactive approach to align sustainability goals with the SC's strategic framework.

Sustainability, while essential, is not yet fully embedded in EC's corporate culture. Herrmann's discussions across departments revealed that strict project schedules and adherence to established practices often overshadow sustainability goals. An environmental manager remarked, "Sustainability efforts feel secondary to the need to meet production deadlines." Compliance officers recited this sentiment, emphasizing that most initiatives are reactive, driven by regulatory requirements rather than proactive cultural shifts. This adherence to established practices, while ensuring reliability and precision, limits opportunities for experimentation with sustainable materials and practices that could entail more significant risks. Despite these cultural limitations, Herrmann noted signs of a gradual shift influenced by growing consumer demand for environmentally friendly solutions. R&D engineers expressed optimism, highlighting how sustainability considerations are beginning to influence client specifications. "We're seeing a steady shift in priorities," one engineer shared, "which could eventually reshape EC's corporate culture."

The risk, transparency, strategy, and culture analysis revealed strengths in EC's SC but highlighted critical gaps in sustainability integration. Herrmann found that while operational reliability remains strong, transparency beyond first-tier suppliers is limited, and sustainability efforts are primarily compliance-driven. These findings provide a crucial foundation as EC navigates the ESA proposal's sustainability challenges. Herrmann's analysis also revealed that different scenarios for addressing these challenges are emerging. These scenarios now need to be critically assessed in light of sustainability goals, operational reliability, and the strategic opportunities presented by the ESA proposal.

A strategic dilemma in the path to sustainable SCM

As the leadership team examines its response to the ESA proposal, sustainability emerges as both a guiding principle and a challenge. The company's commitment to sustainable practices aligns with several United Nations SDGs (Appendix 6), such as SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). EC's current initiatives, including waste reduction, lightweight composite materials, and efficient resource utilization, focus on meeting established standards and norms rather than proactively driving sustainability. This project-driven approach ensures adherence to client requirements but limits the integration of broader sustainability practices into its products and operations. While these efforts enhance EC's reputation as a responsible innovator, they reflect sustainability as a secondary consideration rather than a core strategic objective.

The theoretical implications of a sustainably managed SC underscore the long-term benefits of integrating environmental, social, and economic objectives commonly referred to as the triple bottom line (TBL) (Elkington 1998). For EC, adopting sustainable supply chain management

(SSCM) practices could enhance financial performance and minimize operational disruptions (Appendix 7). These practices also strengthen stakeholder trust, a critical factor in maintaining its competitive positioning. Examples from frameworks like Carter & Rogers (2008) demonstrate that SSCM supports profitability and aligns with evolving market and regulatory demands. These practices enable companies to address global sustainability challenges, attract environmentally conscious investors, and reduce risks associated with SC vulnerabilities. These elements are crucial as EC navigates the ESA proposal, weighing the trade-offs between short-term operational gains and long-term strategic resilience.

A defining choice of balancing sustainability and opportunity

The leadership team at EC headquarters reached a critical point in their discussion as the ESA proposal led to a decision: should the company fast-track production and compromise sustainability to seize an immense market opportunity or prioritize its long-term commitments, even at the risk of losing the contract? Erik Markestein raised concerns about the delivery schedule, noting, "We would have to raise production capacity immediately, which means compromising some of our environmental obligations. This could seriously damage our reputation." CEO Rolf Alter countered, "But missing this chance could cost us our competitive advantage in New Space. Establishing EC as a leader in space mining composites is a unique opportunity." As the leadership team continued the discussion, it became evident that each decision carries significant implications for EC's future direction and sustainability commitments.

The first option discussed was accelerating production, prioritizing the ESA contract at the expense of sustainability goals. This approach would involve intense resource mobilization, streamlined processes, and potentially suspending downstream supplier audits. The immediate benefits included increased revenue, enhanced market leadership, and increased reputation as a key supplier for high-profile missions. However, the risks were equally significant.

Compromising on sustainability could harm EC’s brand image, introduce quality issues, and result in regulatory non-compliance, weakening its credibility in the industry.

The alternative was to uphold EC’s sustainability commitments by renegotiating the delivery timeline with ESA. This approach would reaffirm EC’s reputation as a responsible innovator and align with Luxembourg’s policy objectives. Sustainability-focused decisions could attract environmentally conscious clients and investors while reducing non-compliance risks and SC disruptions. Yet, delaying the project posed risks of losing the contract to competitors and financial strain due to lower short-term income. Internal conflicts could also arise as stakeholders prioritize immediate returns over long-term goals.

The leadership team recognized that this decision exceeds operational considerations, involving EC’s identity and vision for the future. Rolf Alter reflected, “This decision is about more than numbers; it’s about the kind of company we want EC to be.” Herrmann, tasked with consolidating departmental insights, emphasized, “We must weigh the opportunity against the potential costs to our principles and reputation.” The team debated extensively, aware that their choice would set a standard for EC’s role in the evolving New Space economy. As the meeting concluded, the leadership team faced a pivotal moment. Should EC accelerate production to secure immediate gains or adhere to its sustainability commitments and risk losing the contract? Alternatively, could a renegotiation strike a balance between these competing priorities? With time running out and ESA expecting a decision by the following morning, the team had to act decisively.

Teaching note

Case summary

Among the leaders worldwide in sophisticated composite materials, EC must make a difficult choice based on an ESA high-stakes proposal. Based in Luxembourg, EC has specialized in lightweight honeycomb structures and ready-to-assemble components since 1985, providing sectors like aerospace, defense, and the developing New Space industry. Its components are critical for high-performance applications, combining strength, precision, and weight optimization, which are essential for missions in the demanding space environment.

The ESA proposal invites EC to provide parts for a space mining mission aiming at a celestial object with plenty of resources close to Earth. Although EC is positioned as a major participant in the sector by this possibility, its capacity to maintain sustainable SC practices is threatened by the tight delivery schedule. The choice affects EC's operating capability, its reputation as an innovator, and long-term alignment with sustainability targets. With the private sector leading space exploration and commercialization developments, this proposal is pivotal in the New Space sector. Luxembourg's proactive role in fostering space innovation, through initiatives such as the LSRI and its pioneering legal framework allowing ownership of extracted space resources, has positioned EC to capitalize on these opportunities. This support enhances EC's competitive advantage and emphasizes its responsibility to balance rapid growth with sustainability and ethical resource management.

EC's SC emphasizes precision and reliability. Its strengths include robust relationships with first-tier suppliers, compliance with international certifications, and environmental impact reduction. However, its project-driven nature and reliance on proven materials constrain flexibility and innovation in sustainability. The leadership now faces a critical decision: prioritize immediate gains by fast-tracking production or uphold its sustainability commitments, potentially risking the contract. This choice lays the groundwork for a more in-depth study of

EC's strategic orientation and captures more general difficulties in including SSCM in an industry under change.

Learning objectives

The sustainability challenges and strategic decisions in space mining and the New Space economy are investigated in this case study. EC's response to the ESA proposal examines integrating sustainability into a project-driven SC under tight deadlines. The case highlights the role of technology, global sustainability goals, and ethical considerations, fostering discussions on strategy in emerging industries. The learning objectives are:

1. **Understanding the macro environment**: Understand the dynamics of the New Space economy and its related risks, technological developments, and economic possibilities. Discover Luxembourg's significant influence in shaping this sector.
2. **Analyzing SSCM in high-pressure contexts**: Investigate how to efficiently integrate SSCM concepts into operations while meeting tight project timelines combining sustainability obligations with operational objectives.
3. **Connecting strategic decisions with SDGs**: Examine how corporate plans correspond with the SDGs, focusing on responsible production, innovation, and environmental stewardship in the space sector.
4. **Exploring strategic positioning in emerging industries**: Evaluate the strategic options that EC may use to increase its position in the competitive New Space business, drawing on its experience, Luxembourg's ambitions, and sustainability-driven innovations.

These objectives provide a foundation for discussing complex challenges in emerging industries, fostering critical thinking and informed decision-making. The case is intended for courses in SCM, Sustainability, Strategy, Corporate Social Responsibility (CSR) and Business Ethics.

Teaching plan

This teaching plan is designed to fit courses in *SCM, Sustainability, Strategy, CSR, and Business Ethics*. The 90-minute session encourages participation through interactive and reflective tasks suited to each course's topic. *Note: Depending on the course, instructors can devote the entire 40 minutes to either III)a) or III)b), or divide it evenly (20 minutes each) if both areas are appropriate.*

I. **Introduction to EC and the New Space economy** (*10 min*): Introduce EC and explain its role in the New Space economy. Summarize Luxembourg’s strategic contribution to promote sustainability and innovation in space mining.

II. **Discussion of New Space challenges: opportunities and risks** (*15 min*): Explore the challenges faced by companies in the New Space sector, including sustainability concerns and regulatory uncertainties. Discuss EC’s opportunities for growth in the New Space economy, balancing technological innovation with environmental impact.

III. **Case analysis tailored to course focus**:
   a. **SCM and strategy** (*40 min / 20 min / 0 min*): Analyze trade-offs in reaching sustainability targets against ESA deadlines. Discuss EC’s plans for keeping transparency and reducing SC risks.
   b. **Sustainability and ethics** (*40 min / 20 min / 0 min*): Examine how sustainability (e.g., SDGs) in EC’s activities may affect sustainability and ethical issues regarding equitable distribution of benefits and resource extraction.

IV. **Debate on EC’s strategic decision** (*10 min*): Discuss EC’s alternatives: accept, renegotiate, or reject the ESA proposal. Discuss how each decision will affect EC’s competitiveness, reputation, and sustainability in the long run.

V. **Instructor’s final remarks** (*5 min*): Emphasize balancing immediate operational concerns, long-term sustainability, and ethical objectives by summarizing main lessons.

Questions for discussion

1. **The New Space economy and space mining context**: The New Space economy introduces both opportunities and challenges for companies entering this emerging field.
    a) What distinguishes New Space, e.g., space mining from traditional industries?
    b) How does Luxembourg's legal and financial support influence the opportunities and risks for EC in the space mining sector?
2. **SC challenges and strategic positioning**: Managing a SC in a high-pressure, high-tech industry like New Space requires balancing operational needs with long-term goals.
    a) What are the key trade-offs EC faces when deciding between meeting ESA's tight deadline and ensuring long-term sustainability in its SC?
    b) How should EC address SC risks, including reliance on critical materials and geopolitical uncertainties, while maintaining operational efficiency?
    c) What role does transparency and collaboration with suppliers play in strengthening EC's SC, particularly in meeting sustainability goals and ensuring accountability?
    d) How can EC's' strategy and culture support long-term sustainability in SC decisions while meeting immediate operational needs?
3. **Sustainability and strategic decision making**: Sustainability and ethical considerations are crucial in emerging industries with high environmental and social impact.
    a) How does aligning with global sustainability priorities, such as the SDGs, influence EC's response to the ESA proposal, competitive position, and future opportunities?
    b) Should EC accept the ESA proposal, renegotiate its terms, or decline it? What are the implications of each decision for EC's long-term strategy?

Case analysis

1a) In numerous aspects, the New Space economy, especially space mining, diverges from traditional sectors. The following provides an examination of the opportunities and difficulties businesses have in this developing industry:

Table1: Key differences between traditional industry and the new space economy

Aspect	*Traditional Industry*	*New Space economy*
Leadership	Typically inhibiting innovation and adaptability, government-led with centralized decision-making connected to national goals frequently follows a set agenda	Private-sector driven with decentralized, market-oriented decisions fostering competition, efficiency, and rapid innovation
Market potential	Stable, mature markets with predictable supply and demand; growth is incremental and limited to Earth-based models	Untapped markets like NEAs with rare minerals, speculative, high-risk ventures with the potential to expand economic frontiers
Regulation	Operates under mature, well-defined frameworks with clear resource rights and accountability; national boundaries restrict scope	Evolving frameworks like the LSRI introduce ambiguities in property rights, requiring global collaboration
Technology	Standardized, predictable technologies with decades-long lifecycles focused on efficiency improvements and stability	Cutting-edge innovations like robotics and AI drive rapid advancements; shorter lifecycles increase complexity and risk
Capital intensity	Moderate investments with predictable return over short timelines; favors incremental innovations over disruptive risks	High upfront investments with speculative returns over decades; attracts capital for transformational opportunities
Sustainability	Reactive measures driven by regulations or public pressure; impacts are localized and typically well-understood	Proactive alignment with SDGs, integrating sustainability into core operations; impacts extend beyond Earth, raising ethical concerns

1b) Luxembourg's proactive legal and financial support plays a pivotal role in shaping the space mining sector, influencing both opportunities and risks for companies operating in this emerging field:

Legal Framework: The 2017 Space Resources Act lowers legal uncertainty by granting ownership rights for extracted resources, therefore encouraging private investment. Its conformity with the Outer Space Treaty (1967) guarantees that operations stay aligned with international standards, establishing a strong basis for international collaboration.

Financial Support: Effective tax laws and dedicated funds for investment help lower financial entrance obstacles for projects that require funding. These steps help businesses such as EC absorb upfront production expenses for space mining uses and R&D.

Opportunities: Luxembourg's legal clarity in the global market enhances EC's credibility, making it a preferred partner for international space ventures. Access to a concentrated ecosystem of space-focused companies facilitates collaboration and innovation. Financial incentives improve EC's capacity to scale operations and diversify into high-potential markets.

Risks: Regulatory ambiguities persist outside Luxembourg, especially concerning property rights and resource accountability, exposing EC to operational conflicts in global markets. Dependence on national policies may limit EC's flexibility in addressing external regulatory changes. Additionally, the speculative nature of space mining necessitates a cautious approach to balancing investments against long-term profitability.

2a) The Triple Bottom Line (TBL*)* concept, introduced by Elkington (1998), integrates economic, environmental, and social considerations into organizational decision-making, urging businesses to balance profitability with sustainability. Building on this, Carter and Rogers used the TBL as the foundation for SSCM, emphasizing its role in aligning SC processes with long-term economic, environmental, and social goals (2008). For EC, the TBL framework is crucial to addressing the trade-offs required to meet ESA's tight deadlines while ensuring sustainability. These trade-offs across economic, environmental, and social dimensions are explored:

Economic Dimension: Significant resources are needed to meet ESA's strict deadlines, which raises manufacturing costs through labor overtime and accelerated logistics. Securing ESA's contract guarantees revenue instantly, but it draws resources away from long-term investments in SC sustainability, like infrastructure improvements and energy-efficient technologies.

Environmental Dimension: Tight production plans limit EC's capacity to use sustainable practices, increasing emissions and resource use. Furthermore, giving short-term operational efficiency top priority above environmental issues bears the risk of permanent problems like regulatory non-compliance and damage to reputation.

Social Dimension: Tight production schedules put significant pressure on employees, which raises burnout risk and decreases employee satisfaction. These pressures may undermine workforce stability and productivity. Moreover, the urgency to meet deadlines may deprioritize EC's broader social responsibilities, including ethical labor practices and community engagement, potentially affecting its reputation as a responsible organization.

Trade-offs: The TBL framework underscores the importance of balancing immediate operational demands with long-term sustainability. Navigating these trade-offs for EC calls for strategic decision-making to match its SC procedures with ESAs' needs and its dedication to social, environmental, and financial sustainability.

2b) Emphasizing the need to balance operational efficiency and resistance to different risks, Carter and Rogers underline risk management as a fundamental component of SSCM (2008). Maintaining SC stability while fulfilling ESA's targets for EC depends on controlling dependency on vital resources and reducing geopolitical uncertainty. EC's current situation and the SSCM framework are the basis for an analysis of these SC-related risks:

Table 2: Risk factors, impacts, and mitigation strategies for EC

Risk factor	*Impact on EC*	*Mitigation strategy*
Dependency on critical materials	Due to its reliance on a few suppliers for certain essential materials of space components, EC risks delays if those suppliers experience interruptions or price volatility. Production schedules may be delayed by these risks, especially when there is little notice	EC can reduce its reliance by broadening its supply base and looking into alternate sources for essential components. More steady, predictable supply flows can be achieved by reinforcing ties with suppliers and negotiating long-term agreements

Geopolitical uncertainties	Being a part of a global SC exposes EC to geopolitical risks, including trade restrictions and instability in areas where materials are sourced. These unknowns may impact prices and cause interruptions in the availability of supplies	EC should focus on obtaining goods from politically stable areas to mitigate this, and it should keep regional warehouses or buffer stockpiles on hand to handle any interruptions. Additionally, establishing a multi-regional, diverse supply network will lessen dependence on any one geopolitical zone
Operational efficiency vs. risk mitigation	The need to fulfill ESA's deadlines puts more emphasis on operational effectiveness at the expense of proactive risk management. Prioritizing speed over thorough risk evaluations could leave EC vulnerable to future crises.	EC should implement flexible production schedules that can be modified for unforeseen hazards. EC can handle these trade-offs without compromising operating deadlines by utilizing risk-monitoring technologies, keeping strategic reserves, and creating backup plans.

2c) Collaboration and transparency are essential for strengthening EC's SC, mainly to accomplish sustainability targets. Transparency enhances information flow, facilitating better decision-making and lowering risks, claim Carter and Rogers (2008). Koberg and Longoni further link transparency to the configuration of SCs, noting that it influences how effectively sustainability initiatives are implemented and tracked (2019). For EC, transparency and collaboration play distinct but interconnected roles in addressing the challenges of its SC.

Fostering accountability through SC transparency

- **Status quo**: EC ensures first-tier supplier compliance with sustainability standards through audits and reporting, enabling goal alignment and mitigating environmental impacts. However, focusing on first-tier suppliers limits visibility into lower tiers, raising risks of unsustainable practices downstream.
- **Implications**: Transparency requires significant resources to extend monitoring to lower tiers. While collaboration with immediate suppliers strengthens alignment, this approach demands time and effort that could slow production, especially under ESA's tight deadlines. Finding a balance between achieving more visibility and maintaining operational efficiency is critical to meeting its dual goals of sustainability and production.

SC structures and the challenge of visibility

- **Status quo:** EC's SC configuration prioritizes strong relationships with first-tier suppliers, ensuring quality and operational reliability. However, this structure lacks mechanisms to engage with lower-tier suppliers, creating gaps in sustainability monitoring across the extended SC.
- **Implications:** The SC configuration directly influences EC's ability to implement transparency. While focusing on first-tier suppliers supports efficiency, limited engagement with lower tiers hinders comprehensive sustainability efforts. Expanding visibility requires investments that may reduce efficiency and clash with ESA's tight production timelines. Balancing the structural efficiency of the SC with the need for extended oversight is key to aligning EC's operational and sustainability priorities.

Conclusion: Although cooperation and transparency are essential to EC's SC sustainability, their application necessitates trade-offs between operational effectiveness, resource allocation, and monitoring depth. To balance these efforts with the operational demands placed on it by ESA, EC should concentrate on improving transparency and cooperation at the first tier while progressively expanding monitoring systems to lower tiers.

2d) Carter and Rogers highlight that a company's strategy establishes the direction for sustainability integration, while culture reinforces consistent application in decision-making (2008). At EC, both dimensions are crucial for embedding long-term sustainability into SSCM while managing operational pressures.

Strategic limitations and sustainability initiatives: EC's project-driven operations limit flexibility in adopting sustainable materials and technologies, as tight deadlines and budget constraints prioritize operational efficiency. Sustainability R&D is still insufficiently funded, and cost-effectiveness frequently precedes sustainability considerations. However, efforts to integrate sustainability within these limitations are reflected in programs like waste management and photovoltaics. Although sustainability is considered, profit primarily motivates procurement decisions, indicating an unbalanced trade-off between immediate benefits and long-term environmental objectives.

Cultural foundations and constraints: EC's culture emphasizes collaboration and operational efficiency, supporting supplier engagement in sustainability practices, such as responsible procurement. However, focusing on meeting immediate project demands often obscures deeper cultural commitments to sustainability. While certain practices align with environmental goals, sustainability lacks a central role in EC's cultural framework, requiring greater reinforcement to ensure consistency across its employees and within its SC.

3a) Global sustainability priorities, particularly the United Nations' SDGs, are critical for shaping EC's response to the ESA proposal, enhancing its competitive position, and creating future opportunities (United Nations 2015). The SDGs provide a framework to demonstrate EC's commitment to sustainability, aligning strategic goals with global expectations and trends.

Table 3: Aligning ECs strategy with United Nations SDGs for sustainability and growth

SDG	*Impact on ESA proposal*	*Competitive advantage*	*Future opportunities*
SDG 8 *Decent work and economic growth*	Ethical labor practices and contributions to regional economic development align with fair work and economic growth standards	Reinforces EC's reputation as a fair employer and responsible regional actor, meeting client expectations for ethical practices	Strengthened regional presence and fair employment practices enhance EC's credibility for future partnerships and international projects
SDG 9 *Industry, innovation and infrastructure*	Luxembourg's support for innovation and industrial capabilities (e.g., Space Research Program) align with the focus on sustainable innovation	Positions EC as a key player in leveraging Luxembourg's infrastructure for advanced composites in aerospace	Expands opportunities for EC to participate in cutting-edge space mining projects and public-private collaborations in Luxembourg's ecosystem
SDG 12 *Responsible consumption and production*	Waste management initiatives, including recycling programs and efficient material use demonstrate responsible production efforts	Procurement prioritizes profit but includes some sustainability considerations, giving EC partial alignment with sustainability goals	Improving waste management systems and adopting sustainable practices in material sourcing could increase EC's attractiveness to sustainability-focused projects

SDG 13 *Climate action*	Lightweight composites serve to lower emissions, thereby supporting targets for climate change. Restricted use of renewable energy technologies reflects present limitations	Limits its differentiation without additional R&D but positions EC as a partial contributor to climate action through product innovation	EC's environmental credentials could be strengthened, and new markets could be opened by increasing the use of renewable energy and investing in green technologies

3b) The ESA proposal must be accepted, renegotiated, or rejected. Every decision affects operations, expansion, and sustainability. These choices are assessed in the table:

Table 4: Three strategic responses to the ESA proposal and their implications

Option	*Advantage*	*Disadvantage*	*Implications*
Accept the proposal as is	- Secures a high-profile contract, strengthening EC's partnership with ESA - Reinforces EC's reputation as a capable player in the New Space economy - Immediate revenue helps stabilize operations	- Strain on EC's SC, risking to compromise on quality and sustainability - Compromises on environmental and social goals could lead to reputational damage - Limited time to implement sustainable practices reduces alignment with future global trends	Positions EC as a preferred ESA supplier but undermines its ability to integrate sustainability, potentially weakening its competitive edge long-term
Renegotiate the proposal	- Provides flexibility to align production timelines with sustainable practices - Ensures supplier accountability through more robust audits and quality control - Demonstrates EC's commitment to responsible practices to ESA and stakeholders	- ESA may perceive renegotiation as inflexibility, risking the loss of the contract - Delays revenue generation and market leadership opportunities in the New Space sector	Aligns EC's operations with sustainability objectives, building long-term credibility and positioning EC as an industry leader committed to innovation and responsibility
Decline the proposal	- Focus on internal initiatives like R&D for sustainable materials and projects for environmental management - Aligns with EC's sustainability priorities - It avoids operational disruptions caused by tight deadlines	- Loss of ESA proposal and immediate revenue weakens EC's visibility in the competitive New Space industry - Missed opportunity to gain experience in high-stakes space mining projects	Reinforces EC's sustainability commitments but at the cost of growth in the New Space economy, potentially limiting its ability to compete in future space projects

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Supplementary Material

Appendix 1: Key milestones in EC’s production and expansion

Year	*Event*
1985	Start of production at Euro-Composites S.A. in Echternach, Luxembourg
12 August 1985	First honeycomb order by Henshall Bonded Assemblies, UK
31 October 1985	Qualification of honeycombs and of the production site according to LN 29970 by MBB GmbH, Germany and Airbus Group
Spring 1987	Qualification of honeycombs and of the production site by Boeing, USA Qualification of the panel production by Buderus Sell, Germany
24 March 1988	Incorporation of Euro-Composites Corporation in Culpeper
1 January 2006	Incorporation of the production site Euro-Composites GmbH, Bitburg, Germany
1 October 2007	Our Center of Excellence resumes work in a separate building
1 March 2009	EC starts on a 2500m² production area (Hall 12) into the production of assemblies for aircraft interiors (structures like for example Galleys)
1 March 2011	Expansion of the production area from 7000m² to 9020m² at Euro-Composites Corporation in Culpeper Virginia, USA
1 April 2015	Realization of new shipping area with larger storage capacity. The available area of former shipping department (Hall 4) is now used For production of railway components
2018	New Hall 4 & 5 at Euro-Composites Corporation in Culpeper Virginia, USA (extension of honeycomb production and added value products)
2018	Start of production in Hall 6.1 for Space & Defense Products with our ultra-precise CNC-machine and one of the largest cleanrooms in Europe for space application
2019	Qualification according to EASA 21 subpart J, EC becomes a design organization. EC is qualified by the Luxembourgian government as a NATO supplier
2020	Production facilities for the manufacturing of aluminum honeycomb in alloys 5052 and 5056 in Bitburg, Germany

Figure 1: Company history of Euro-Composites; Retrieved from: Euro-Composites S.A.

Appendix 2: Honeycomb structures

Raw honeycomb block:

Figure 2: Honeycomb block during further processing; Retrieved from: Moovijob.com

Closeup look at Kevlar honeycomb structure serving as an intermediary product:

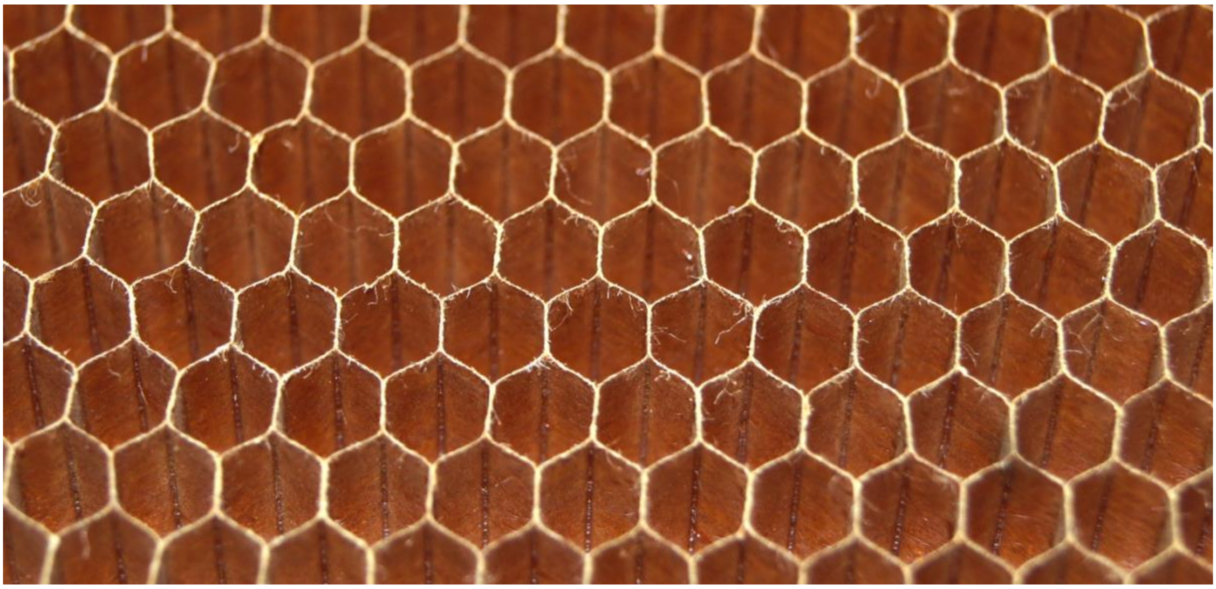

Figure 3: Closeup looks at honeycomb structure; Retrieved from: Euro-Composites S.A.

Structural, light-weight panel to be used for spacecraft construction:

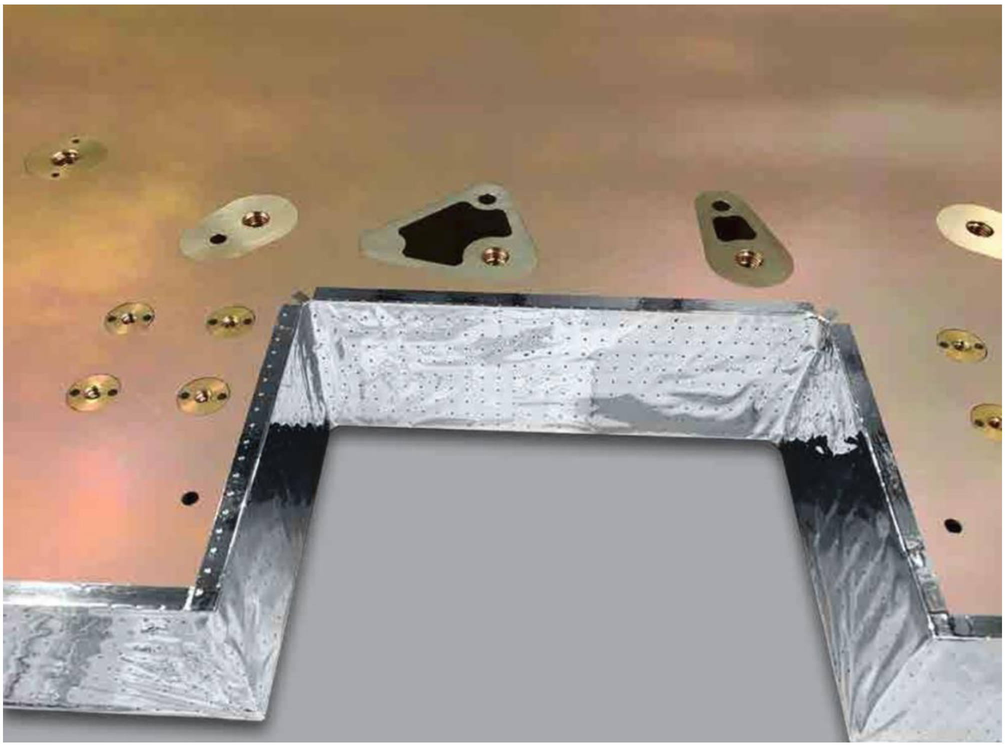

Figure 4: Ready-to-assemble structural panel for space application; Retrieved from: Euro-Composites Group

Appendix 3: Production process

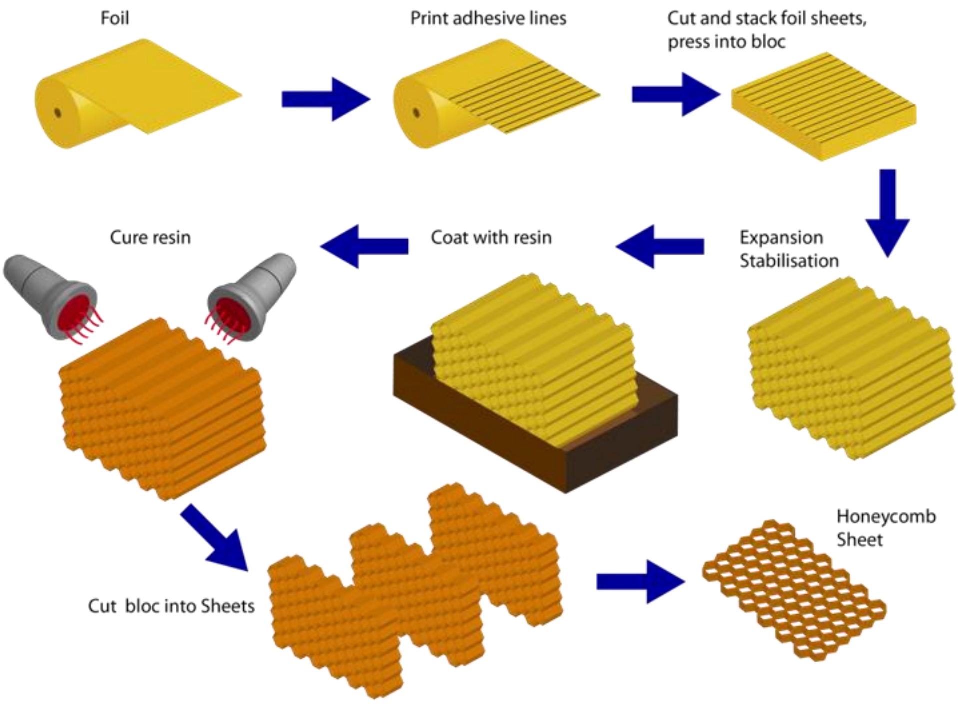

Figure 5: Known NEAs; Retrieved from: Euro-Composites Group

Appendix 4: EC's cleanroom setup is among the largest in Europe

Figure 6: Largest cleanroom with 13m operating height; Retrieved from: Euro-Composites Group

Figure 7: Smaller cleanroom for manual application; Retrieved from: Euro-Composites Group

Appendix 5: Known NEAs

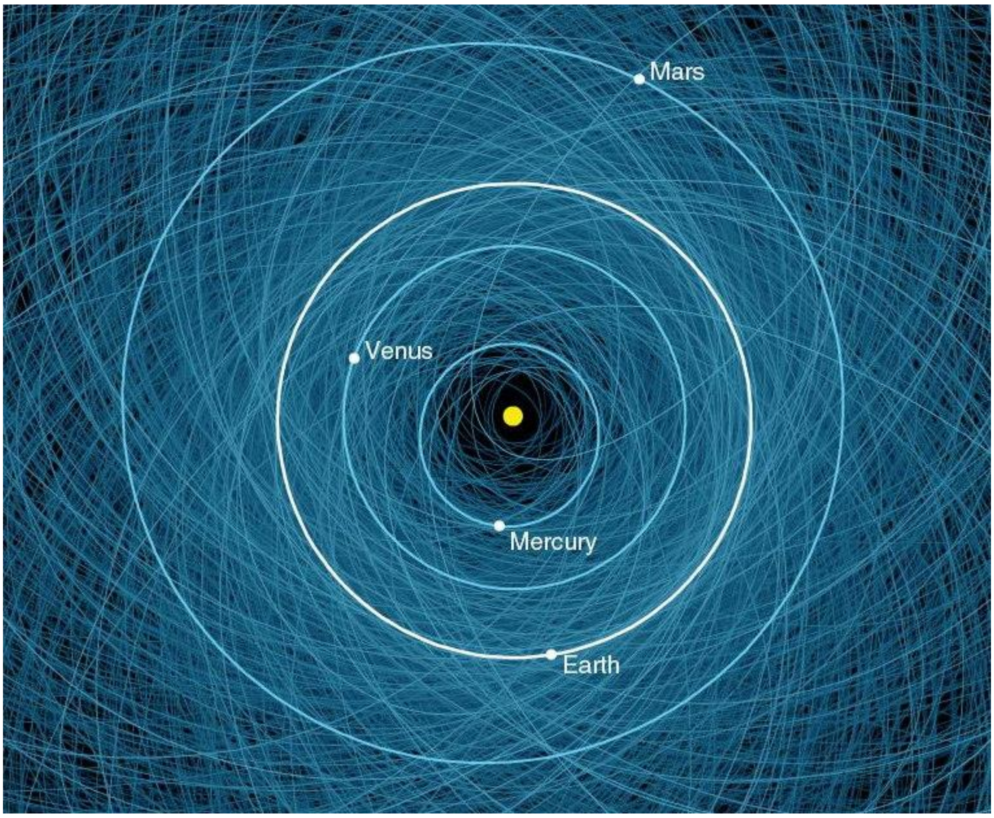

Figure 8: Known NEAs; Retrieved from: Space.com, Wall

Appendix 6: Relevant SDGs overview

SDG	*Target*	*Description*	*Indicators*
8 DECENT WORK AND ECONOMIC GROWTH	**8.4**	Improve global resource efficiency in consumption and production and decouple economic growth from environmental degradation.	**8.4.1** Material footprint, material footprint per capita, and material footprint per GDP. **8.4.2** Domestic material consumption and related metrics.
	8.5	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.	**8.5.1** Average hourly earnings of employees, by sex, age, occupation, and disability. **8.5.2** Unemployment rate, by sex, age, and disability.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	**9.4**	Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource efficiency and adoption of clean technologies.	**9.4.1** CO_2 emissions per unit of value added. **9.4.2** Proportion of total energy from renewable sources in the industry.
	9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors, and encourage innovation.	**9.5.1** Research and development expenditure as a proportion of GDP. **9.5.2** Number of researchers per million inhabitants.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	**12.2**	Achieve sustainable management and efficient use of natural resources.	**2.2.1** Material footprint, material footprint per capita, and material footprint per GDP. **12.2.2** Domestic material consumption and related metrics.
	12.5	Substantially reduce waste generation through prevention, reduction, recycling, and reuse.	**12.5.1** National recycling rate, tons of material recycled.
	12.6	Encourage companies to adopt sustainable practices and integrate sustainability information into their reporting cycle.	**12.6.1** Number of companies publishing sustainability reports.
13 CLIMATE ACTION	**13.2**	Integrate climate change measures into national policies, strategies, and planning.	**13.2.1** Number of countries adopting and implementing climate change mitigation/adaptation strategies.
	13.3	Improve awareness and capacity on climate change mitigation, adaptation, impact reduction, and early warning.	**13.3.1** Number of countries that have integrated mitigation, adaptation, and early warning systems into policies. **13.3.2** Education and training on climate change.

Figure 9: Relevant SDG indicators 8, 9, 12, and 13 Retrieved from: (United Nations, n.d.)

Appendix 7: A framework of sustainable SSCM

Framework:

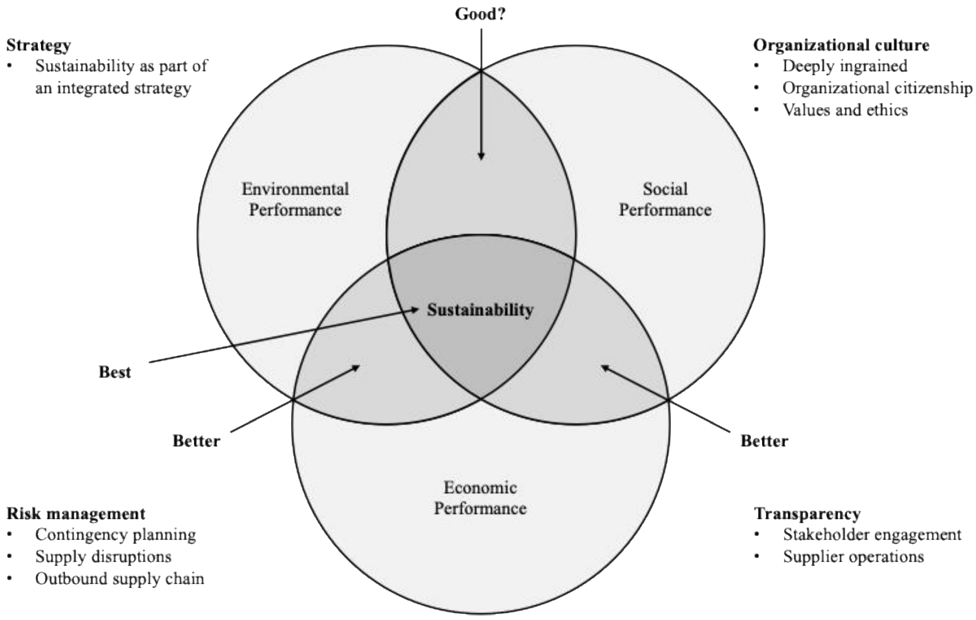

Figure 10: SSCM framework; Retrieved from: Carter and Rogers (2008)

Leveraging the SSCM framework:

Key areas	*Implication*
Long-term profitability	Integrating sustainable practices into SC processes reduces environmental and social risks and drives operational efficiency. Companies that adopt sustainable innovations are better positioned to gain competitive advantages, reduce costs over time, and tap into new market opportunities driven by sustainability-focused clients.
Investor and client trust	Demonstrating a commitment to transparency and ethical SC practices attracts environmentally conscious stakeholders. This fosters relationships with investors and clients, leading to greater brand loyalty and expanded market reach in industries where sustainability is highly valued.
Risk mitigation	Effective risk management strategies aligned with sustainability help reduce vulnerabilities to disruptions. From geopolitical risks to environmental challenges, aligning risk management with sustainable SC practices ensures better resilience and compliance with evolving regulatory standards.
Regulatory and market adaption	As global standards shift toward sustainability, companies with robust SSCM practices are better positioned to meet these demands. This proactive alignment minimizes disruptions from regulatory changes, secures certifications, and positions the organization as an industry leader.
Organizational alignment	Embedding sustainability into SC strategy and culture ensures that efforts extend beyond compliance. This creates opportunities for innovation, enhances reputation, and contributes meaningfully to achieving global sustainability targets like the SDGs.

Figure 11: SSCM implication; Retrieved from: Carter and Rogers (2008)