RESEARCH SUMMARY

Artificial Intelligence and Machine Learning for Space Domain Awareness

Characterizing the Impact on Mission Effectiveness

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ISSUE

To address the growing demands of operating in the space domain, space domain awareness (SDA) operators must determine how to prioritize sensor observations more effectively, scale up to meet the sheer volume of resident space objects, and develop analytic capabilities that reflect the complexity of orbital mechanics and space operations, all while maintaining the responsiveness necessitated by operations in a warfighting domain. These factors present significant challenges to those tasked with the SDA mission and point to this mission as a prime candidate for support from artificial intelligence (AI) and machine learning (ML) tools, because such tools have the potential to increase the analysis tempo, expand the amount of usable data for this analysis, and free up operator time for more-complex tasks. AI/ML tools can help SDA operators meet these increasing challenges. For example, leveraging AI/ML to optimize sensor scheduling could improve the accuracy of the space catalog by allowing more-efficient use of existing sensing resources. AI/ML tools can also facilitate the calculation of close proximity risks and provide indications and warning by flagging abnormal events.

Although AI/ML tools have the potential to help meet these SDA challenges, the impact of these tools on the overall success of the SDA mission is not well understood, and this lack of understanding is a barrier to planning and optimizing the integration of the tools. This research seeks to develop insight into these research questions:

- How can existing AI/ML and automation technologies benefit the SDA mission?
- Which processes within the SDA mission area can be improved by increased automation and AI/ML?
- What are the prerequisites and enabling technologies that are necessary for AI/ML implementation?
- What limitations should be considered when employing these technologies?

APPROACH

Our approach for this research focused on characterizing the nature of the impact that AI/ML tools could bring to the SDA mission. To accomplish this, we examined the processes that make up this mission, the metrics for these processes, the opportunities for impact, and the impact of these tools on the process and the outcomes. The research presented here focuses in detail on the conjunction assessment (CA) mission to enable us to look

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at a singular SDA process in depth. CA is the probabilistic process by which the 18th and 19th Space Defense Squadrons (SDSs) quantify the risk of collision in space.

To support this assessment, we interviewed stakeholders, reviewed existing academic and doctrinal literature, developed detailed process maps, and built exploratory AI/ML models.

KEY FINDINGS

- Because of the growing demands and changing nature of the SDA mission, AI/ML tools have a high opportunity for impact if they can be force multipliers for SDA operators.
- AI/ML tools cannot address all the challenges of the SDA mission, but process changes can help these tools achieve greater impact.
- Realizing significant impacts from AI/ML requires moving to an architecture that enables more AI/ML development and fielding.
- AI/ML tool development that supports more-optimized sensor tasking could have a cascading impact on the rest of the SDA mission.
- Better quantification of risk and uncertainty tolerance can support the improved performance of AI/ML tools focused on prediction and classification.

RECOMMENDATIONS

- Space Systems Command SDA Acquisition Delta (SSC/SZG) and the Air Force Research Laboratory should provide clear guidance to AI/ML tool developers to focus on tools that address the needs of operators today but could also benefit a future SDA architecture.
- AI/ML tool development should focus on force multipliers that help meet the growing detection and characterization challenges faced by the 18th and 19th SDSs. SSC/SZG should look for opportunities to invest in these tools.
- SDA operators—in particular, at the 18th SDS, 19th SDS, and National Space Defense Center—should seek ways to articulate mission needs, sensor requirements, and acceptable uncertainty to optimize potential enhancements from AI/ML tools.
- Space Operations Command, via the SDA Mission Area Team, should examine where SDA processes could be modified to enable more-significant impact from AI/ML tools.
- AI/ML tool development should focus on those tools that enable more-effective and more-efficient sensor tasking, and SSC/SZG should seek ways to acquire and develop those tools. Efforts at the 18th SDS to capture observation intent should also be supported, as these efforts, in combination, are key enablers.
- SSC/SZG should continue to support efforts in AI/ML tool development and ensure that there are processes and infrastructure in place to test and validate these models.
- The availability of high-quality training data is another enabler for AI/ML impact, and USSF should support efforts at Space Systems Command in its Cross Mission Data team to ensure the availability of these data to AI/ML tool developers.

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