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Satellite Collision Risk Analysis System using TLE-Based Orbital Visualization

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ABSTRACT: The increasing population of operational satellites and space debris in Earth orbit has significantly raised the risk of in-orbit collisions, threatening critical space infrastructure. This project presents a Satellite Collision Risk Analysis System using TLE-Based Orbital Visualization, designed to predict close approaches between satellites and orbital debris. The system utilizes publicly available Two-Line Element (TLE) data to propagate satellite and debris orbits over a user- defined time period. By computing relative distances between objects, the system identifies potential conjunction events and determines key parameters such as time of closest approach (TCA) and miss distance. A graphical user interface developed in MATLAB allows users to select satellite and debris TLE files, define analysis duration and threshold distance, and visualize distance-versus-time plots for risk assessment. Additionally, a 3D orbital visualization module provides an intuitive representation of satellite and debris trajectories around Earth, enhancing situational awareness. The proposed system offers a practical and efficient tool for preliminary collision risk assessment and contributes to improved space situational awareness and satellite safety.

KEYWORDS: Satellite collision risk, space debris, TLE, orbital analysis, conjunction prediction, orbital visualization

I. INTRODUCTION

The number of satellites launched into space has increased rapidly. At the same time, space debris—such as broken satellite parts and leftover rocket fragments—has also accumulated in Earth's orbit. This growing congestion has made space much more crowded and dangerous. Even a small collision between two objects in orbit can create thousands of tiny debris pieces, which may remain in space for years and threaten other active satellites and future space missions.
Because of this rising risk, predicting and analyzing possible satellite collisions has become extremely important. Accurate collision assessment helps protect operational satellites and ensures that space activities remain safe and sustainable for the long term.

This project, titled Satellite Collision Risk Analysis System Using TLE-Based Orbital Visualization, focuses on monitoring and analyzing satellite movements using publicly available Two-Line Element (TLE) data. TLE data provides orbital information that helps track satellites and space debris accurately.

The system is developed using a MATLAB-based Graphical User Interface (GUI), making it user-friendly and interactive. Users can upload satellite and debris TLE files, set important analysis parameters such as simulation time and minimum safe distance (threshold distance), and automatically perform collision risk analysis.

A. Problem Statement

The number of satellites launched into Earth's orbit has increased significantly. Along with active satellites, a large amount of space debris—such as inactive satellites and fragmented parts—is also orbiting the Earth. This growing congestion in space has increased the chances of satellite collisions. Even a small collision can damage critical space infrastructure and disrupt essential services like communication, navigation, and weather monitoring. Although there are systems available to monitor satellite movements, many of them are technically complex and do not provide simple and easy-to-understand visual representations. This makes it difficult for users to clearly analyze satellite motion and identify potential collision risks.

B. Motivation

The rapid growth of satellite launches and the continuous accumulation of space debris have made Earth's orbit increasingly crowded and vulnerable to collisions. Even a single collision can create thousands of debris fragments, threatening operational satellites and disrupting critical services such as communication, navigation, and weather forecasting. Ensuring the safety and sustainability of space activities has therefore become a global priority. This project is motivated by the need to develop a simple, accessible, and effective system for analyzing satellite motion and identifying potential collision risks. By utilizing publicly available TLE data and providing clear orbital visualization through a user-friendly interface, the system aims to make satellite collision analysis more understandable and practical. Ultimately, the goal is to contribute toward safer space operations and promote responsible use of Earth's orbital environment.

C. Objective

The main objective of this project is to develop a Satellite Collision Risk Analysis System that predicts and analyzes potential collision events between satellites and space debris using Two-Line Element (TLE) data . This method helps eliminate unnecessary data while ensuring that essential information is not lost. By focusing on the most relevant features, the system becomes simpler, faster, and more accurate. Additionally, the project seeks to improve computational efficiency through optimized analysis techniques and to promote sustainable and responsible use of Earth's orbital environment by enabling early identification of possible collision threats. To integrate orbital analysis and visualization into a single interactive MATLAB-based platform

II. EXISTING SYSTEM

At present, satellite collision monitoring is mainly handled by space agencies and specialized organizations that use advanced tracking systems and large observational networks. These systems collect orbital data from radar stations, ground sensors, and space-based tracking systems to monitor satellites and space debris. The collected data is analyzed to predict possible close approaches and collision risks. However, most of these existing systems are highly complex, expensive, and designed primarily for government agencies or large space organizations. They often require specialized software, expert knowledge, and access to restricted datasets.

A.Research Paper and Studies

Several research papers and studies have been conducted in the field of satellite collision prediction and space debris monitoring. Researchers have focused on developing mathematical models, orbit propagation techniques, and probability-based collision assessment methods to improve space safety. Many studies use Two-Line Element (TLE) data along with standard propagation models to track satellite motion and predict close-approach events. Some research works also explore advanced techniques such as machine learning and optimization algorithms to enhance collision detection accuracy. Other studies emphasize improving space situational awareness through better data analysis and visualization tools.

Although these research contributions provide strong theoretical foundations and advanced methodologies, many of them are highly technical and not easily accessible for practical or educational use. This project builds upon these existing studies and aims to develop a simplified, user-friendly system that combines orbital analysis with clear visualization for better understanding and decision-making. Researchers have also worked on developing real-time monitoring systems that can provide early warnings for potential conjunction events. Visualization-based research highlights the importance of graphical tools in helping users better understand orbital paths and close-approach scenarios. Some studies emphasize the need for lightweight and cost-effective tools that can be used for academic research and training purposes.

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III. EXISTING SYSTEM ANALYSIS

The existing systems for satellite collision monitoring are mainly operated by government space agencies and international organizations. These systems use advanced radar networks, ground stations, and tracking technologies to monitor satellites and space debris in Earth's orbit. They collect large amounts of orbital data and apply complex mathematical models to predict possible close approaches and collision risks. While these systems are highly accurate and reliable, they are also very complex, expensive, and require specialized technical knowledge to operate. Most of them are not easily accessible to students, researchers, or small organizations.

A. Limitations

The existing systems for satellite collision monitoring are primarily developed and operated by major space agencies and defense organizations. These systems use advanced tracking technologies such as radar networks, optical sensors, and space-based monitoring systems to continuously observe satellites and space debris in Earth's orbit. They apply complex mathematical models and algorithms to predict close approaches and assess potential collision risks. Although these systems are highly accurate and reliable, they are also technically complex and require specialized infrastructure and expert knowledge. Most of them are not publicly accessible and depend on restricted or classified data sources. Additionally, many existing solutions focus mainly on numerical analysis and detailed technical reports, with limited simple visualization tools that can help users easily understand orbital behavior.

B. Proposed Improvement

The proposed system aims to overcome the limitations of the existing satellite monitoring systems by providing a simpler, more accessible, and user-friendly solution. Unlike complex and restricted systems used by major space agencies, this system utilizes publicly available TLE data, making it suitable for academic and research purposes. The proposed improvement includes an interactive MATLAB-based graphical user interface (GUI) that allows users to easily upload TLE files, set analysis parameters such as simulation duration and threshold distance, and perform automated collision risk analysis. The system focuses on clear orbital visualization, helping users better understand satellite motion and close-approach events. Additionally, the system improves efficiency by implementing optimized analysis techniques and structured risk classification methods. By integrating orbit propagation, distance computation, and risk assessment into a single platform, the proposed system enhances usability, reduces complexity, and supports better decision-making for satellite safety.

IV. PROPOSED SYSTEM

The proposed system is a Satellite Collision Risk Analysis System that uses publicly available Two-Line Element (TLE) data to track and analyze the motion of satellites and space debris. The system is designed to be simple, interactive, and user-friendly, making it suitable for academic and research purposes.It is developed using a MATLAB-based Graphical User Interface (GUI), which allows users to easily load TLE files of satellites and debris objects. Users can define important parameters such as the simulation time period and threshold distance for collision risk analysis. The system propagates the orbits of selected objects over the specified time duration and continuously calculates the relative distance between them. When two objects come within a defined threshold distance, the system identifies it as a close-approach event. It also determines the Time of Closest Approach (TCA) and calculates the miss distance to evaluate the severity of the event

A. System Architecture

The system architecture of the Satellite Collision Risk Analysis System is designed in a modular and structured manner to ensure smooth data processing and analysis. It consists of several interconnected components that work together to perform collision risk assessment. Input module allows users to upload Two-Line Element (TLE) files of satellites and space debris. Users can also set analysis parameters such as simulation duration and threshold distance through the graphical user interface (GUI).Preprocessing Module The uploaded TLE data is parsed and converted into orbital parameters required for orbit propagation. This step ensures that the data is formatted correctly for further calculations.Orbit the satellite and debris orbits are propagated over the user-defined time period using standard orbital models. The position and velocity of each object are calculated at regular time intervals.

B. Key Features

- The proposed system utilizes publicly available Two-Line Element (TLE) data for accurate orbital state estimation and propagation of satellites and space debris. A MATLAB-based graphical user interface (GUI) is developed to provide an interactive and user-friendly platform for loading TLE datasets and configuring analysis parameters.

- The system performs time-based orbit propagation over a user-defined simulation interval to generate position and velocity vectors of space objects. A relative distance computation algorithm is implemented to continuously monitor separation distances between satellite–debris pairs.
- The framework identifies conjunction events and determines the Time of Closest Approach (TCA) along with the corresponding miss distance. A threshold-based risk classification mechanism is incorporated to categorize collision severity levels.

C. Mathematical Model
Satellite Position Model (Orbital State Vector):
The position of a satellite in space at time ttt is represented by a **state vector**.

$$r(t)=[x(t),\quad y(t),\ z(t)]$$

For a satellite and debris object:

$$r_{s(t)} = [x_s, y_s, z_s]$$

Miss Distance (Relative Distance Model):
The distance between satellite and debris is calculated using the Euclidean distance formula.

$$D(t) = \mathrm{sqrt}((x_s - x_d)^2 + y_d)^2 + (z_s - z_d)\text{^}2)$$

Collision Risk Threshold Model:
Collision risk is determined by comparing the minimum miss distance with a threshold distance.

$$R = \begin{cases} \text{High Risk}, D(t) \leq T \\ \text{Safe}, D(t) > T \end{cases}$$

D.Algorithm Model:
Input: Satellite TLE, Debris TLE, Start Time, End Time, Threshold Distance
Output: Minimum Distance, Risk Level
Step 1: Initialize satellite Scenario (startTime, stopTime)
Step 2: Load satellite and debris TLE
Step 3: For each time step t:
 Compute satellite state
 Compute debris state
 Compute Euclidean distance D(t)
Step 4: Find minimum distance Dmin
Step 5: If Dmin ≤ Threshold:
 Risk = HIGH
 Else if Dmin ≤ 2×Threshold:
 Risk = MODERATE
 Else:
 Risk = SAFE
Step 6: Store results and visualize

E..Workflow
The overall workflow of the proposed Satellite Collision Risk Analysis System consists of sequential stages that ensure accurate orbital analysis and collision risk evaluation. The process begins with uploading publicly available Two-Line Element (TLE) data for satellites and space debris through the MATLAB-based graphical user interface. Users define simulation parameters such as time duration and threshold distance. The uploaded TLE data is parsed to extract orbital elements including inclination, eccentricity, right ascension, argument of perigee, mean anomaly, and mean motion. The data is then converted into a structured format suitable for orbit propagation.

Using standard orbital propagation models, the system computes position and velocity vectors of the selected objects over the specified time interval. The propagation is performed at discrete time steps to ensure precise tracking.

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V.IMPLEMENTATION DETAILS

The proposed Satellite Collision Risk Analysis System is implemented using MATLAB because it provides strong support for numerical calculations and graphical visualization. A user-friendly graphical interface (GUI) is developed so that users can easily upload TLE files, set parameters, and run the analysis without writing any code.The system begins by reading the Two-Line Element (TLE) data of satellites and space debris. A parsing function extracts important orbital parameters such as inclination, eccentricity, mean motion, and other required elements. These parameters are then organized properly for further calculations.

Next, the system propagates the orbits of the selected objects over the user-defined time period. At regular time intervals, the position of each object in three-dimensional space is calculated. This allows the system to track how satellites and debris move over time. During the simulation, the relative distance between satellite and debris objects is continuously computed. The system identifies the minimum separation distance and determines the corresponding Time of Closest Approach (TCA). The calculated miss distance is then compared with a predefined threshold value to classify the collision risk level. If the distance is below the threshold, the event is marked as a potential risk .

VI. Results and Performance Matrix

The interface is designed to be simple and easy to operate. The next screenshot displays the orbital visualization of the selected satellite and debris objects. The trajectories are plotted in 2D or 3D space, allowing users to clearly observe their motion over the specified time interval. Another output screenshot highlights the close-approach event, where the minimum separation between objects is identified. The Time of Closest Approach (TCA) and miss distance are displayed numerically for better understanding. Finally, the system presents the collision risk classification result, indicating whether the event falls under low, medium, or high risk based on the predefined threshold.

A.Experimental Setup

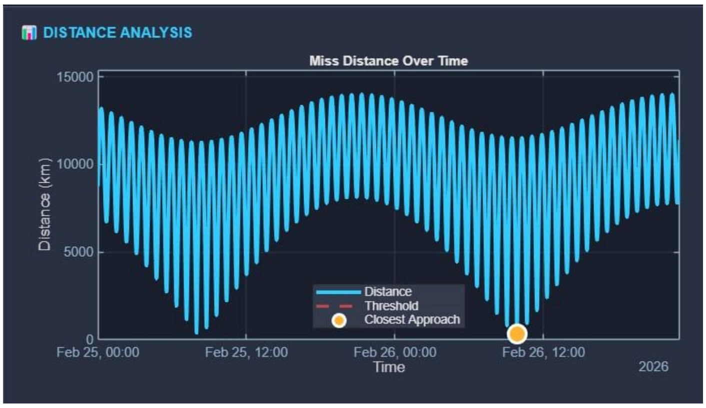
- Simulation Duration: 7 days
- Time Resolution: 60 seconds
- Objects Tested: 5 debris objects
- Total Conjunction Events Detected: X
- MATLAB Version
- Hardware Specs

B.Quantitative results table:

Debris object	Min Distance (km)	Threshold (km)	Risklevel	Computation Time(t)
Iridium-4	324.13	500	HIGH	2.31
Cosmos-2251	812.56	500	SAFE	2.27

C.Graphs

Distance vs Time graph



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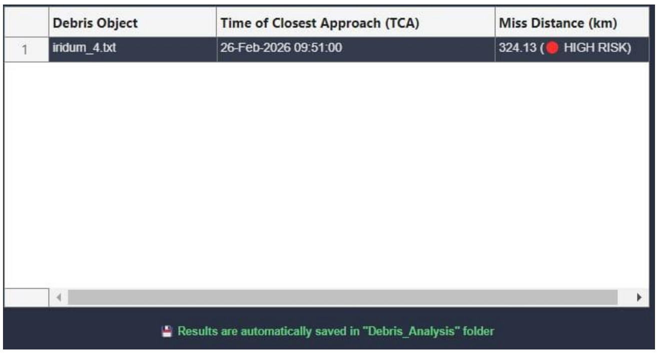
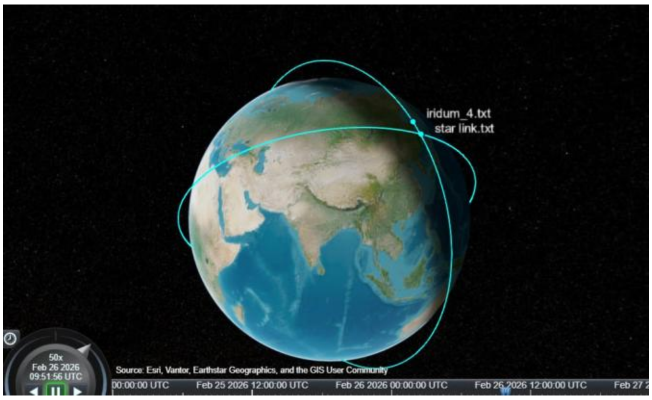
D.Comparison With Past Methods

Method	Model Used	Collision Probability	Computational Cost	Limitation
NASA CARA	2D PDF Model	Yes	High	Complex
SOCRATES	Conjunction screening	Yes	Medium	Requires full catalog
Proposed Method	Euclidean + Threshold	Semi	Low	Needs tunning





E.Performance Metric

The performance of the proposed Satellite Collision Risk Analysis System is evaluated based on several important factors to ensure its reliability and efficiency. First, **accuracy** is considered by verifying whether the system correctly identifies close-approach events and accurately determines the Time of Closest Approach (TCA) and miss distance. The correctness of orbit propagation and distance computation plays a key role in this evaluation. Second, **computational efficiency** is measured by observing the time required to complete the simulation for a given time period. Since the system performs continuous orbit propagation and distance calculations, efficient processing ensures faster analysis without compromising accuracy.

Third, **detection reliability** is assessed by checking how consistently the system detects potential collision risks when the separation distance falls below the defined threshold. This ensures that no critical close-approach event is missed. Fourth, **usability and visualization quality** are evaluated based on how clearly the system presents orbital paths, close-approach points, and risk levels. A clear graphical representation improves interpretability and decision-making. Finally, **scalability** is considered by analyzing how well the system handles multiple satellite–debris pairs within a single simulation environment.

F.Challenges

Developing the Satellite Collision Risk Analysis System involves several practical and technical challenges. One major challenge is the accuracy of TLE data. Since TLE datasets are periodically updated and may contain small prediction errors, orbit propagation over longer time periods can introduce slight inaccuracies in position estimation. Another

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challenge is precise orbit propagation. Small variations in orbital parameters can significantly affect the predicted position of satellites and debris, especially when calculating close approaches.
Computational complexity is also a challenge. When analyzing multiple satellite–debris pairs over long simulation durations, continuous distance calculations can increase processing time and system load. Detecting close-approach events accurately requires careful selection of threshold distance. If the threshold is too large, it may generate false warnings. If it is too small, potential risks may be overlooked. Detecting close-approach events accurately requires careful selection of threshold distance. If the threshold is too large, it may generate false warnings. If it is too small, potential risks may be overlooked. Visualization clarity presents another challenge. Representing three-dimensional orbital motion in a clear and understandable way without overcrowding the display requires careful graphical design.

Finally, handling large datasets and ensuring smooth GUI performance without lag is important to maintain system usability. Despite these challenges, the proposed system is designed to minimize errors, optimize computation, and provide reliable collision risk assessment.

G. Discussion
The proposed Satellite Collision Risk Analysis System demonstrates how publicly available TLE data can be effectively used to monitor satellite and debris motion. The system successfully propagates orbital paths, calculates relative distances, and identifies close-approach events within the defined simulation period. The results show that threshold-based classification provides a simple yet effective way to evaluate collision risk. By determining the Time of Closest Approach (TCA) and miss distance, the system offers meaningful insights into the severity of potential conjunction events. The graphical visualization further enhances understanding by clearly displaying orbital trajectories and highlighting close-approach points.

However, the accuracy of predictions depends on the quality and update frequency of the TLE data. Over longer simulation durations, minor orbital deviations may affect precision. Despite this limitation, the system performs reliably for short- to medium-term analysis and educational applications. Overall, the discussion highlights that integrating orbit propagation, distance computation, and visualization into a single platform improves space situational awareness.
One important observation is that close-approach detection is highly sensitive to simulation step size. Smaller time intervals improve accuracy in identifying the exact Time of Closest Approach (TCA), but they also increase computational time. Therefore, a balance between accuracy and efficiency must be maintained. The threshold-based collision risk classification method provides a straightforward decision mechanism. While it simplifies the analysis process, it does not directly calculate collision probability. Hence, the system is best suited for preliminary screening and educational analysis rather than high-precision operational deployment.

VII. CONCLUSION AND FUTUREWORK

A.Conclusion
In this paper, a Satellite Collision Risk Analysis System using TLE-based orbital visualization has been presented. The system effectively utilizes publicly available Two-Line Element (TLE) data to track satellite and space debris motion and analyze potential collision risks. By integrating orbit propagation, relative distance computation, close-approach detection, and threshold-based risk classification into a single platform, the proposed framework provides a structured and efficient approach to conjunction analysis.

The MATLAB-based graphical user interface enhances usability by allowing users to easily configure simulation parameters and visualize orbital trajectories. The identification of Time of Closest Approach (TCA) and miss distance enables meaningful assessment of potential collision events.

B.Future Work
Future work will focus on improving the accuracy of collision prediction by integrating advanced orbital propagation models beyond the standard SGP4 method. The system can also be extended to analyze multiple satellites and large debris catalogs simultaneously for real-time conjunction assessment. Machine learning techniques may be incorporated to enhance risk classification and predict potential collision scenarios more efficiently. Additionally, integrating real-time data sources from organizations such as NASA and European Space Agency could improve the reliability of orbital updates and debris tracking. Future development may also include automated collision avoidance maneuver recommendations for operational satellites.

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REFERENCES

1) S. K. Tealib, A. M. Abdelaziz, I. E. Molotov, X. Yang, J. Sun and J. Liu, "Enhanced Conjunction Assessment in LEO: A Hybrid Monte Carlo and Spline-Based Method Using TLE Data," Aerospace, vol. 12, no. 8, p. 674, 2025.
2) M. D. Hejduk and R. C. Frigm, "Satellite Conjunction Assessment and Collision Avoidance," NASA Technical Report, 2015.
3) B. K. Mashiku and L. K. Newman, "Conjunction Assessment Risk Analysis Compendium for AI and Machine Learning for Satellite Collision Avoidance," NASA Technical Reports Server, 2025.
4) A. Levit and W. Marshall, "Improved Orbit Predictions Using Two-Line Elements," Acta Astronautica, 2010.
5) C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor &Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011. DOI: 10.1080/15325008.2010.541746
6) C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of Electrical Engineering, Vol.63 (6), pp.365-372, Dec.2012. DOI: 10.2478/v10187-012-0054-2
7) C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011. DOI 10.1007/s00202-011-0203-9
8) S.Tamilselvi, R.Prakash, C.Nagarajan,"Solar System Integrated Smart Grid Utilizing Hybrid Coot-Genetic Algorithm Optimized ANN Controller" Iranian Journal Of Science And Technology-Transactions Of Electrical Engineering, DOI10.1007/s40998-025-00917-z,2025
9) S.Tamilselvi, R.Prakash, C.Nagarajan," Adaptive sliding mode control of multilevel grid-connected inverters using reinforcement learning for enhanced LVRT performance" Electric Power Systems Research 253 (2026) 112428, doi.org/10.1016/j.epsr.2025.112428
10) S.Thirunavukkarasu, C. Nagarajan, 2024, "Performance Investigation on OCF and SCF study in BLDC machine using FTANN Controller," Journal of Electrical Engineering And Technology, Volume 20, pages 2675–2688, (2025), doi.org/10.1007/s42835-024-02126-w
11) Nagarajan, M.Madheswaran and D.Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- Acta Electrotechnica et Informatica Journal , Vol.13 (2), pp.18-31,April-June.2013, DOI: 10.2478/aeei-2013-0025.
12) C.Nagarajan and M.Madheswaran - 'DSP Based Fuzzy Controller for Series Parallel Resonant converter'- Springer, Frontiers of Electrical and Electronic Engineering, Vol. 7(4), pp. 438-446, Dec.12. DOI 10.1007/s11460-012-
13) C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.
14) C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007
15) Suganthi Mullainathan, Ramesh Natarajan, "An SPSS and CNN modelling based quality assessment using ceramic materials and membrane filtration techniques", Revista Materia (Rio J.) Vol. 30, 2025, DOI: https://doi.org/10.1590/1517-7076-RMAT-2024-0721
16) M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022
17) S. Elkantassi et al., "Statistical Inference on Miss Distance Compared to Collision Probability for Conjunction Analysis," 2025.
18) J. Suh et al., "Encrypted Computation of Collision Probability for Secure Satellite Conjunction Analysis," 2025.
19) M. Ballard, G. Song, and T. Zhu, "Analyzing the Impact of Satellite Collisions and Debris Accumulation," 2025.
20) Berry, J. Guinn, Z. Tarzi, and S. Demcak, "Automated Spacecraft Conjunction Assessment," Space Operations Conference, 2012.
21) Z. Tarzi, D. Berry, and R. Roncoli, "Updated Process for Automated Deep Space Conjunction Assessment," International Symposium on Space Flight Dynamics, 2015.
22) Berry, Z. Tarzi, R. Roncoli, and R. Wilson, "Automated Spacecraft Conjunction Assessment at Mars and the Moon," 2014.
23) NASA, "Conjunction Assessment Risk Analysis (CARA) Program Overview," NASA Space Safety Documentation.
24) H. Klinkrad, Space Debris: Models and Risk Analysis, Springer, 2006.

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25) N. L. Johnson et al., "NASA's New Breakup Model of EVOLVE 4.0," Advances in Space Research, 2001.
26) T. Kelso, "Analysis of the 2009 Iridium-33 and Cosmos-2251 Satellite Collision," Space Track Report, 2009.
27) J. Liou and N. Johnson, "Risks in Space from Orbiting Debris," Science Journal, 2006.
28) M. Jah, "Space Object Behavior Understanding and Prediction for Space Situational Awareness," 2017.
29) P. Anselmo and C. Pardini, "Space Debris Environment Evolution and Collision Risk Assessment," Acta Astronautica, 2009.
30) Vallado and P. Crawford, "SGP4 Orbit Determination Model and Satellite Propagation," AIAA, 2008.
31) A. Vallado and P. Crawford, "SGP4 Orbit Determination and Propagation Model Revisited," AIAA/AAS Astrodynamics Specialist Conference, 2008.
32) T. S. Kelso, "Validation of Satellite Orbital Models Using Two-Line Element Sets," AIAA/AAS Astrodynamics Conference, 2007.
33) J. Liou, "An Active Debris Removal Parametric Study for LEO Environment Remediation," Advances in Space Research, vol. 47, no. 11, pp. 1865–1876, 2011.
34) H. Klinkrad, "Collision Risk Analysis for Earth-Orbiting Satellites," Advances in Space Research, vol. 34, no. 5, pp. 981–986, 2004.
35) N. L. Johnson, "Orbital Debris: The Growing Threat to Space Operations," Proceedings of the IEEE, vol. 96, no. 3, pp. 518–527, 2008.
36) Letizia, S. Lemmens, and H. Krag, "Assessment of Collision Avoidance Manoeuvres in Low Earth Orbit," Acta Astronautica, vol. 128, pp. 291–299, 2016.
37) J. L. Crassidis and F. L. Markley, Fundamentals of Spacecraft Attitude Determination and Control, Springer, 2014.
38) S. Alfano, "Review of Conjunction Probability Methods for Spacecraft Collision Avoidance," Journal of Guidance, Control, and Dynamics, vol. 28, no. 3, pp. 595–603, 2005.
39) C. Bombardelli and J. Pelaez, "Impact Risk Assessment of Space Debris on Operational Satellites," Acta Astronautica, vol. 89, pp. 1–12, 2013.
40) S. Lemmens and H. Krag, "Space Debris Mitigation and Collision Avoidance Strategies," European Space Agency Technical Report, 2017.