TEAM – TENSORS

TRACK 1

PREDICTIVE ORBIT COLLISION WARNING SYSTEM

1. OM JADHAV
2. ANUJ JHA
3. AKSHAT BHALANI
4. KAWALJEET SINGH
5. ATHARVA DEO

– DJ SANGVI COLLEGE OF ENGINEERING

THE PROBLEM

Space is Getting Crowded and Dangerous

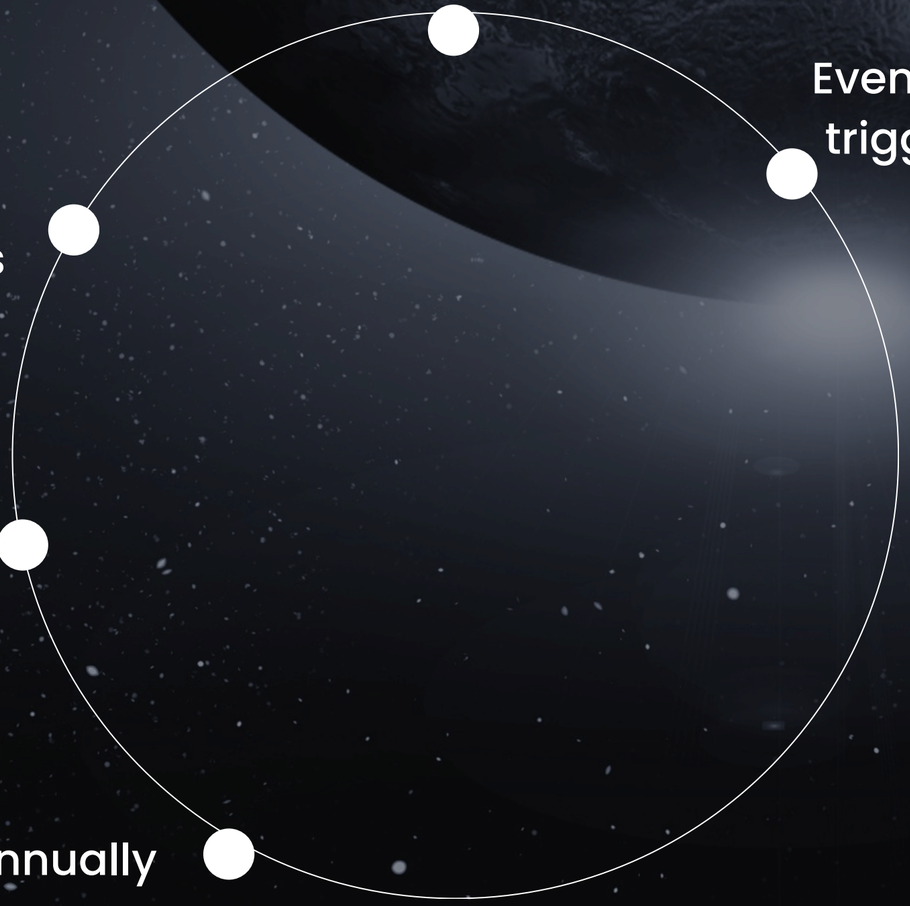
34,000+ debris objects larger than 10cm

Even a small collision may trigger Kessler Syndrome

Avg Collision Velocity = 10km/s

130M debris smaller than 1mm

$1–2 billion lost annually



Existing warning systems provide limited prediction windows and lack ML-powered risk assessment, making collision avoidance reactive rather than proactive.

Collision warnings are often late, uncertain or inaccurate.

Current systems rely on manual monitoring / basic propagation methods.

CHALLENGES & SOLUTIONS

Challenge	Explanation	Solution
Sensor Range vs Response Time	LIDAR range ~100 km gives only ~13 sec response at orbital speeds	Wide-angle detection (500+ km) • Pre-computed maneuvers • Predictive tracking • Emergency fixed ΔV
False Positives → Fuel Waste	Sensor noise or benign objects trigger unnecessary avoidance	Multi-stage filtering • Adaptive fuel-based thresholds • False-positive learning • Fuel-aware cost function
Unknown / Untracked Debris	Majority of debris <10 cm untracked by ground sensors	• Detect all sensor-field objects • Equal risk for unknowns • Debris-density maps for vigilance
TLE/Tracking Data Noise (Ground System)	Public orbital data has drift errors; updates often infrequent	• ML-enhanced SGP4 • AstriaGraph high-frequency data • Ensemble models reduce noise
Real-Time Computation Load	Collision probability must update every orbit cycle	• Vectorized compute • Cloud microservices • Redis caching + real-time WebSockets
Limited Historical Collision Data	Few actual collision events for ML training	• Synthetic data generation • Anomaly detection models • Augment with historical CDM conjunction reports

PROPOSED SOLUTION

An AI-powered early-warning platform that forecasts satellite–debris close approaches 24–72 hours in advance with high reliability.

01.

Intelligent Orbit Prediction Engine

- Real-time ingestion of TLE, orbital data ,optical data
- ML-enhanced trajectory forecasting to correct SGP4 propagation errors
- Continuous re-evaluation as new TLE updates arrive

02.

Advanced Risk Assessment & Alerts

- Collision probability scoring using ensemble ML models
- Color-coded visual warnings (Low/Medium/High risk)
- Automated notifications for high-risk conjunctions

03.

Insightful Monitoring & Analytics Dashboard

- 3D orbit visualization and path projections
- Historical collision pattern analysis for long-term learning
- Trend insights to help optimize avoidance strategies

INNOVATIVE SOLUTIONS/ UNIQUENESS

PREDICTIVE ML ARCHITECTRE

- LSTM NNs for trajectory forecasting
- Random Forest for collision probability classification
- Continuous learning from close approach data

EDGE AI FOR SPACE

- Our decision engine is designed to be computationally lightweight
- Perfect for deployment on resource-constrained satellite hardware
- Real-world "Edge AI" application for space environments
- Minimal power consumption with maximum safety impact

EXTENDED PREDICTION WINDOW

- 24-72 hour forecasts vs. industry standard 6-24 hours
- Uncertainty quantification for debris with limited tracking data
- Gives operators time for multi-stakeholder coordination

RISK PRIORITIZATION ENGINE

- Multi-factor risk scoring (velocity, mass, probability, asset value, data confidence)
- Smart filtering to reduce alert fatigue
- Adaptive thresholds based on tracking data quality

OPEN DATA INTEGRATION

- Hybrid Data Fusion Approach
- Satellites: TLE data (precise, frequent updates)
- Debris: Radar/optical tracking from SSN + ESA databases
- Sensor fusion algorithms to correlate and validate observations
- Kalman filtering for debris trajectory estimation from sparse observations

TECH STACK

Layer	Technologies / Tools	Purpose
Data Sources	*AstriaGraph API, Space-Track.org, Celestrak*	Live / historical satellite & debris tracking data
Programming Languages	*Python, JavaScript (React)*	Backend computation, frontend dashboard
Orbit & Physics Engine	*SGP4, Skyfield*	Accurate orbital propagation & simulation
Machine Learning	*PyTorch, Scikit-learn, XGBoost*	Trajectory prediction, drift correction, risk scoring
Streaming & Pipelines	*Apache Kafka*	Real-time data ingestion & event pipelines
Backend Services	*FastAPI, Redis Pub/Sub*	APIs, real-time alerts, risk computation
Frontend / Visualization	*React, D3.js, Three.js*	Dashboard, 3D orbit visualization, heatmaps
Simulation Framework	*Python + Skyfield + Custom ΔV Engine*	Real-time maneuver simulation environment
Databases	*PostgreSQL, TimescaleDB, Redis Cache*	Time-series storage, fast reads, caching
Infrastructure / DevOps	*AWS/Azure, Docker, Kubernetes, GitHub Actions*	Deployment, scalability, CI/CD automation
Monitoring	*AWS CloudWatch, Grafana (optional)*	System health, performance metrics

ARCHITECTURE

System Architecture

Satellite Collision Avoidance Simulation

- Initial State Setup
- Real-Time Simulation Loop
- Orbit Propagation
- Virtual Onboard Sensor
- Decision Engine
- Autonomous Maneuver Module
- Output Visualization

Data Layer

- AstriaGraph API
- Space-Track.org
- Celestrak Mirrors
- Historical Conjunction Database

Application Layer

- Risk Assessment API
- Bayesian Collision Probability Engine
- Real-Time Alert Engine
- Mission Dashboard

Processing Layer

- Data Ingestion Pipeline
- Preprocessing Engine
- SGP4 Orbit Propagation Module
- Conjunction Screening Engine
- ML Prediction Models

Infrastructure Layer

- Cloud Deployment
- Docker + Kubernetes
- CI/CD Pipeline
- Database Layer

FUNCTIONALITY DEMO

PHASE 1: CONTINUOUS MONITORING (ALWAYS ON)

- Continuously scan 360° with LIDAR & cameras.
- Onboard ML detects and identifies potential debris.
- Maintain a live track file for all targets.

PHASE 2: THREAT DETECTION (TRIGGERED)

- Estimate trajectory of close-approach objects.
- Run simulations to calculate precise collision probability.
- High-risk threats trigger an emergency response.

PHASE 3: AUTONOMOUS AVOIDANCE (RESPONSE)

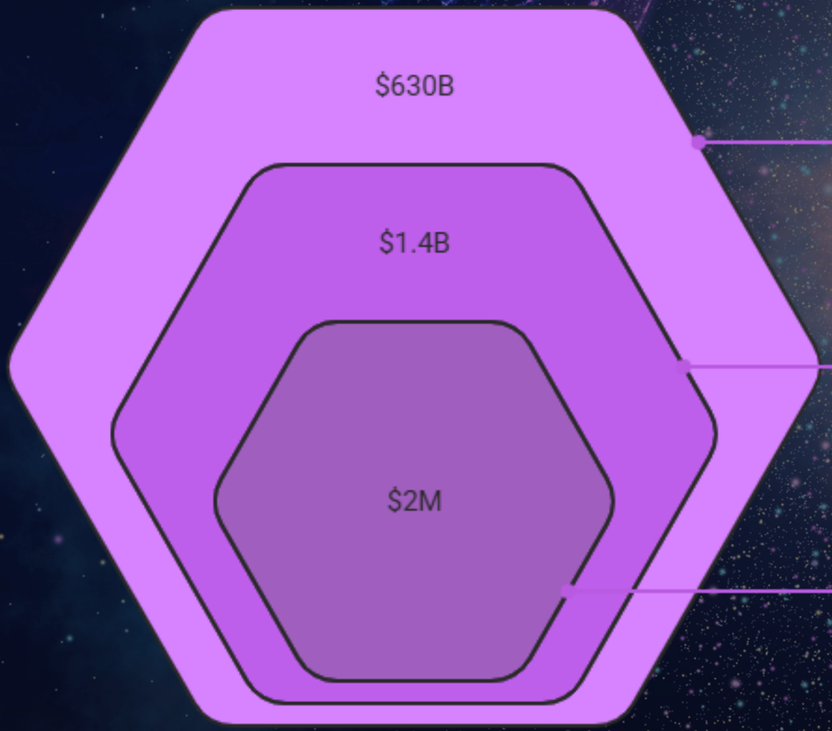
- AI agent computes optimal, fuel-efficient maneuver.
- Run final safety checks (fuel, mission constraints).
- Execute maneuver within 60 seconds of threat confirmation.
- Log all sensor data and decisions to the black box.

PHASE 4: GROUND REPORTING (POST-EVENT)

- Report the threat and maneuver on the next ground pass.
- Ground control validates the autonomous decision (monitoring only).
- Ground can disable the system, but cannot block an emergency dodge.

MARKET OPPORTUNITY & BUSINESS PLAN

Satellite Insurance Market Size and Revenue Projections



Global Space Economy

Total global space economy in 2024

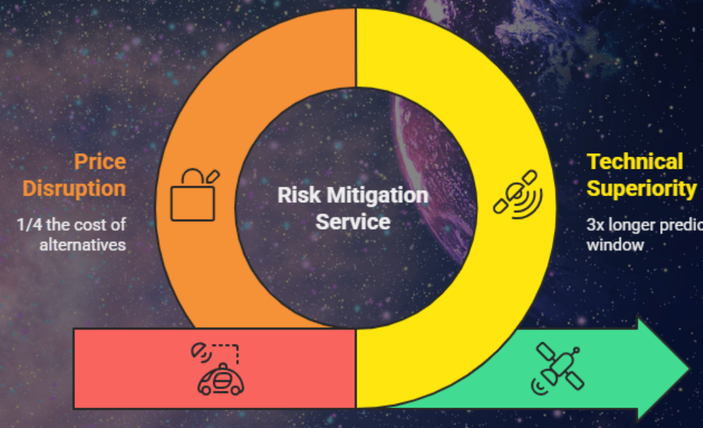
Satellite Insurance Market

Annual satellite insurance market

Annual Recurring Revenue

Projected ARR by Year 3

Cost-Effective Satellite Collision Mitigation



Go-to-Market Strategy

Characteristic	Primary Market	Secondary Market	Emerging Market
Customer Base	1,000+ companies	Government & Defense	Mega-Constellations
Key Focus	Adoption via subscription	Reliability and mission security	Scalability for massive data
Revenue Driver	Tiered subscription model	Enterprise contracts, consultation	Unlimited API access, custom pricing


THANK
YOU