Quantifying the Benefit of Orbital Optimisation to Defend and Protect Space Based Assets

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Abstract

The potentially dramatic increase in Low Earth Orbit (LEO) satellites in the next few years will increase the probability of damage to national space assets from hazards such as congestion at orbital pinch points.

The technology described seeks to increase the probability of satellite survival in congested orbital environments through the use of Artificial Intelligence (AI) based optimisation of satellite manoeuvre.

TP Group Plc has patent pending innovative suites of AI tools uniquely able to support Operators in delivering resilient, critical space capabilities, along with deep space domain knowledge gained through experience of UK and Allied Space programmes, including SKYNET 4, 5 and 6.

The Problem

To enhance space resilience and operational effectiveness, it is important to protect and defend critical space interests against hazards and threats in an increasingly congested and contested environment, working in co-operation with allies and partners.

As reported in the press (e.g. The Space Review[i], the BBC[ii] and other media outlets), the increasing amount of space debris in LEO, and the growing interest in “mega-constellations” of LEO satellites with the potential to create yet more debris creates new challenges and enhances the risk to satellites in LEO.

To illustrate the forecast burgeoning growth of satellites in LEO, in January 2019 there were about 1,957 satellites in orbit[iii], but reports suggest that this number will grow by orders of magnitude. To name just three major driving developments:

- OneWeb[iv] is developing an initial constellation of 648 that will reportedly grow to 2,000 satellites for a global broadband communications network
- Boeing[v] has submitted plans for a system of between 1,400 and 3,000 satellites
- SpaceX[vi] is exploring a system of 4,000 satellites.

With the arrival of such LEO mega constellations, there is the rapidly increasing probability of accidental collision in space, especially when taking orbital decay within a congested and contested environment into account along with the pinch points that occur near the earth’s poles; as most LEO satellites are typically deployed in a sun synchronous orbit. Even with

the companies involved vowing to be good citizens in LEO, something else will be required in order to alleviate the problems that this large number of satellites could create.

This problem could be considerable for national satellite systems as such systems are typically based on only a limited number of highly capable satellites, making the repercussions of collision with debris particularly significant.

Our Solution

Our solution has the potential to provide accurate and precise conjunction warning and mitigation for national LEO constellations. The solution is based on TP Group Plc's AntsOnDeck (AoD) system[vii] which provides rapid path planning in dynamic complex environments, optimised within constraints.

AoD is an innovative patent pending (UK Patent Application No. 1811086.6) software system that could add value to any Autonomous System capability. What makes it different from current systems is its ability to optimise routes against user-defined measures of performance, time and cost. As a result, it delivers real-time, dynamic route management with collision avoidance in complex environments, taking account of environmental conditions and platform dynamics. AoD is currently being developed for Autonomous Surface Vessels with UK Ministry of Defence funding and has been trialled at sea to TRL 6.

Because AoD is an agent-based system that employs a risk based metaheuristic approach to optimising path planning, including dynamic collision avoidance, the underlying AI system, is not constrained to any one operating environment.

This system, if developed for space and deployed, could:

- Extend the capabilities of AoD to the space environment.
- Ingest large amounts of data to accurately predict the planned path of a constellation of satellites in LEO, accounting for orbital decay.
- Forecast and alert any collisions with known objects (other satellites and debris).
- Initiate or model the autonomous manoeuvre of the satellite(s) at risk to avoid the collision, whilst accounting for the constraints of the scope for the satellite to move, and the requirement for it to keep delivering its capability and availability.

The system would take account of the limitations of the environment; there are limited options available to avoid a collision between orbiting objects such as a satellite and a piece of debris with individual orbital velocities of typically 6-7km /second (for sun synchronous LEO). They are realistically limited to increasing or decreasing the velocity of the satellite (as inclination changes are too fuel intensive). The earlier a velocity correction can be made, the more fuel/propellant efficient the action is. Thus, by using AoD, which will be able to consider potentially hundreds of other satellites/objects posing a threat to a national satellite, a collision path can be identified one or many orbits before a potential impact and a corrective change to the velocity made, with the minimum of fuel expended by the satellite.

The system's identification of a potential collision could generate an automated message sent to, for example, national Space Operations Control Centres which would minimise the risk of the target satellite's controllers making a later velocity correction which could be nugatory at best, and disastrous at worst.

Such a system would be critical to mitigating the premature loss of satellites along with any associated reputational damage and meet the needs of rapid path planning to offer the possibility of improving the resilience of the system over others in an increasingly congested and contested environment by:

- Enhanced predictive Space Situational Awareness.
- Understanding the orbital decay of the satellites in a constellation.
- Offering the ability to autonomously manoeuvre satellites within the constellation to avoid collision with hazards and threats, while maintaining capability and availability.

In future this system could also be extended to autonomously manoeuvre the satellite for purposes other than collision avoidance, namely for optimisation of the capability of a constellation.

The system would initially be implementable as a low cost software only solution, running on a ground station and be capable of spiral development and be platform agnostic.

The system will require up-to-date details of objects in the zones of interest (both satellite and tracked debris). In the initial phase, open source data such as that provided by www.heavens-above.com and www.space-track.org would be used, with future phases seeking to use the more detailed, high integrity information available to the government, such as fresh ephemeris (Two Line Elements) from national Space-Track facilities

Summary

The unique AoD AI system, already being developed for UK Maritime applications, could be exploited, in support of national space based ISR operations and procurement in order to increase the resilience of current and future assets:

- To provide hardening of the satellite systems.
- Facilitate satellite defence measures.
- To provide accurate and precise conjunction warning and prediction of “problem” satellites and debris.

A system of this sort would have benefit outside of Defence and Security, commercial constellation owners will face the same challenges, albeit with potentially less valuable assets at risk.

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[i] Space traffic control: technological means and governance implications http://www.thespacereview.com/article/3473/1

[ii] Mega-constellation satellites will need 'rapid disposal' https://www.bbc.co.uk/news/science-environment-39632181

[iii] Record Number of Satellites in Orbit https://allthingsnuclear.org/lgrego/2018satellitedata

[iv] OneWeb launches mega-constellation pathfinder satellites https://www.bbc.co.uk/news/science-environment-47374246

[v] Boeing proposes big satellite constellations in V- and C-bands https://spacenews.com/boeing-proposes-big-satellite-constellations-in-v-and-c-bands/

[vi] SpaceX Launches First Starlink Satellites In Space Internet Battle https://www.forbes.com/sites/jonathanocallaghan/2019/05/23/spacex-launches-first-starlink-satellites-in-space-internet-battle/#6b69a1079024

[vii] Optimised Autonomous Routing in dynamic and complex environments. http://www.antsondeck.com/