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SATURN, the UK Ministry of Defence Grand Challenge winner

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A major robotics competition generated many ideas to detect military threats in the urban environment.

Urban environments can be extremely hostile for soldiers. Threats are difficult to spot because of urban clutter, and it is impossible to predict what soldiers will face over the next wall or around the corner. Therefore, the UK's Ministry of Defence (MoD) organized a major robotics competition to promote development of technologies that will help identify threats in urban areas. The Grand Challenge was an open invitation to academia, small enterprises and defence prime contractors, which was answered by 14 teams (most with representation from more than one sector). Their aim was to develop an autonomous system that could spot four types of threats in urban environments, including improvised explosive devices, marksmen, 'technicals' (weaponized four-wheel-drive vehicles) and groups of armed people. A competitive demonstration was held in August 2008 at the MoD training facility Copehill Down Village (Wiltshire). Points were awarded for both the degree of autonomy achieved and the number of threats identified correctly, while false-positive detections resulted in deductions.

Some of the wide array of entries focused on development of novel sensor platforms, while others concentrated on how multiple sensor platforms could interact. For example, Team Cortex developed a novel unmanned aerial vehicle (UAV) that could take off and land vertically, while Team Swarm developed a very simple quad-rotor UAV but focused on the benefits of emergent behaviour in multiplatform 'swarms.' The design of the winning entry, SATURN, relied on two types of UAV[1] and one unmanned ground vehicle (UGV) to carry sensors into the urban environment. A central ground-control station (GCS) received transmitted sensor feeds (optical and IR imagery from the UAVs, and optical and IR imagery as well as radar from the UGV). Threat-detection software,[2] capable of detecting each of the four threat types without human input, analysed these feeds automatically. A database logged threat detections and drove adaptive decision-making software to automatically task the vehicles at the navigation level, with guidance and control functions delegated to the vehicles themselves. For example, a low-probability threat detection would prompt the software to direct a platform for a closer look.

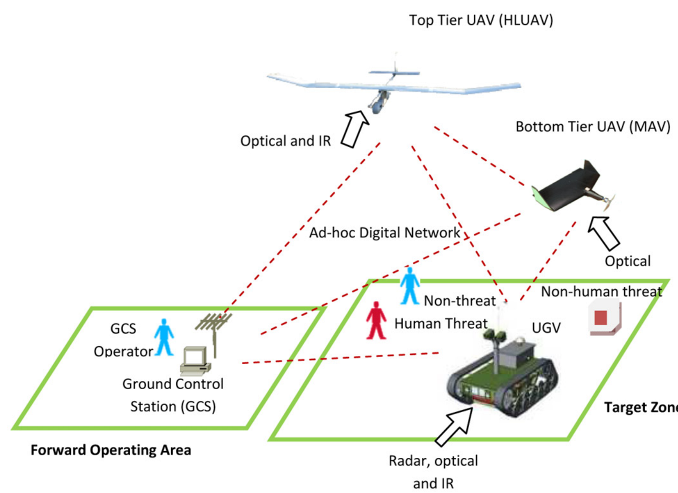

Figure 1. SATURN's high-level architecture. UAV, UGV: Unmanned aerial and ground vehicle, respectively. HLUAV: High-level UAV. MAV: Micro air vehicle.

We faced many challenges in implementing this approach within the competition's one-year development timeframe. For example, we decided early on that we required a mobile ad hoc network (MANET) communication architecture to handle both node (platform) movement and urban clutter: the UAVs would be used to provide a multihop route from the UGV to the GCS (see Figure 1) when clutter would otherwise have prevented communication. Integrating and testing the MANET data links on the disparate platforms proved a major development effort. We designed and built platforms according to the Challenge's requirements (including safety elements), and integrated sensors. For the UAVs, we developed control laws that would enable navigation, guidance and control without human intervention. This required extensive flight testing. Figure 2 shows an example of one of our UAV types. We also developed (from scratch) a GCS that integrated automated threat-detection and decision-making software.

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Figure 2. Example of one of our UAV types.

During the competitive finale, our operations did not run smoothly. At the outset, the top-tier (high-altitude) UAV suffered from motor failure, leading to a loss of throttle control. Although this was terminal for that component's mission, the control law programmed into the autopilot was sufficiently robust to handle the failure gracefully and allow a safety pilot to recover the vehicle. The potentially more devastating consequence of the failure was a break in communications. However, our choice of communication architecture enabled multiple sorties to readily cover this using the smaller, bottom-tier (low-altitude) UAVs to patch up the MANET. Sufficient functionality remained in the system to adapt to the failure and continue detecting threats (and also win the competition).

Our SATURN system demonstrated the benefits of a multi-platform approach to threat detection in urban environments. Inadvertently, because of problems encountered in the finale, it also demonstrated the virtue of a MANET approach to communication for this type of system. Although employing multiple platforms and a distributed communication architecture, the setup was heavily centralized. All data processing was carried out on one host, and the MANET was effectively configured as a star with one UAV providing a repeater service for the UGV. In dynamic real-world environments, this architecture is potentially vulnerable to single points of failure.

In addition, because the Challenge prioritized autonomy above all else, available human resources were underused: we had designed potential synergies between human and machine intelligences out of the system. Navigation functions were also centralized. For example, the software 'agents' on board the UAVs were delegated low-level guidance and control functions, when the hardware support required to process sensor data and self-navigate can, in fact, be carried on board, and the vehicles could readily host dedicated navigation-software agents. Our future work will, therefore, focus on how teams of humans and UAVs can operate together more effectively to accomplish a variety of common tasks (such as search and surveillance). We will consider a range of features, including the implications of the communication architecture (e.g., bandwidth as a resource), and the combined presence and interaction of human and software agents.

The SATURN system was developed by Team Stellar, consisting of members from Stellar Research Services, Selex Galileo, TRW Conekt, Marshall Systems Design Group, Cranfield University and Blue Bear Systems Research.

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