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Developing Artificial Intelligence for Noncooperative Space Operations Using Kerbal Space Program

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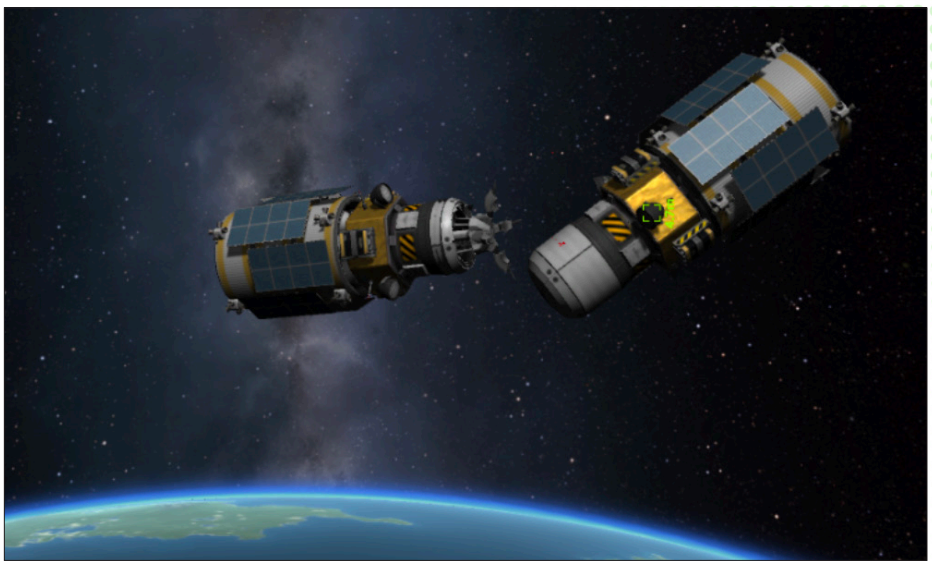
With nearly 9,000 active and inactive satellites in orbit, space has become more crowded and competitive than ever before. Solving nascent problems in this domain—such as avoiding collision with debris or servicing malfunctioning satellites—requires more than just knowledge of orbital mechanics and spacecraft control. With so many different factors at play in the orbital domain, problems here are best modeled as serious games. When it comes to the field of game theory (the study of strategic interactions between multiple decision makers, each with their own objectives), some of the most promising solutions relay on modern-day artificial intelligence (AI).

Simulations are essential for training AI to solve problems in space environments. However, there is a scarcity of publicly available simulation engines for the space domain.

"Before we can even start to develop AI, we need learning environments in which AI can be trained and the testing environments in which we evaluate how well that AI performs relative to other solutions," said Dr. Ross Allen, Artificial Intelligence, Group 01, who is leading a team to develop such spacefaring AI. "However, there are pitfalls to be avoided here and I've had to learn hard lessons about developing simulators to train and test AI."

Allen describes how, in past projects, he and his teammates attempted to build custom physics simulators from scratch for every new AI project. However, this has proven to be a deceptively challenging and lengthy undertaking. Although early-stage simulator development is straightforward and rapid, experience has shown that it takes years to create the extensibility, documentation, user interfaces, and validation testing required for meaningful AI training and testing. Therefore, Allen and his team set out to develop such a simulation environment by extending the popular video game, Kerbal Space Program (KSP), into an open-source library: Kerbal Space Program Differential Games (KSPDG).



The image above shows two satellites engaged in noncooperative proximity operations simulated using the Kerbal Space Program game engine.

"By using the game engine, we are able to leverage decades of software development, a large user community, and a rich collection of game modification tools to make the environment more realistic."

There is a rich history of using popular video games to advance the state of the art in artificial intelligence. Chess, Go, Poker, and StarCraft have each been host for major milestones in machine learning research. KSP is a popular, commercial-off-the-shelf space agency simulator that features little green aliens as intrepid astronauts. Allen and his team looked past the cartoony KSP graphics and saw a sophisticated multi-physics simulator capable of modeling all aspects of the aerospace domain: orbital mechanics, aerodynamic drag, spacecraft collisions and docking,

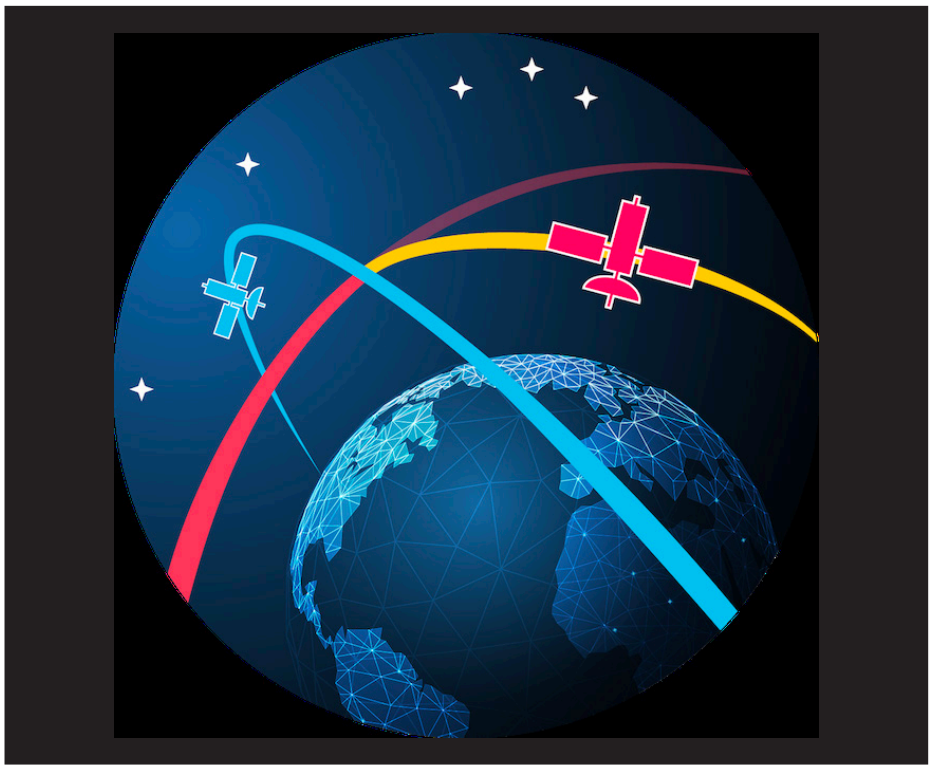
Operations Using Kerbal Space Program (continued)

and more. Furthermore, users are able to rapidly design new spacecraft and on-orbit mission scenarios using a highly intuitive user interface. Perhaps most importantly, KSP is highly modifiable; allowing users to create new software tools within the game to improve realism and create interfaces for plugging in AI agents. "It would take years for us to develop a fraction of KSP's simulation capabilities and user interfaces. Why would we spend that time and money when I can spend $60 to buy a copy of KSP right now?" said Allen.

Expanding upon KSP, Allen and his team have created the KSPDG challenge suite. This software library defines a set of on-orbit challenge problems in which users must create autonomous control algorithms for maneuvering spacecraft in noncooperative proximity operations. From simple pursuit-evasion games to multi-agent target-guarding engagements, KSPDG is designed to spur development of AI for a wide range of problems within the orbital domain.

"The goal of the KSPDG challenge suite is to define a set of hard problems that drives AI innovation for non-cooperative space operations. Furthermore, we are open-sourcing those problems and inviting industry and academia to attempt to tackle them by hosting a competition session at AIAA SciTech 2024 Forum," said Allen. The SciTech competition—which is kicking off presently—will consist of four months of preliminaries in which participants attempt to solve the on-orbit challenges and vie for top spots on a public leaderboard. Then an elimination round will occur and the top performers will be invited to present their agents at the AIAA SciTech conference; 8-12 January in Orlando, Florida.

"This project sits right at the crossroads of the Laboratory's expertise in AI and space domain operations, and seeks to answer a nascent national security problem in the space domain: how can we safely rendezvous and service satellites that are noncooperative?" asked Allen.



The image above is the emblem for the Kerbal Space Program Differential Game challenge problem suite.

Those interested in finding out more can read team's publication on KSPDG and find the source code on GitHub. If interested in participating in the AIAA SciTech challenge, please fill out this survey run by AIAA organizing committee.