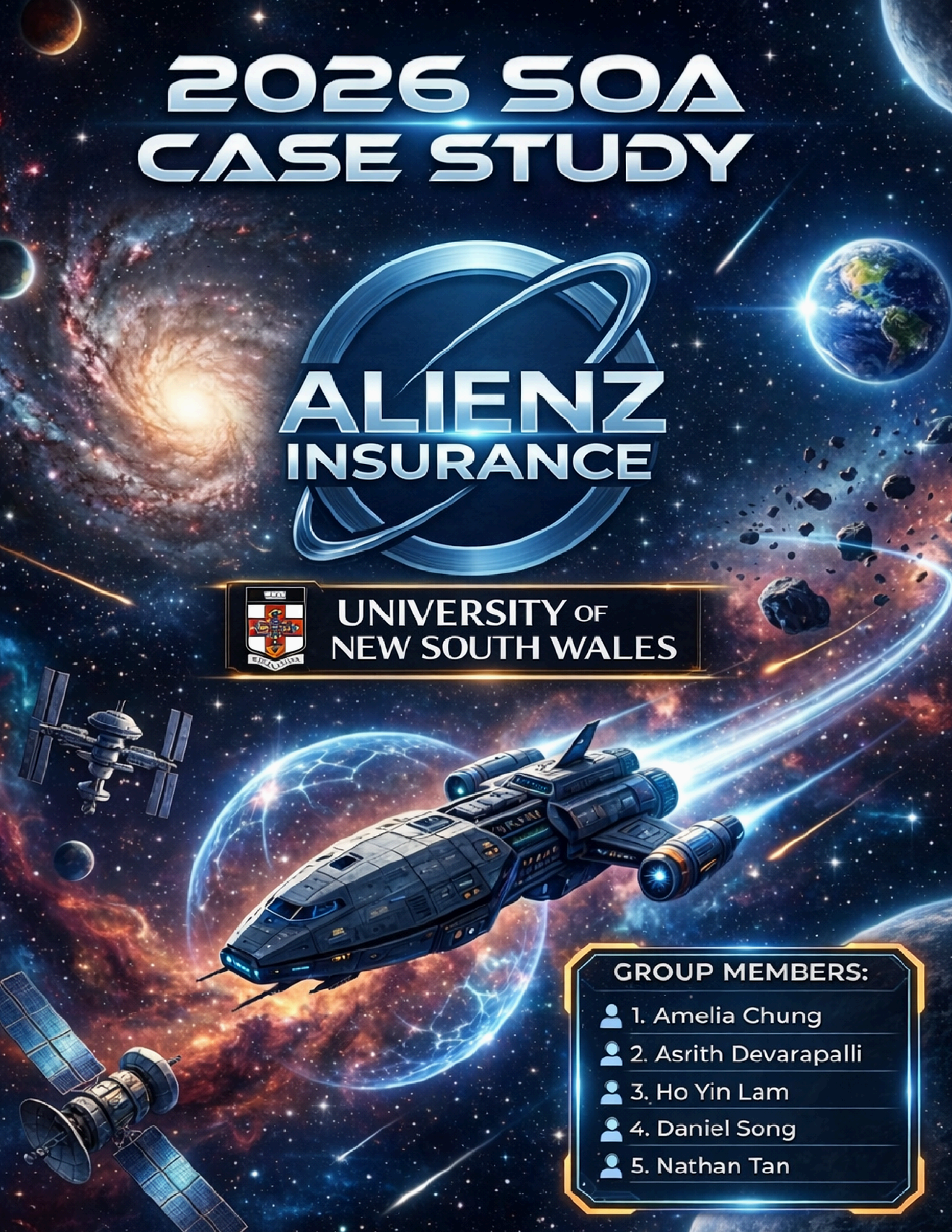
2026 SOA
CASE STUDY
ALIENZ
INSURANCE
UNIVERSITY OF
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1) Executive Summary

For the partnership between Galaxy General Insurance Company and Cosmic Quarry Mining Corporation to be most fruitful, we propose a highly structured strategy based on rigorous stochastic aggregate loss modelling. To safely underwrite our projected 10-year present value expected pure cost of 90.21 Billion Đ, we are targeting a 10-year Gross Premium of 166.54 Billion Đ, yielding a projected net revenue of 7.47 Billion Đ. However, the portfolio exhibits extreme tail-risk volatility, generating a 99-percentile Value at Risk (VaR) of 197.97 Billion Đ for 10 years. Our recommendation is to include all four requested products: Workers' Compensation (WC), Equipment Failure (EF), Business Interruption (BI), and Cargo Loss (CL), as bundling them allows the steady premium flows from high-frequency WC and EF policies to offset the capital required for the severe BI and CL exposures.

Design Features: The portfolio is bifurcated into two tiers to address the distinct resources, characteristics and environmental challenges of the three solar systems.
Tier 1 - Attritional Risk Layer (WC & EF): This is specifically tailored for the high-traffic, high-debris environment of the Helionis Cluster, which utilises traditional occurrence-based indemnity structures with high deductibles.
Tier 2 - Catastrophic Risk Layer (BI & CL): This product is specifically tailored for the correlated tail-risks of the Bayesia System and the severe frontier isolation of Oryn Delta. In Bayesia, BI utilises a parametric trigger linked to the solar_radiation index; if radiation exceeds a critical threshold, causing system-wide sensor degradation, a fixed daily payout is automatically deployed. For Oryn Delta, CL utilises a transit-index agreed-value structure where the 680,000K maximum cargo payout is automatically compounded by a projected 2.5% interplanetary inflation rate to prevent value erosion, ensuring Cosmic Quarry's economic returns are fully protected.

Adaptability & Scalability
As Cosmic Quarry expands deeper into uncharted space, risk profiles will inherently shift. The parametric grid utilised in the Bayesia system is infinitely adaptable; as new station_id platforms are constructed, they will seamlessly integrate into the existing solar_radiation trigger networks without requiring ground-up underwriting. Furthermore, our pricing model utilises Generalised Linear Models (GLMs) that scale automatically with exposure growth, ensuring coverage remains continuously available and adequately priced.

Environmental, Social and Governance (ESG) Considerations
To ensure long-term sustainability, our portfolio embeds multiple ESG incentives directly within the ratings algorithm. Through dynamic experience rating, Cosmic Quarry receives premium credit for maintaining a high safety_training_index in extreme gravity zones and for strict adherence to maintenance_int schedules. Conversely, vessels routed through avoidable high-debris zones face premium surcharges.

Integration into Cosmic Quarry's Enterprise Risk Management (ERM) Framework - Marketing
Our marketing team should present the Integrated Interstellar Portfolio as a vital capital optimisation tool within Cosmic Quarry's ERM framework. The extreme volatility of Bayesia and

Oryn Delta creates significant balance sheet uncertainty, forcing Cosmic Quarry to hold substantial liquid capital under ERM requirements to self-insure against frontier losses and system-wide solar storms. By purchasing this portfolio for 166.54 Billion Đ, Cosmic Quarry transfers its 197.97 Billion Đ tail-risk onto Galaxy General, which we protect via Catastrophe Excess of Loss reinsurance, immediately freeing trapped liquidity to reinvest in operational expansion, new Quantum Bores, and workforce development.

2) Product Design

To effectively manage the vastly different risk profiles across Cosmic Quarry's operations, Galaxy General should deploy an "Integrated Interstellar Portfolio" (Stanislav, 2024). This portfolio is bifurcated into two layers - Tier 1 (Attritional) and Tier 2 (Catastrophic) - to balance high-frequency operational maintenance with low-frequency, high-severity financial protection:

- **Tier 1: Attritional Risk Layer (WC & EF):** Focuses on managing high-frequency, low-severity claims characteristic of the Helionis Cluster's high-traffic environment. The primary challenges are elevated debris density and a ~1.13g gravity environment, which increase wear-and-tear and occupational hazards. The design utilises traditional indemnity structures, with dynamic rating to incentivise compliance with safety standards.
- **Tier 2: Catastrophic Risk Layer (BI & CL):** Focuses on systemic, correlated, and total-loss threats in the Bayesia System and Oryn Delta. Due to severe frontier isolation (e.g., extreme 240 AU distances and 60-month transit times), the product design relies on independent long-range telemetry, utilising parametric triggers for Business Interruption (BI) and a transit-indexed agreed-value structure for Cargo Loss (CL). This tier contains financial incentives/penalties to promote corporate resilience and safety adherence.

For a comprehensive breakdown of the specific quantitative triggers, strict coverage exclusions and the dynamic premium rating modifiers - including up to 25% credits and 40% surcharges engineered to actively enforce corporate safety - please refer to the detailed explanation of design features in Appendix 1.

a) Pricing & Rating Factors

Premiums are a dynamic function of the Pure Premium (E[S]) derived from stochastic Monte Carlo models, augmented by a Risk Margin that scales directly with the observed variance of the specific hazard (Lemaire, 1998). Generalised Linear Models (GLMs) are utilised to isolate predictive operational variables, allowing the rating engine to automatically adjust to the realities of each system.

Product	Primary Rating Variables	System Weighting & Actuarial Justification
Workers' Compensation	gravity_level, safety_training_index	Highest in Helionis (High Frequency): High gravity environments directly inflate the frequency and severity of musculoskeletal claims, demanding heavy premium loading.
Equipment Failure	usage_intensity solar_radiation	Highest in Bayesia (Tail Risk): Radiation spikes cause instantaneous electronic degradation, shifting EF from a predictable wear-and-tear risk to a volatile, heavy-tailed exposure

Business Interruption	energy_backup_score supply_chain_index	Highest in Bayesia/Oryn (Correlation): Poor backup scores heavily penalise premiums, as a single solar event can trigger simultaneous, system-wide communication and production stoppages.
Cargo Loss	transit_duration vessel_age, pilot_exp	Highest in Oryn Delta (Severity): The 240 AU distance and 60-month duration maximise the probability of a total loss, requiring peak risk margins to cover extreme uncertainty.

Table 1. Primary Rating Factors for Each Product & Justifications

b) Risk and Capital Allocation

Pricing of the Integrated Interstellar Portfolio is designed to capture the baseline expected 10 year present value cost of 90.21 Billion Ð. However, our stochastic aggregate loss models mathematically prove that capital allocation cannot be driven by the pure premium mean. The portfolio exhibits extreme tail-risk volatility, generating a standard deviation of 38.02 Billion Ð- nearly three times the expected cost. Consequently, Galaxy General's internal capital reserving and external risk transfer strategies must be strictly dictated by our modelled tail metrics to ensure regulatory solvency during a 1 in 100 year catastrophic event. Short and long-term ranges for each hazard are provided in Appendix Section 3.

a) Internal Capital Reserving (Solvency Floor)

To safely underwrite Cosmic Quarry's expansion, Galaxy General must establish a massive liquid capital reserve (Marsh, 2021). Our stress testing established a 99-percentile VaR of 197.97 Billion Ð. This figure represents our absolute capital floor; it is the amount of risk Galaxy General will retain internally to survive a 1-in-100-year systemic event. To fund this reserve, the steady, high-frequency premium cash flows generated by our Tier 1 attritional products (Helionis Cluster) will be aggressively invested into high-yield, long-duration assets, deliberately matched against the 60-month liability duration of the Oryn Delta transit to combat the projected 2.5% interplanetary inflation rate.

b) Reinsurance Strategy (Bridging the 20.85 Billion Ð Gap)

While Galaxy General can safely hold internal reserves up to 197.7 Billion Ð VaR(0.99) threshold, absorbing the extreme tail violates our internal risk appetite. If this 1-in-100-year threshold is breached, the Conditional Tail Expectation (TVaR(0.99)) of 218.82 Billion Ð. To bridge this 218.82 Billion Ð capital gap, we mandate a comprehensive three-pronged reinsurance strategy: (See appendix section 1). Detailed reinsurance rationale)

1. Catastrophe Excess of Loss (CAT XL): Deployed to protect us from the extreme tail risk of the Bayesia System. By setting the attachment point at our VaR retention limit, this treaty provides a coverage layer that strictly caps our exposure at the TVaR ceiling.
2. Quota Share (Proportional Reinsurance): Stabilises day-to-day liquidity required to fund immediate capital reduction on our Tier 1 attritional risks. The ceded premium required to fund this is already fully integrated into our portfolio's 30% pricing expense loading.
3. Facultative Reinsurance: Surgically transfers the risk of isolated deep-space total losses by securing bespoke facultative coverage explicitly for Oryn Delta shipments with a value of 500,000K or greater

c) Final Pricing Recommendation

The fundamental pricing equation applied across the portfolio is:

Gross Premium = Expected Loss + Cost of Capital + Expenses + Profit Margin

Our models project a 10-year Expected Loss of 90.21 Billion Đ. However, extreme volatility driven by heavy-tailed CL (Standard Deviation: 38.02 Billion Đ) requires a dedicated capital charge as it would critically undercapitalise Galaxy General against the 197.97 Billion Đ VaR (0.99) and 218.82 Billion Đ TVar(0.99) tail exposures. To fund necessary reserves, we apply a 20% capital charge and target a 65% permissible loss ratio, yielding a comprehensive 166.54 Billion Đ gross premium.

Strategic Decoupling and Modular Pricing:

While our product design bifurcates hazards based on operational behaviour and claims trigger mechanisms (Tier 1 Attritional vs Tier 2 Catastrophic), our Commercial Pricing Strategy is driven by capital intensity and is strategically decoupled from the operational design (Earnix Team, 2024)). Given that CL is the most significant capital burden, Galaxy General proposes a modular pricing structure, offering two distinct tiers:

1. **Core Coverage Package:** Includes BI, WC and EF because the hazards exhibit more stable financial variance; they are priced with a predictable, moderate cost of capital margin.
2. **Cargo Loss Coverage (Modular Addition):** Priced separately as an optional or standalone capital module due to its massive tail risk and severe reserving requirements.

To optimise costs, the Cargo module utilises a layered risk-retention approach (Bidav, 2024):

1. **Deductible:** Policyholders retain an initial 34,000K (5% of max cargo value) to absorb high-frequency attritional damage (e.g., micro-meteoroid degradation).
2. **Primary Retention:** Galaxy General covers severity above the threshold up to the 680,000K maximum fleet exposure limit.
3. **Risk Transfer:** Extreme total-loss events are partially transferred via CAT XL reinsurance to protect Galaxy General's solvency.

Applying this framework to the fully underwritten comprehensive portfolio (Core + Cargo) yields the following 10-year pricing structure:

- **Expected Loss:** 90.21 Billion Đ
- **Cost of Capital (20% Risk Margin):** 18.04 Billion Đ
- **Capital-Adjusted Pure Premium:** 108.25 Billion Đ
- **Target Gross Premium: 166.54 Billion Đ**

The pricing structure directly supports our aggregate returns, measured via Risk-Adjusted Return on Capital. Short-term returns are highly volatile, while standard attritional years exceed target thresholds, worst case correlated scenarios severely suppress returns by approaching capital tolerance limits. However, over the long-term, the strategic integration of proportional quota share and CAT XL protects our pricing framework, ultimately stabilising RAROC and securing our targeted 5% corporate profit margin, For details on the pricing reasons and methodologies, see Appendix 1.

3) Summary of Pricing and Capital Modelling

Aggregate annual losses for the four hazard areas (Business Interruption, Cargo Loss, Equipment Failure, and Workers' Compensation) were estimated using an actuarial collective risk model. Generalised linear models with exposure offsets were used to model claim frequency, allowing expected claim counts to scale appropriately with operational exposure. While Poisson regression models were used for BI, EF and WC claims, a negative binomial regression model was used for CL claims to account for overdispersion in shipment incident frequency.

For claim severity, a combination of parametric and regression methods was used (Swiss Re, 2023). Log-normal distribution was used for BI and WC severities. This reflects the multiplicative nature of operational disruption costs and injury-related expenses. Gamma GLM was used for Equipment Failure and Cargo severities, allowing claim size to adjust with operational characteristics such as usage intensity, cargo weight, environmental conditions, etc.

a) Aggregate loss distribution for each hazard coverage

In order to model the aggregate loss, we developed an aggregate loss model using a Monte Carlo simulation framework. By modelling and bridging the frequency and severity of claims for each hazard coverage area and running Monte Carlo simulations 10,000 times for each hazard coverage, we acquire a good estimate of the probability distribution of total annual losses. To evaluate financial viability, we assessed both short and long term aggregate projections. In the short-term, the portfolio generates an expected aggregate cost of 8.26 Billion Đ, yielding a mean net revenue 0f 0.80 Billion Đ. However, driven by primarily CL variance, there is a 30.2% probability of a year 1 underwriting loss. Over the 10-year projection, the portfolio generates a present value cost of 90.21 Billion Đ, and is expected to generate 7.47 Billion Đ in mean net revenue. Still it exhibits extreme volatility with a portfolio standard deviation of 38.0 Billion Đ, where a 1 in 100 year event (P01) could plunge long-term net-revenue to a loss of 100.29 Billion Đ. Below is the summary of the aggregate loss distributions for each hazard area: (For detailed modelling methodologies, see Appendix section 2)

Business Interruption (BI): Exhibits a moderately right-skewed distribution. Claim frequency is predominantly influenced by operational maintenance factors, specifically energy_backup_score and maintenance_freq. Conversely, claim severity is largely independent of covariates, suggesting that the magnitude of loss, once interruption occurs, behaves as a random variable. Across all systems, BI generates a baseline mean of 4.32 million Đ, but extreme events push the 99th percentile (P99) to 10.87 million Đ.

Cargo Loss (CL): Characterised by a highly heavy-tailed distribution. Claim frequency is driven by specific transit variables and environmental hazards, including route_risk, debris_density, solar_radiation, and pilot_experience. Claim severity is contingent on specific route risks/hazards, in addition to the type and volume of shipments (cargo_type and weight). While the all-systems median is 6.51 billion Đ, generating an extreme 1 in 100-year (P99) exposure of 30.82 billion Đ.

Equipment Failure (EF): Displays a normal-leaning (light-tailed) distribution, reflecting primarily attritional losses. Key influential factors on claim frequency include equipment type (specifically ReglAggregators) and solar system location (with increased frequency noted in the Helionis Cluster). The severity of EF claims is primarily driven by equipment type, notably

Quantum Bores. This stability is reflected in the metrics; the mean is 60.68 million Đ, with a tightly constrained P99 for only 66.70 million Đ.

Worker's Compensation (WC): Demonstrates low claim amounts and minimal variation (light-tailed). The primary determinant for frequency involves occupation and accident history. Severity is statistically unaffected by the covariates. WC provides highly stable cash flows, with an all-systems mean of 2.62 million Đ and a P99 of 3.44 million Đ.

b) Stress Testing

To stress test an extreme 1-in-100-year scenario to assess severe tail risks quantitatively, we developed a deterministic extreme scenario: the Carrington-class coronal mass ejection. Please refer to Appendix Section 3 for results. In this stress test, a compounding, system-wide shock was parameterised. Rather than assuming hazard areas operate independently, this scenario tests the portfolio's resilience when multiple solar systems and coverage lines fail simultaneously.

The Scenario Profile

A massive, unpredictable solar flare erupts, sending a wave of electromagnetic and particle radiation across the mining territories.

- **Bayesia System:** Already vulnerable to sharp, temporary spikes of electromagnetic radiation, the system suffers catastrophic grid overloads.
- **Oryn Delta:** The dwarf star's sporadic, unpredictable flares neutralise the newly deployed amplified beacons and mobile relay drones, causing a system-wide communication blackout.
- **Helionis Cluster:** While physically shielded from the worst of the radiation, the system suffers severe supply-chain bottlenecks as transit routes are grounded.

Modelling the Financial Shock

To simulate this 1-in-100 year event in our Monte Carlo environment, baseline parameters of the models were shocked. (For parameter multipliers, see Appendix Section 3). Stress testing results)

1. **Frequency Multipliers (The Domino Effect):** We applied aggressive hazard loadings to our expected claim counts. The electromagnetic surge causes immediate, widespread Equipment Failures (EF), which in turn trigger an unprecedented volume of Business Interruption (BI) claims as mining extraction halts across Bayesia and Oryn Delta.
2. **Severity Multipliers (The Response Delay):** Frequency alone does not capture a true catastrophe. Because communication networks are jammed, emergency response and repair crews are severely delayed. We mathematically shocked the expected severity of claims across the board. A minor Workers' Compensation injury or a routine cargo route delay rapidly escalates into a maximum-limit total loss due to the inability to deploy medical or mechanical support.

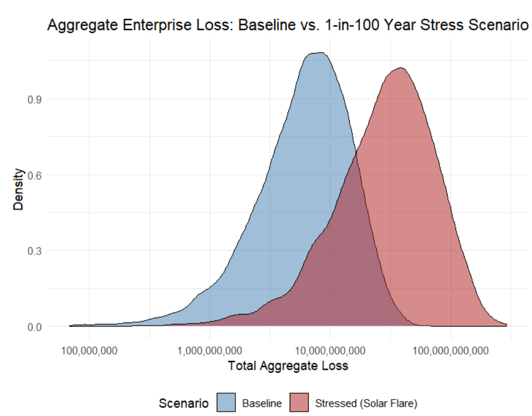

Figure 1. Comparison of aggregate loss distribution between baseline and extreme stressed-scenario

When these shocked parameters are run through 10,000 simulation trials, the resulting aggregate loss distribution exhibits a massive "tail shift." The stressed 99th percentile (P99) extends drastically beyond our baseline expectations. (See Figure 1.) This indicates that Galaxy General Insurance Company cannot rely on standard operational cash flow to cover this delta.

4) Risk Assessment

a) Risk identification by hazard area coverage for each solar system

Risk Identification was conducted within a comprehensive Enterprise Risk Management framework, categorising threats into financial, operational and strategic risks across the three distinct solar systems. (*For extended methodology, refer to Appendix 4A)*.

Helionis Cluster: The High-Traffic Frequency Hub

Risk in this established system is driven by operational density and environmental debris.

Operational & Financial: The two major asteroid clusters create localised debris_density compounded by a 1.13g gravity environment, actively driving high-frequency, attritional EF and WC claims. Pilot_experience and vessel_age are the primary actuarial predictors for CL severity due to the need for real-time hazard avoidance

Strategic: Severe concentration risk, with up to 85% BI losses clustering around just two high-density transit routes.

Bayesia System: The Radiative Tail Risk

Modelled using the Epsilon proxy, Bayesia's risk profile is defined by extreme electromagnetic volatility from its binary K-type star pair.

Operational & Financial: The solar_radiation index acts as a catastrophic system-wide trigger. Radiation causes instantaneous "electronic degradation", bypassing standard mechanical wear. During high-radiation events, average EF claims for specialised machinery leap from a ~15K baseline to over 700K.

Strategic: Correlated radiation events severely impact multiple station_id locations simultaneously, significantly neutralising the benefits of geographic diversification.

Oryn Delta: The Severity Frontier

Evaluated via the Zeta proxy, this expanding territory represents the ultimate severity frontier defined by extreme isolation.

Operational & Financial: Extreme distance (up to 240 AU) and 60-month transit durations introduce severe economic risk; a 2.5% interplanetary inflation rate compounds nominal claim costs by 13.1% over a single transit window. Severe collisions guarantee total cargo losses, maximising the ~680,000K insured limit and leaving virtually zero margin for salvage.

Strategic: Rapid corporate expansion outpaces safety governance; proxy data indicates a concerning safety_training_index of only 2.8 out of 5, dramatically elevating WC risks.

b) Correlated risk scenarios

Although risks are assessed individually, systemic drivers can generate correlated losses across coverages. (*See Appendix 4B for full scenario list)*

Scenario Wide Electromagnetic	A high solar_radiation event (~1.0 index) causes instantaneous EF (electronic degradation) and BI (grid failure) claims across Bayesia

Cascade (Solar storm) Most severe portfolio wide contagion	originating from the binary star pair (electronic degradation) and Business Interruption (grid failure). Simultaneously, the wave disrupts Oryn Delta communication relays and causes catastrophic CL in Helionis due to ships deviating into high-gravity orbital shear zones.
Interplanetary Supply Chain Collapse (The Hub Bottleneck) Local asteroid fragmentation event	A massive debris_density surge severs primary Helionis transport routes, plummeting the supply_chain_index. This triggers local BI claims and starves Oryn Delta of vital resources, triggering simultaneous BI claims there despite no physical frontier damage.

c) Scenario Testing

Scenarios	Financial Impact
Attritional case	Aggregate loss approximately equals expected loss, return on capital exceeds target threshold; no reinsurance attachment triggered
Moderate-case	Loss severity exceeds baseline expectations but remains within capital tolerance thresholds (e.g., elevated debris_density in Helionis or moderate radiation spikes in Bayesia). These common scenarios may increase aggregate losses above expected value but below reinsurance attachment levels. Hence return on capital reduces but remains positive.
Worst-case	Correlated risk scenarios detailed above simultaneously trigger EF, BI and CL across multiple systems, causing tail amplification. Aggregate losses approach/exceed 1-in-100-year thresholds creating material capital strain. Reinsurance attachment is activated through a statistical trigger to prevent solvency breach.

d) Threat Table

The complete 5-tier threat matrix is available in Appendix 4C, including systemic equipment defects and chronic gravitational exposure risks.

Rank	Risk Types	Affected Systems	Critical Variable Trigger	Likelihood	Actuarial Impact & ERM category	Mitigation strategy
1	Interstellar Solar Storm	Bayesia (Primary); All (Secondary)	Solar_ radiation (>0.9)	Rare (1 in 100-year event)	Extreme Tail Risk (Financial): Simultaneous multi-platform BI and EF claims breaking risk independence	Secure CAT XL reinsurance: implement parametric BI triggers for immediate liquidity; mandate max energy_backup_score
2	Deep Space Total Cargo Loss	Oryn Delta	Transit_ duration, distance	Low-Moderate (Cumulative over 60 months)	Catastrophic Severity (Financial): single event maxing out ~680,000K limits; extreme inflation exposure	Purchase bespoke Facultative Reinsurance; implement asset liability matching; adjust premium dynamically for inflation

3	Asteroid Fragmentation Surge	Helionis Cluster	debris_density	High (Attritional Hub environment)	Contagion Risk (Operational): Drives immediate EF spikes and plummets supply_chain_index	Proportional reinsurance (quota share) for cash flow; enforce strict underwriting limits on vessel_age and pilot_experience

e) Narrative of Risk Differences Among the Solar Systems

Helionis Cluster (Frequency Hub)	Risk here is a manageable function of industrial volume and density. The primary challenge is the high frequency of attritional claims caused by heavy traffic and localised debris. Because these risks are independent and voluminous, they are highly predictable. Risk mitigation here focuses on rigorous maintenance_freq and optimising pilot_experience
Bayesia System (Correlated Tail Risk)	This system introduces severe environmental volatility. The risk profile shifts from mechanical wear to electromagnetic degradation. The defining feature is the breakdown of geographic diversification; because solar radiation impacts the entire system simultaneously, risks are highly correlated, requiring advanced dependency based modeling to price the extreme tail risk accurately.
Oryn Delta (Severity Frontier)	Representing the highest uncertainty, Oryn Delta is defined by "Frontier Isolation". The extreme distance (up to 240AU) and transit_duration (up to 60 Earth months) guarantee that minor incidents escalate into total losses. The physical impossibility of rapid hazard response transforms standard operational hiccups into catastrophic severity events, demanding bespoke capital reserving and aggressive inflationary protections.

To ensure long-term sustainability, our portfolio embeds rigorous ESG incentives directly into the pricing algorithm. Through dynamic experiences rating, Cosmic Quarry receives premium credits for actively avoiding high debris_density zones, maintaining top-tier safety_training_index scores for human capital protection, and strictly adhering to maintenance_int schedules to enforce proactive corporate governance (See Appendix 4D for the comprehensive ESG framework).

5) Assumptions

Key assumptions that have the largest impact include:

Aspect	Assumption	Rationale
Data Clean Up	For Cargo Loss claim amount values, the claim amounts that exceeded the range were right-censored	Exploratory analysis showed that the outliers are unlikely to be actual severe losses. See detailed Rationale in Appendix 5.
Claim Frequency	Business Interruption, Equipment Failure and Workers' Compensation claim frequencies are modelled using Poisson GLMs, based on dispersion	Diagnostic checks indicated these lines did not display substantial overdispersion

	diagnostics	
Cargo Loss Frequency Model	Negative Binomial GLM is used due to its high variance-to-mean ratio	Accounts for overdispersion present in cargo loss data, prevents underestimation of uncertainty
Claim Severity - BI & WC	Lognormal distributions	Captures the right-skewed severity behaviour
Claim Severity - CL & EF	Gamma GLMs with a log link	Model strictly positive, right-skewed losses and log link ensures stable relativities and interpretable multiplicative effects from covariates
Solar System Projection Adjustment	Mismatching data. Adjusted differences using solar-system relativities derived from the Online Encyclopedia	Bayesia receives a higher coefficient due to advanced orbital infrastructure, while Oryn Delta reflects higher operational risk from developing infrastructure
Economic Trend	Extracted from the provided CSV file	Ensures consistent valuation of long-term losses over the 10-year projection horizon
Exposure Growth	Follows linear annual increments as specified in the case study: 25% total growth over 10 years for Helionis Cluster and Bayesia System, 15% growth for Oryn Delta	Follows the operational expansion plans described in the case study
Frequency-Severity Independence	Claim frequency and severity are assumed to be independent.	Simplifies simulation modelling when no strong empirical dependence between claim count and claim size is observed
Operational Mix Stability	Mix of operational exposure within each solar system remains stable within each simulation year	Isolates the effect of frequency, severity and macro-economic drivers on aggregate loss projections

6) Data Limitations

A primary limitation arises from the historical dataset mismatch. Claims data is available for Helionis, Epsilon and Zeta, whereas future operations occur in Helionis, Bayesia and Oryn Delta. This means that a proxy calibration approach is required: While proxy mapping preserves structural similarity, it introduces parameter uncertainty. Sensitivity testing is therefore needed to assess the impact of proxy mis-specification on aggregate loss tails and capital requirements.

<u>Additional limitations include:</u>

- Limited data on extremely correlated solar storm events
- Potential inflation misalignment over long transit windows in Oryn Delta
- Limited granularity in human capital risk variables
- For the frequency data, EF had high levels of data incompleteness, thus median imputation was implemented to allow for better data efficiency, even if variance was reduced

AI Tool Declaration: AI tools were used only for grammar checking, cover page design and condensing the risk assessment section for concision.

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8) Appendix

Section 1). Product Design

Detailed Design and Pricing Rationale
Tier 1: Attritional Risk Layer
The Tier 1 layer's main focus is on managing the high-frequency and low severity claims, characteristic of the Helionis Cluster's high-traffic environment

- Resources & Challenges: The main challenge is the elevated debris density and ~1.13g gravity environment, which actively increase wear-and-tear and occupational hazard rates. However, the system's distinct resource is its accessibility. As physical claims adjustment and rapid medical response are highly viable within this hub, we can utilise traditional indemnity structures.
- Design Features: For Workers' Compensation, the policy provides medical expenses and lost wages for injuries such as machinery entrapment and musculoskeletal strain, with periodic payments strictly indexed to claim_length. Coverage is triggered by proof of occupational injury within specifically rated gravity_level zones. However, because our regression models show a direct correlation between high gravity (~1.13g) and prolonged recovery times, injuries sustained while bypassing mandated safety protocols or operating in zones where the safety_training_index is below a 2.0 threshold are strictly excluded. Further, to proactively manage human capital risk, this policy incorporates dynamic rating: Cosmic Quarry will receive a 15% premium credit for maintaining a stellar safety_training_index of 4.5 to 5.0, while steep premium surcharge of 35% will be applied for sustained operations in extreme gravity_level zones exceeding 1.30g. Similarly, Equipment Failure is structured as a maintenance-linked indemnity policy covering physical damage to assets like Quantum Bores, capped at the asset's depreciated equipment_age value. The actuarial trigger requires the failure to occur within standard engineering tolerances (e.g usage_intensity under 18 hours per day). We strictly exclude failures resulting from neglected maintenance_int schedules, ensuring we do not insure intentional over-utilisation. This line further incentivises operational governance by offering a 12% premium credit for maintenance performed 20% ahead of mandatory maintenance schedules, while applying a punitive 25% premium surcharge to assets consistently operating in the 16-18 hour usage_intensity danger zone.

Tier 2: Catastrophic Risk Layer
Conversely, the Tier 2 product focuses mainly in protecting against the systemic, correlated and total-loss threats found in the Bayesia System and Oryn Delta.

- Resources & Challenges: The most definitive challenge of these systems is severe frontier isolation. In Bayesia, solar storms could cause system-wide communication blackouts, while Oryn Delta suffers from extreme 240 AU distances and 60-month transit times. Traditional post-loss physical damage inspections are logically impossible. Therefore, our product design relies on the systems' primary technological resource: independent long-range telemetry.
- Design Features: Business Interruption utilises a parametric trigger mechanism. The policy provides a fixed daily payout replacing lost net revenue, which is automatically triggered if independent telemetry shows the solar_radiation index exceeding 0.90 for more than four consecutive hours, or if a localised supply_chain_index drops by more than 50%. This deploys instant liquidity without the need for claim adjusters. To incentivise corporate resilience against these systemic threats, the pricing model applies a steep 25% premium credit to stations maintaining a maximum energy_backup_score of 5, while levying a severe 40% premium surcharge on platforms lacking critical power redundancy (scores of 1 or 2). For Oryn Delta, Cargo Loss utilises a transit indexed agreed-value structure to cover total losses from catastrophic collisions. The maximum 680,000K payout is automatically compounded by the 2.5% interplanetary inflation rate over the 60-month transit window, preventing value erosion. This coverage is triggered by a total loss of long-range telemetry, with strict exclusions applied to losses occurring on unauthorised transit routes or those involving pilots whose pilot_experience rating falls below the safety established by the Zeta proxy data. To further align with ESG and safety standards on the frontier, this policy applies a 20% premium credit for utilising pilots possessing "Master-level" pilot_experience (exceeding baseline requirements by 5+ years), alongside a 35% premium surcharge for deploying aging vessels with a vessel_age exceeding 15 years on these perilous transits.

Detailed Reinsurance Rationale:

The strategy is mandated to bridge the 218.82 Billion Đ capital gap between the VaR (197.97 Billion Đ) and the TVaR (218.82 Billion Đ).

1. Catastrophe Excess of Loss (CAT XL): This non-proportional insurance is the cornerstone of our solvency protection, explicitly designed to decapitate the extreme tail risk of the Bayesia System. Because solar storms trigger highly correlated, multi-platform Business Interruption and Equipment Failure claims, our CAT XL treaty is structured to attach precisely at our 109.1 Billion Đ internal retention limit, providing cover up to the 218.82 Billion Đ TVar ceiling. This perfectly neutralises the catastrophic spike of a system-wide grid failure.
2. Quota Share (Proportional Reinsurance): To protect the day-to-day liquidity required to fund our internal reserves, we will utilise the Quota Share treaty for our Tier 1 risks. By ceding a fixed percentage (e.g 20%) of all Helionis Workers' Compensation and Equipment Failure premiums and losses to a reinsurer, we stabilise our annual cash flow against unexpected frequency surges in attritional claims.
3. Facultative Reinsurance: As Oryn Delta transits represent a "Severity Frontier" where a single asteroid collision triggers a massive, localised maximum payout of 680,000K, standard treaty limits are insufficient. We will purchase bespoke Facultative Reinsurance

certificates for any Oryn Delta cargo shipment exceeding 500,000K in value. This allows us to surgically transfer the isolated risk of deep-space total losses on a case by case basis, preventing a single severe collision from eroding our primary capital reserves.

Pricing Reasonings

Applying this risk-based framework to our model outputs, the 10-year present value expected loss required to cover all combined attritional claims is 90.21 Billion Đ. We apply a targeted 20% cost of capital charge or risk margin (18.04 Billion Đ) to fund the massive reserves required by the portfolio's extreme variance. This yields a capital-adjusted pure premium of 108.25 Billion Đ. Integrating the required 30% expense ratio (to fund administration and the crucial CAT XL reinsurance purchases) alongside a 5% corporate profit margin sets our targeted permissible loss ratio at 65%. Therefore, should Cosmic Quarry elect to fully underwrite the comprehensive portfolio (Core Package + Cargo Loss), Galaxy General proposes a Combined Total 10-year Target Gross premium of 166.54 Billion Đ (108.25 Billion Đ / 0.65), representing the "all-in" ceiling; should the client elect to purchase only the Core coverage and self-insure the CL module, this premium will decrease substantially as the extreme capital charges are removed.

Coverage Modules

Equipment Failure	L1: Attritional L2: Operational Shock L3: Catastrophic ● Trigger: debris cascade event, solar radiation index	Exclusions (Mosqueda, 2025): ● Wear and tear ● Lack of maintenance ● Known pre-existing defects
Cargo Loss	L1: Transit Loss L2: Transport Event ● Collision, system failure L3: Debris Catastrophe	Exclusion (Roanoke, 2021): ● Improper packaging ● Losses caused by wear and tear ● Deliberate, intentional damage done by policyholder ● Damage occurring due to the natural behavior or characteristics of the goods
Workers' Compensation	L1: Standard Injury L2: Severe Injury L3: Multi-Employee Event ● Radiation surge, site failure	Risk Mitigation: ● Premium discounts for safety upgrades, good return-to-work outcomes ● Psychological / mental-health risk management
Business Interruption	L1: Short-Term Disruption ● < 48 hours? L2: Extended Operational Shock L3: Cross-System Catastrophe ● Communication blackout	Exclusion: ● Planned shutdowns ● Market price fluctuations

Reinsurance Impact on Portfolio Tail Metrics

To assess the effectiveness of the proposed reinsurance strategy, three reinsurance structures were applied to the simulated 10-year present value aggregate cost distribution. Subsequently, their impact on VaR(0.99), TVaR(0.99) were measured.

Catastrophe Excess of Loss: non-proportional aggregate treaty that attaches at the economic capital threshold: Var(0.99) - E[Loss]. This represents the point beyond which losses exceed what the expected premium flow can absorb, and exhausts at the TVaR ceiling. This ensures the reinsurer absorb the alyer between these two tail metrics.

For the second structure, Quota Share proportional reinsurance, transfers a fixed 20% of all Tier 1 losses - WC and EF - to a reinsurer. Since WC and EF represent less that 1% of total portfolio losses, this structure provides negligible tail reduction. This structures serves more as a cash flow stablisiation rather than hedging strategy. Lastly, the third structure applies both treaties simultaneously. Finally, a Risk-Adjusted Return on capital is computed as the ratio of net underwriting profit. This is defined as the present value of gross premiums minimus expected losses - to economic capital.

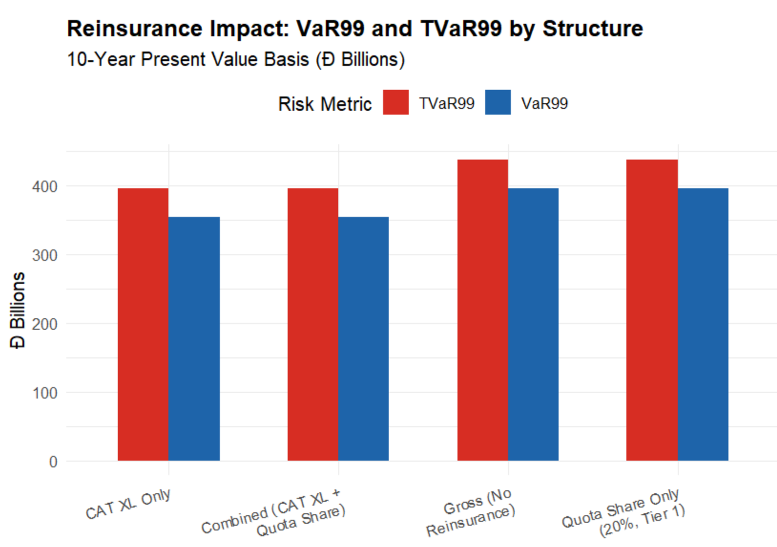


Figure 1: Impact of Reinsurance Structures on Portfolio Tail Risk Metrics.

This figure shows that the CAT XL treaty provides meaningful tail risk reduction, while the Quota Share has minimal effect on portfolio-level metrics. The Quote Share's limited impact is due to the fact that WC and EF together represent less than 1% of the total losses and hence they do not materially affect portfolio-level tail metrics. This is consistent with the intended purpose of stabilising attritional cash flows rather than solvency protection.

Section 2). Modelling detail

The annual aggregate losses were simulated under a mixed framework. Claim counts are generated from a fitted Poisson frequency model; severities generated from fitted lognormal distribution. Using one representative prediction row per solar system, the implied expected annual BI claim counts differ by each solar system. In the aggregate simulations, BI shows statistically meaningful tail risk relative to its mean. The all-system BI distribution has a significantly higher 99th percentile and TVaR than expected loss. This indicates that capital needs are driven by rare but severe disruption years rather than typical attritional risks.

The Cargo Loss section uses a negative binomial frequency model combined with Gamma GLM severity model. The severity model was generated by bootstrapping real historical shipment records. This allows cargo value, weight and cargo type to display variation in a realistic way. When simulating different solar systems, the shipment characteristics were kept realistic but overrode the environment-related risk factors to reflect each system's operating conditions. Result shows that Cargo Loss is the main driver of portfolio risk, especially in extreme years. The P99 and TVaR measurements explode to levels far above the average. Ultimately, Galaxy's capital requirement is determined by rare but massive cargo events, rather than more stable and predictable losses from BI, WC or equipment failure.

The Equipment Failure component was simulated using both Poisson frequency model and Gamma GLM severity model applied across an explicit equipment inventory by system and equipment type. The simulation uses rate per unit x number of units to form system-level expected counts and apply weightings by equipment type. Similar to WC, it contributes to high frequency equipment losses rather than small, extreme catastrophic shocks.

Workers' compensation aggregate losses were simulated using the Poisson frequency model and lognormal severity model. This structure shows that WC is typically high frequency but has lower severity relative to cargo and hence more stable at the portfolio level. By interpreting the outputs, WC exhibits low CV between the mean and upper percentiles. Overall, this component contributes more to the predictable attritional loss rather than extreme tail capital risk.

Section 3). Modelling Results
Aggregate Loss Distributions by Line of Business

Business Interruption:

Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
BI - Helionis	2,402,772	1,701,246	0.708	2,101,110	3,326,853	5,560,227	7,679,934	9,006,965
BI - Bayesia	1,163,519	1,172,543	1.008	882,896	1,715,163	3,464,037	5,197,982	6,019,888
BI - Oryn	757,230	946,387	1.25	478,191	1,162,741	2,602,134	4,070,025	5,129,211
BI - All Systems	4,323,521	2,261,645	0.523	4,047,923	5,689,052	8,438,092	10,872,502	12,172,600

Workers' Compensation:

Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
WC - Helionis	1,450,409	223,673	0.154	1,432,904	1,576,553	1,835,518	2,081,453	2,309,181
WC - Bayesia	671,135	150,405	0.224	653,227	752,230	938,251	1,124,179	1,267,421
WC - Oryn	500,658	129,947	0.26	482,508	570,018	726,593	888,435	1,027,747
WC - All Systems	2,622,202	301,181	0.115	2,597,590	2,800,314	3,143,351	3,438,067	3,685,023

Equipment Failure:

Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
EF - Helionis	43,408,223	2,112,117	0.049	43,391,854	44,816,967	46,922,184	48,386,415	49,229,125
EF - Bayesia	11,845,505	1,120,602	0.095	11,831,991	12,577,323	13,717,801	14,507,592	14,971,156
EF - Oryn	5,422,666	802,575	0.148	5,403,509	5,952,484	6,780,474	7,415,823	7,716,473
EF - All Systems	60,676,394	2,521,259	0.042	60,698,875	62,338,340	64,800,270	66,701,317	67,574,873

Cargo Loss:

Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
Cargo - Helionis	3,353,517,444	4,661,039,263	1.39	1,586,905,908	4,530,180,859	12,590,880,070	22,802,556,986	27,846,493,667
Cargo - Bayesia	2,471,115,914	3,355,284,672	1.358	1,198,340,263	3,311,613,753	9,396,082,215	15,618,694,870	19,344,534,349
Cargo - Oryn	2,396,625,141	3,290,010,656	1.373	1,140,781,283	3,212,579,284	9,210,912,878	15,278,521,345	19,133,169,874
Cargo - All Systems	8,221,258,498	6,600,051,523	0.803	6,511,964,263	11,230,261,901	21,130,648,852	30,821,474,447	36,462,512,431

Short-Term Projections (Year 1 - 2175)

Year 1 Income Statement

Item	Value
Gross Premium	Đ12,723,843,757
Expected Claims	(Đ8,255,650,723)
Expenses (30% of Premium)	(Đ3,817,153,127)
Investment Income (Float)	Đ153,434,967
Expected Net Revenue	**Đ804,474,874**

Metric	Value
Combined Ratio	**94.90%**
Probability of Underwriting Loss (Y1)	**30.20%**

Year 1 Net Revenue Distribution

Metric	Value (Đ)
Mean Net Revenue	804,474,874
Standard Deviation	11,007,391,584
P50 (Median)	4,899,595,391
P25	-2,081,106,824
P05 (1-in-20 Year Loss)	-21,573,835,448
P01 (1-in-100 Year Loss)	-42,707,216,644
TVaR01	-55,452,985,203
Probability of Loss (Pr_Loss)	**30.20%**

Long-Term Projections (Years 1, 5, 10 and 10-Year PV)

Aggregate Costs

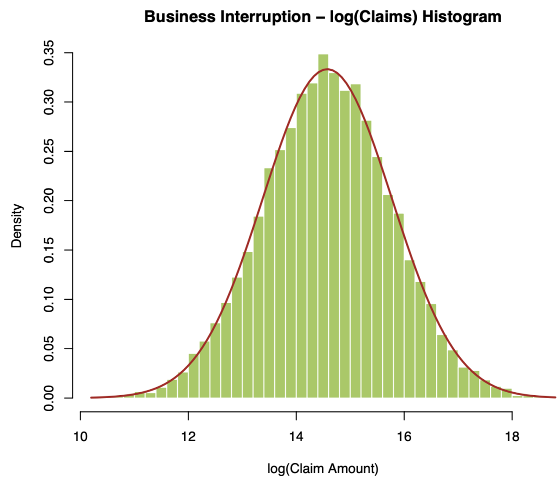
Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
Y1 Costs	8,255,650,723	11,007,391,584	1.333	4,160,530,206	11,141,232,420	30,633,961,044	51,767,342,241	64,513,110,800
Y5 Costs	10,785,727,150	14,638,387,232	1.357	5,118,481,444	14,414,831,274	40,066,620,821	67,191,880,171	85,893,376,276
Y10 Costs	14,470,761,069	19,569,636,145	1.352	7,028,958,338	19,469,830,897	53,484,594,404	92,166,498,368	115,289,539,249
10yr PV Costs	90,210,536,490	38,020,340,360	0.421	85,260,919,914	112,816,618,385	161,861,191,270	197,965,883,632	218,821,479,128

Net Revenue Distribution

Line	Mean	SD	Median	P25	P05	P01	TVaR01	Pr_Loss
Y1 Net Revenue	804,474,874	11,007,391,584	4,899,595,391	-2,081,106,824	-21,573,835,448	-42,707,216,644	-55,452,985,203	30.20%
Y5 Net Revenue	792,347,482	14,638,387,232	6,459,593,188	-2,836,756,642	-28,488,546,189	-55,613,805,539	-74,315,301,644	30.60%
Y10 Net Revenue	1,260,516,821	19,569,636,145	8,702,319,553	-3,738,553,007	-37,753,316,513	-76,435,220,478	-99,558,261,359	30.50%
10yr PV Net Rev	7,466,492,538	38,020,340,360	12,416,109,114	-15,139,589,357	-64,184,162,242	-100,288,854,603	-121,144,450,100	37.50%

Business Interruption (BI)

EDA of BI claims indicates that loss amounts are right-skewed but becomes approximately symmetric when converted into log-scale. The histogram of log-transformed BI severities suggests that a lognormal distribution provides a reasonable representation of the underlying claim severity process. This behaviour is consistent with the operational characteristics of interstellar mining, where most disruption events result in moderate operational delays while a small number of events generate significant losses due to extended shutdown periods of facilities or networks.



Lognormal distribution was selected for modelling BI claim severity due to its ability to capture both the central mass of claims and heavy right tail associated with extreme operational disruption events. This is later adopted in the aggregate loss modelling framework used for product pricing.

Stress test results on extreme scenario:

Parameter multipliers (relative to baseline parameters)

Type of shock	Helionis Cluster	Bayesia System	Oryn Delta
Frequency Shock	1.25	3.5	3
Severity Shock	1.15	2.5	2

Line	Mean	SD	CV	Median	P75	P95	P99	TVaR99
BI - Stressed	18,237,192	6,739,691	0.37	17,553,159	22,369,234	30,393,857	37,093,334	40,480,267
WC - Stressed	10,948,401	883,781	0.081	10,897,729	11,494,667	12,476,425	13,242,026	13,780,630
EF - Stressed	198,741,768	6,576,678	0.033	198,756,066	203,134,764	209,582,935	214,111,255	216,685,142
Cargo - Stressed	40,586,572,752	35,258,238,447	0.869	30,637,612,536	54,777,455,313	111,527,816,467	161,072,615,198	197,244,836,284

Total Portfolio	**40,814,500,113**	**35,258,343,895**	**0.864**	**30,866,847,707**	**54,999,808,505**	**111,757,719,410**	**161,295,046,966**	**197,472,347,627**

Section 4). Risk Assessment
Appendix 4A: Comprehensive Risk Assessment

Risk identification was conducted across all four hazard areas and three solar system within a comprehensive ERM framework, categorising threats into financial, operational and strategic risks.

A. Helionis Cluster: High Traffic Frequency Hub

The Helionis Cluster represents a high-traffic industrial hub where risk is primarily driven by operational density and environmental debris rather than the frontier-style isolation found within Oryn Delta.

- Operational Risks: The system's primary hazard stems from two major asteroid clusters that create localised zones of high_debris density. In this "heavy traffic" environment, human capital risk is severe, making pilot_experience and vessel_age the primary actuarial predictors of Cargo Loss severity. This is due to experienced pilots managing "real-time" hazard avoidance, while vessel_age serves as a proxy for cumulative structural fatigue from repeated micro-impact. In this environment of "heavy traffic," human capital risk is severe, making pilot experience and vessel age the main actuarial predictors of Cargo Loss severity. Experienced pilots are better at managing real-time hazard avoidance, and vessel age acts as a proxy for cumulative structural fatigue resulting from repeated micro-impacts. Such variables are critical as total loss events can reach a maximum severity of ~680,000K per claim.
- Asset maintenance & Process Risk: Data indicates that assets with a usage_intensity exceeding 18 Earth hours experience a 22% higher failure frequency (0.214 claims equipment year), a rate that exceeds those observed in Epsilon and Zeta proxies. A single debris surge can sever transport routes, plummeting the supply_chain_index and creating massive BI losses.
- Occupational hazards WC claims are dominated by machinery entrapment and musculoskeletal strains amplified by the system's elevated mean gravity of ~1.13g, with regression analysis showing that every 0.2g increase in gravity extends the average recovery claim_length by approximately 12%.
- Strategic & Financial Risks: The cluster presents a high concentration risk; up to 85% of BI losses clustering around just two high-density transit routes. This requires a specialised pricing approach accounting for high-frequency attritional losses.

B. Bayesia System: The Radiative Tail Risk

Modeled utilising historical data from the Epsilon proxy, Bayesia presents a risk profile defined by electromagnetic volatility from its binary K-type stair pair.

- Financial Risks (Capital & Insurance): The primary hazard driver is the solar_radiation index, where sharp electromagnetic spikes act as a “system-wide” trigger. Historical data demonstrates much higher claim_amount variance compared to Helionis. During high radiation events (index > 0.8), the average Equipment Failure claim for specialised machinery like Quantum Bores jumps from a baseline of ~15K to over 700K. Capital modeling must utilise heavy-tailed distributions to account for these extreme loss events.
- Operation Risks (Process & Asset Maintenance): Radiation events cause instantaneous “electronic degradation” in sensors. Platforms operating with energy_backup_score of 1 or 2 suffer average downtimes 3.4 times longer than fully redundant stations, resulting in shorter but more frequent system wide BI claims that impact communications infrastructure across multiple platforms simultaneously.
- Strategic Risks (Concentration & Human Capital): Radiation impacts multiple station_id locations simultaneously, significantly reducing the benefits of geographic diversification. The proximity to high radiation zones creates chronic exposure risks, shifting WC injuries toward long-term exposure outcomes.

Oryn Delta: The Severity Frontier

Evaluated via the Zeta proxy, Oryn Delta represents the severity frontier, presenting significantly higher uncertainty due to extreme isolation.

- Financial Risks (Economic & Insurance): The defining characteristics are the combination of extreme distances (up to 240 AU) and transit_duration time of up to 60 Earth months. These variables create extreme economic risk; factoring in a projected annual interplanetary inflation rate of 2.5%, the nominal cost of a claim increases by 13.1% over a 5 year transit window. A collision within the unstable asteroid ring can result in a catastrophic claim reaching ~678,610K, which represents 99.8% of the maximum 680,000K insured limit, leaving virtually zero margin for salvage.
- Operational Risks: EF is driven by high mechanical stress in zones of unpredictable gravitational environments (0.75g to 1.50g). Inconsistent communications across the 240AU expanse can trigger BI stoppages even without physical damage. The impossibility of rapid hazard response significantly extends claim_length recovery periods.
- Sustainability & Competitive: This environmental volatility, coupled with “low-visbility” conditions typical of frontier-style isolation, elevates Workers’ Compensation risks by increasing the statistical likelihood of “Vehicle Accident”. A critical sustainability risk is evident as rapid expansion into these high-hazard zones currently outpaces the implementation of safety protocols; proxy data indicates the safety_training _index for personnel in these expansion zones averages only 2.8 out of 5.

Appendix 4B: Correlated Risk

Fleet-wide technical obsolescence or defeat	Since Cosmic Quarry Mining Corporation utilises standardised machinery types- such as Quantum Bores, FluxStream Carriers and Ion Pulverisers- across all operations, a design flaw or cyber vulnerability in a specific equipment_type would trigger a global spike in Equipment Failure claims. This correlation is particularly dangerous as it ignores solar system boundaries, affecting the Helionis Cluster, Bayesia and Oryn Delta simultaneously.
Frontier recovery stalemate (distance-severity correlation)	In the Oryn Delta, the extreme distance and transit_duration create a correlation between CL and BI. A failure in communication infrastructure doesn't just halt production; it prevents the dispatch of hazard responses, ensuring that a repairable Equipment failure escalates into a total CL due to physical impossibility of timely intervention.

Appendix 4C: Threat Table

Rank	Risk Types	Affected Systems	Critical Variable Trigger	Likelihood	Actuarial Impact & ERM category	Mitigation strategy
1	Interstellar Solar Storm	Bayesia (Primary); All (Secondary)	Solar_radiation (>0.9)	Rare (1 in 100 year event)	Extreme Tail Risk (Financial): Simultaneous multi platform BI and EF claims breaking risk independence	Secure Catastrophe Excess of Loss reinsurance: implement parametric BI triggers for immediate liquidity; mandate max energy_backup_score
2	Deep Space Total Cargo Loss	Oryn Delta	Transit_duration, distance	Low-Mode rate (Cumulative over 60 months)	Catastrophic Severity (Financial): single event maxing out ~680,000K limits; extreme inflation exposure	Purchase bespoke Facultative Reinsurance per shipment; implement asset liability matching; adjust premium dynamically for inflation
3	Asteroid Fragmentation Surge	Helionis Cluster	debris_density	High (Attritional Hub environment)	Contagion Risk (Operational): Drives immediate EF spikes and plummets supply_chain_index	Proportional reinsurance (quota share) for cash flow; enforce strict underwriting limits on vessel_age and pilot_experience

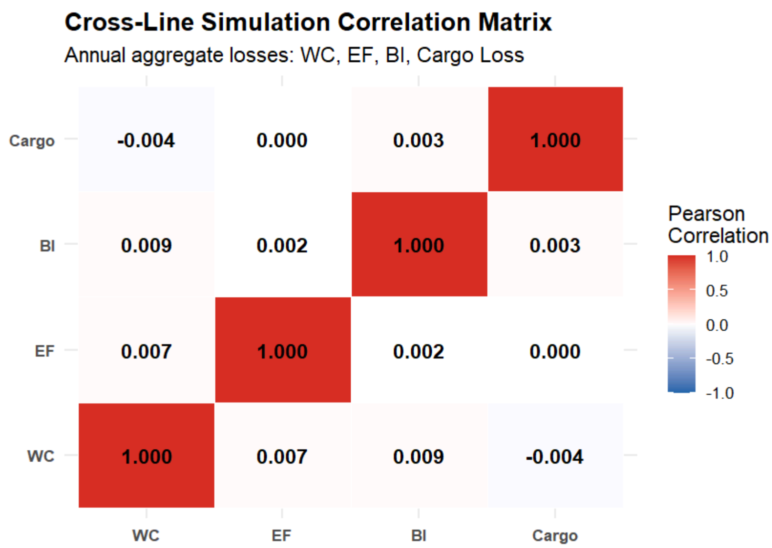
4	Systemic Equipment Defect	All systems	Equipment _age, usage_intensity	Moderate	Concentration Risk (strategic): A flaw in standardized equipment trigger portfolio wide frequency spikes	Mandate strict adherence to maintenance_int schedules; apply premium penalties for usage_inensity exceeding 18 Earth hours/day
5	Chronic Gravitational Exposure	Oryn Delta, Helionis cluster	Gravity_level (>1.13g up to 1.50g)	High (Constant Environmental state)	Human Capital (Operational): Amplifies claim_length for Workers' comp causing long-tail reserving drain	Embed premium credits tied directly to the safety_training_index; require enhanced protective gear for high-gravity operations

Appendix 4D: ESG Table

Environmental (Space Debris Mitigation)	• Energy resilience: Premium credits for high energy_backup_score • Debris mitigation routing discounts: Premium credits will be offered on CL and EF policies if Cosmic Quarry utilises sustainable transport routes that actively avoid or clear zones of high debris_density. This reduces attritional micro-collisions while promoting the sustainable usage of the Helionis industrial hub
Social (Human Capital Protection)	• Workforce Health Incentives: The extreme gravity_level (up to 1.50g) and radiation exposure pose severe chronic health risks. We will implement a dynamic premium discount for WC based on the safety_training_index. If Cosmic Quarry mandates top-tier training and invests in superior protective gear, they receive lower rates, directly incentivising the health and well-being of the interstellar workforce • Additional Protections: Premium incentives for supervision_level improvements, training_gear compliance discounts and active mental health monitoring.
Governance (Operational Resilience)	• Strict Underwriting Exclusions: To prevent intentional negligence (Anthony, 2024), BI coverage will require a mandatory minimum energy_backup_score and EF will mandate strict adherence to maintenance_int schedules. This enforces a culture of proactive corporate governance, ensuring that Cosmic Quarry does not cut safety corners in pursuit of aggressive expansion into the Oryn Delta • Transparency: Policy requires independent annual model validation, AI usage disclosure and clear terms and coverage triggers to avoid dispute risk.

Appendix 4E: Correlation Matrix

This section is conducted to validate the independence assumption.A Pearson correlation matrix was computed across the four business lines. Since each line is simulated independently, correlations near zero are expected and confirm that the model is behaving as expected. Any non-zero correlation would imply co-movement between lines. It is worth noting that near-zero correlations do not mean correlated losses are impossible in reality.



Section 5). Data Assumptions (Detailed Explanation)

- During our exploratory severity analysis of the historical Cargo Loss dataset, we identified severe right-tail anomalies that artificially inflated our preliminary aggregate loss estimates into the trillions. Specifically, we isolated several claims, including three massive outliers exceeding 940 Million Đ, where the recorded claim_amount significantly exceeded the total declared cargo_value of the shipment. Furthermore, these values violated the 678,000K maximum bound established in the provided data dictionary. Because paying out more than 100% of a shipment's value violates the fundamental insurance Principle of Indemnity, we concluded these entries were data corruption errors. To preserve the frequency integrity of the dataset while protecting our severity models from extreme distortion, we programmatically capped all impossible claim amounts at exactly the described cap in the data dictionary.
- For the claim frequencies, Business Interruption, Equipment Failure, and Workers' Compensation were modelled using Poisson GLMs, according to dispersion diagnostics and reflect acceptable dispersion levels. In contrast, Cargo Loss was modelled using a Negative Binomial GLM, due to the high variance-to-mean ratio and to avoid understating the uncertainty of its frequency.

- For claim severities, Business Interruption and Workers' Compensation were modelled using lognormal distributions since these are driven by additive cost components on a multiplicative scale. Cargo Loss and Equipment Failure severities were modelled using Gamma GLMs with a log link in order to fit for the strictly positive, right skewed claim amounts and produce stable relativities.
- Since the training data covers only Helionis Cluster, Epsilon and Zeta, the projections of Bayesia System and Oryn Delta were based on the fitted model parameters, using representative covariate values from the training data, with solar system relativities adjusted to reflect qualitative risk differences described in the Online Encyclopedia. This approach helped incorporate system specific risk adjustments and introduced additional parameter uncertainty. For example, Bayesia's orbital infrastructures were found to be more advanced thus it was given a higher coefficient than the developing Oryn Delta.
- The trends of future claim costs are based on the assumed inflation and interest rates from "srcsc2026interestandinflation.xlsx", with expected losses discounted to present value by using yield curves that were provided.
- Also, the increase in exposure to the different solar systems, are applied as linear annual increments, as explicitly stated in the Case Study description. Projections will increase by 25 percent over 10 years in the Helionis Cluster and Bayesia System and by 15 percent over the same time frame in Oryn Delta.
- Additional assumption: claim frequency and severity are independent. Claim counts are first simulated from the fitted frequency models and claim severities are simulated independently.
- Aggregate loss modelling assumes the operational mix of exposures remains stable within each simulation year.