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Retrofitting Mission-Essential Supplemental Information into Existing Ground Control Stations

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Introduction

Uninhabited Air Systems (UAS) Ground Control Stations (GCS) are built to provide flight-essential information exchange between an operator and vehicle regarding sensor output, control, and status of the vehicle. Most GCS are not designed to deliver mission-essential information from other sources about the target (maps, imagery, airspaces, air traffic, other intelligence, weather, disposition of friendly units in the vicinity, or threats), even though this information is critical for both mission effectiveness and safety of flight.

Current CGS Capability and Proposed Improvements

There are several reasons for the lack of external or supplemental information integration into the GCS. First, information integration would increase the complexity of the GCS software. Software complexity has a large effect on the cost and development schedule of an UAS. Safety of flight demands reliability testing for the GCS software that traces every possible action with their executable code and data paths (NASA-STD-8719.13A, RTCA DO-178B, MIL MIL-STD-882D). This testing is even more intensive if the UAS is capable of weapons delivery. The cost and duration of this reliability testing dictates the GCS software include minimum functionality.

Additionally, most of this supplemental information has net-centric sources. Internet connectivity to the GCS raises security issues that GCS developers simply do not want to deal with. Besides the security issues, mission critical information is often "trapped" in legacy "stovepipe" applications which do not have convenient means to access over the Internet. To make matters worse, there is no coordinated effort among the information sources to provide a single information source or to standardize acquisition of information from existing sources. Without such a single source or access standards, GCS developers simply have no easy way to access net-centric information in the GCS. Special purpose data extraction procedures like the ***Cursor-On-Target (COT)*** approach which requires modification of the source and destination applications are both difficult and expensive to accomplish. This current state of affairs is portrayed in Figure 1.

Another striking result of the GCS isolation is the difficulty of extracting GCS information for use by supplemental information systems. Although the GCS contains the UAS GCS position, sensor geometry, and air vehicle status, there is no way to directly export that information from the GCS! Supplemental information processing must resort to gleaning UAS information from such sources as digital data embedded in the video stream or from external radar transponder tracking! Acquisition of tracking/monitoring and other UAS information could easily be done by inclusion of a read-only digital source embedded in the GCS. The equivalent in manned aircraft avionics is a read-only 1553 data bus port. Non-flight critical avionics can listen to the aircraft data bus while making writes onto the bus is prevented by hardware. Government GCS specifications or the manufacturers on their own initiative, need to include a hardware digital read-only port providing access to the GCS internal data including position, sensor geometry, air vehicle parameters, etc. The read-only hardware might be Ethernet, USB, RS-232/422, IEEE-496, or some other standard easily incorporated into the GCS hardware architecture. This port would allow supplemental information processing and displays to receive the GCS information directly, faster and more simply than relying on more round-about sources.

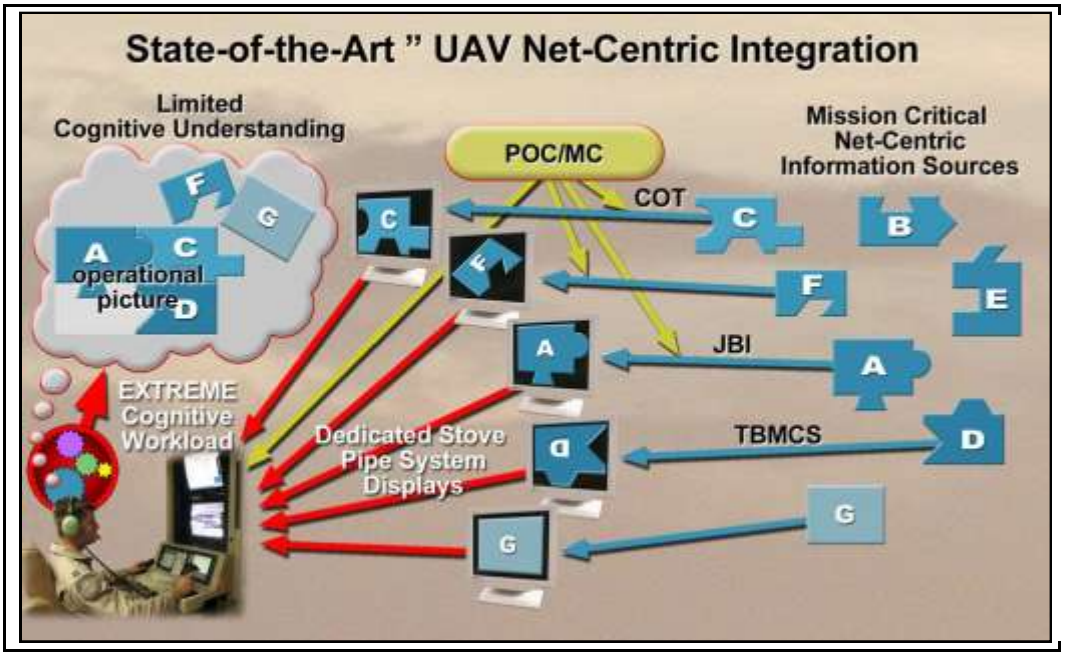

Figure 1: Conceptual representation of "state-of-the-art" supplemental information displays.

It would also be desirable to pass information from net-centric sources directly into the GCS, without incurring security or reliability testing burden. At issue is whether information insertion can be handled with enough confidence to allow insertion of geospatial information like waypoints or targets without compromising the integrity of the system. A selective firewall which permits only certain information to pass would be required. Alternatively, some kind of manually initiated transfer like clipboard copy and paste which requires human intervention might satisfy information assurance. It seems unreasonable to have to type in coordinates when they are available digitally within the supplemental information system. Moreover, retyping information incurs its own risks. Typing errors in entering mission information like coordinates may be more dangerous than the security risks of maintaining the air gap between flight critical and supplement information systems.

Concept of Operations (CONOPS)

Organizations operating UAS are left to develop their own CONOPS, which define how the UAS is deployed, and its command and control. CONOPS determine where supplemental information is gathered, processed, and presented. Detailed discussion of CONOPS could aid the opponents, so they will not be discussed in specifics. However, general observations independent of the organizations can be distilled to provide GCS designers with insights about how supplemental information can best serve user CONOPS. The "manned" aircraft CONOPS treats the UAS operator as an aircraft pilot, with all responsibility for both the vehicle and its mission. An operations center collects, organizes, and delivers supplemental information into the GCS to support the pilot's decision making process. Supplemental displays deliver the information to the pilot in authority. Intelligence or weapons targeting decisions come down the chain of command, but UAS application decisions are made by the pilot of the UAS. This approach simplifies the chain of command, but results in heavy pilot workload.

Other organizations take a more distributed view of responsibility. In these organizations, the pilot's duties are narrowly specified to safety-of-flight, positioning the vehicle for mission tasking, and vehicle recovery. Mission decisions are made by a mission manager, who uses supplemental information to formulate those decisions. The pilot simply executes the decisions made by the mission manager. Such a distributed authority reduces pilot workload, but involves more command and control overhead per UAS.

Whether delivered to the GCS (directly or indirectly) or to a mission manager in the operations center, the necessary supplemental information comes over a variety of sources. These include but are not limited to voice communications (radio, phone, intercom), paper products (maps, reports, photos), and supplemental computer displays. Presentation is highly fragmented (different media, different displays) and information integration is a major task. Some organizations use existing map and mission planning software as an augmentation, using technologies such as COT to gather the information from sources and deliver it into the GCS or command center. This has resulted in an array of displays each carrying part of the necessary information content to accomplish the mission. This is a step in the right direction, but the burden of integrating information makes this an insufficient solution.

New Approach for Integrating Supplemental Information

Placing operators or management between the net-centric information sources and the GCS may solve the testing and security issues, but at considerable cost to the UAS crew and/or mission manager. GCS makers are avoiding the issues associated with this supplemental information, since the organization and understanding this non-GCS sourced information significantly impacts UAS operator workload and effectiveness. The cognitive consequences of this information are under study and ways of improving information management and assimilation are being developed to create a comprehensive solution to the incorporation of supplemental information into existing and future GCS. A ***Service-Oriented-Architecture (SOA)*** has been implemented using intelligent agents operating within a ***Java Agent Development Environment (JADE)***. This system is designed around a "second-generation" ontology which was honed based on implementation experience and extensive conversations with experienced contractor and Government subject matter experts. Net-centric information feeds are implemented using real operational software sources or simulations employing real communication protocols. The net result is a close-to-field-able system which can acquire, filter, integrate, and display net-centric information in support of single or multiple UAV operations.

The allocation of screen resources was made based on UAS assumptions and use case mission scenarios. The UAS was based on a hypothetical extension of the General Atomics Predator B, with similar performance characteristics but assumed a more autonomous mode of operation. These scenarios are unclassified, and include two or three UAS operating out of a single base and performing a series of reconnaissance and weapons strikes. The missions are preplanned, with changes introduced during execution.

Supplemental Information Displays

The display system partitions two large display surfaces into four information regions. The first display supports current situational awareness and contains the ubiquitous "tactical display" which is a spatial representation, a map of the operations area on which information is painted. All UAS ground stations and command facilities maintain such spatial representations of the mission. The tactical display represents the current mission routes, restricted air spaces, other UAS and air traffic, friendly and enemy force dispositions, weather, and other information that may be displayed spatially. Part of this first display surface can be allocated to track Internet Chat as part of current situational representation. An advanced Chat client allows passing information between Chat windows and the other displays, leveraging Chat as a net-centric information feed. This display is shown in Figure 2.

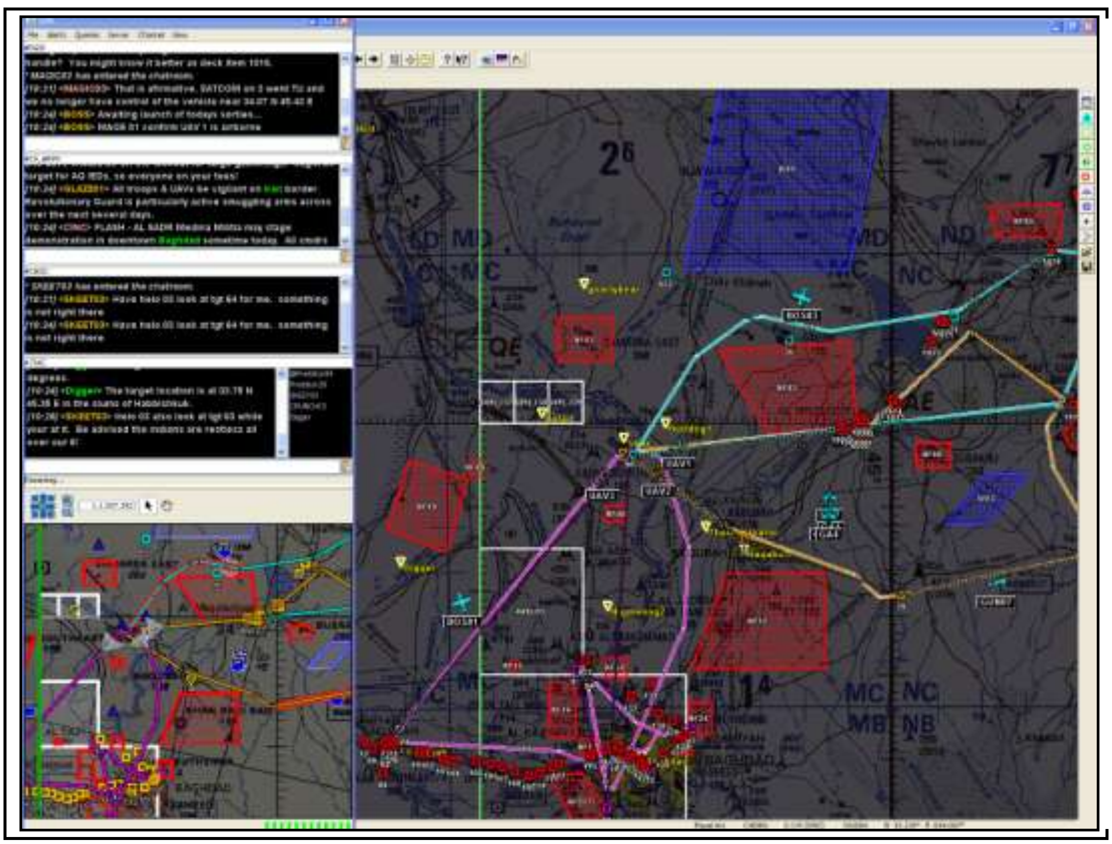

Figure 2: The tactical and Chat display elements for maintaining situational awareness.

The second display surface contains an information gathering and decision support function which is future-oriented in contrast with the "here and now" focus of the first display. The ***Decision Support System (DSS)*** display contains a time line display which plots past, present, and future events on a scrolling linear temporal representation. There is growing awareness of the utility of time lines in mission management, especially in multiple UAS control (Cummings and Mitchell, 2006). Operators may be able to avoid high workload demands by easily anticipating future demands among multiple vehicles. When alternative flight plans are generated by the DSS, alternative time lines are generated and presented side-by-side with the current mission's time line so the temporal consequences of replanning can be understood and is shown in Figure 3.

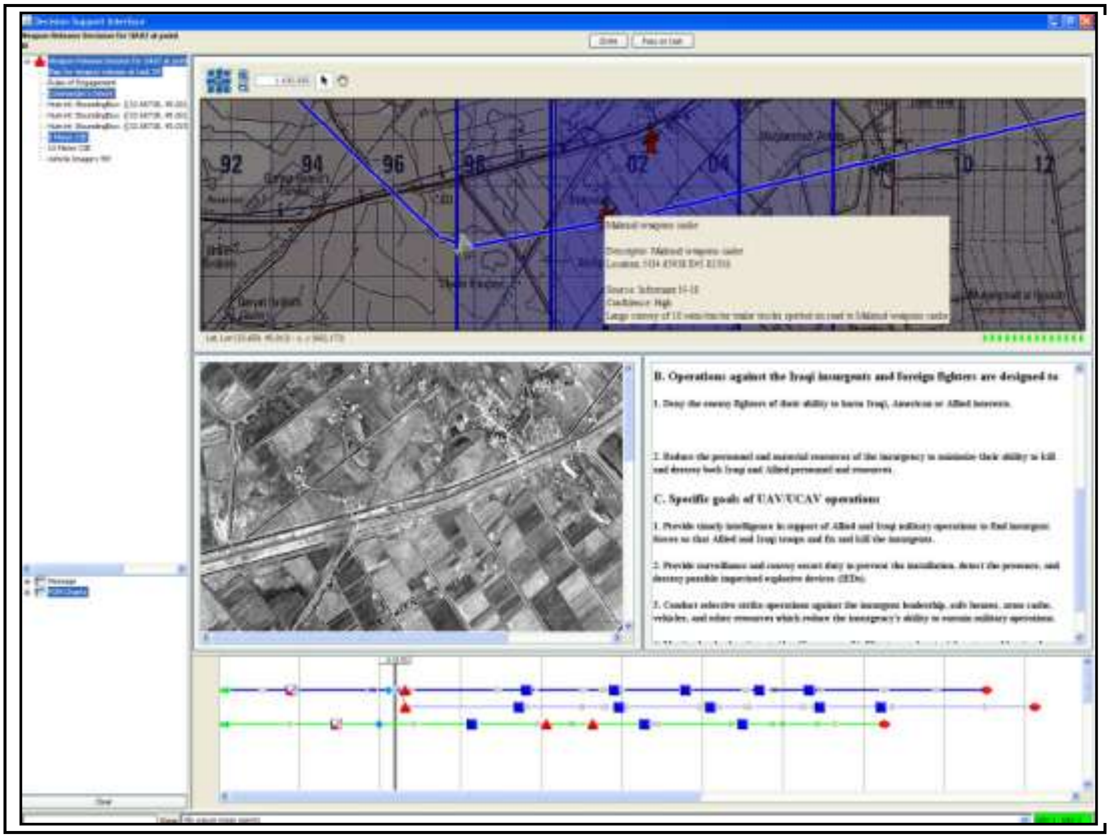

Figure 3: The future-oriented Decision Support System display with workspace and time lines.

The largest part of the DSS display has dynamically changing content driven by mission events or by operator initiated queries. When the mission demands operator intervention to confirm the results of a reconnaissance event or a decision whether to strike a target, the system seeks content relevant to the decision and makes it available in an information queue. The queue's contents are displayed in a multi-pane workspace, the contents of which can be expanded, contracted, removed, or replaced. The conceptual basis for this design is Klein's (1989) Recognition-Primed Decision-making theory. The workspace provides a place for the operator to "recognize" what course of action he or she wishes to follow. Besides these mission driven decisions, operators may initiate their own queries. Mission replanning requests evokes the ***OR Concepts Applied (ORCA) Planning and Utility System (OPUS)*** automated mission planner to generate alternative plans. These plans are simultaneously displayed spatially in the decision queue/workspace in spatial map form and on the time line display as alternative time lines. Additionally, an advanced decision support display format allows comparison of the mission "figures-of-merit" which express the qualities of the mission alternative. This new display format we call a "sprocket" is based on Arnheim (1969) Visual Thinking theory and shows great promise for multi-dimensional, multi-scaled information comparisons (Figure 4). The separation of "what if" and current mission plans avoids their confusion, an important separation of planning from fact. The operator can make queries to supplement mission triggered information or any information available from net-centric sources.

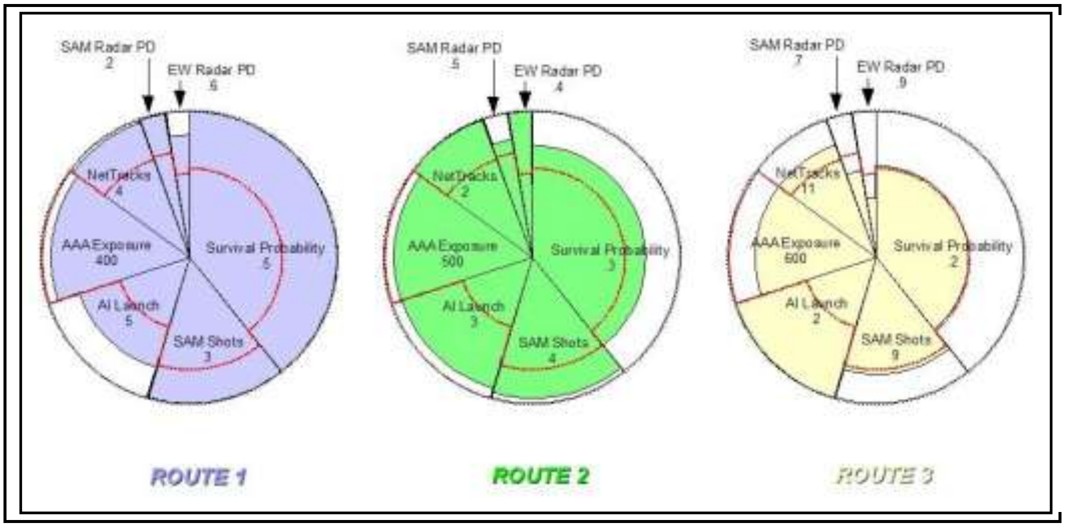

Figure 4: Three "Sprocket" displays showing multiple figures-of-merit for three proposed routes. All scales have been transformed based on weighting (slice size), range, and acceptable threshold so that larger area reflects the better route alternative.

Control of the display content, operator queries, and action initiation is managed by an advanced user interface which employs both traditional mouse pointing and voice recognition that is both natural and easy-to-use. Items in displays can be information augmented using roll-overs, following "flags," or information separated "hooks." Voice commands employ speaker-independent, limited vocabulary based on the Nuance speech recognition engine using a vocabulary based on domain-specific inputs. The system tracks "contexts" from voice and pointer interactions, which facilitate communication much like normal human-to-human communication. Context congruence between the system and operator is maintained by selective speech feedback to ensure operator and system have the same contextual framework. This interface is natural, very fast, and minimizes both errors and most keyboard inputs.

Conclusion

The result of this effort is an ***integrated*** supplemental display system that filters, organizes, and displays information for the UAS operator and/or mission manager in an easy-to-use and timely fashion (Figure 5). This system helps manage the pilot and/or mission manager's information and workload, stores and retrieves mission relevant information, and facilitates "testing-safe" information transfers between the supplemental sources and the UAS. The system uses intelligent agents in a SOA to acquire and organize the information. GCS designers need to adopt a modular design philosophy that easily provide UAS information, accommodates net-centric supplemental information systems, and facilitates information sharing between UAS-GCS-Command Center operations.

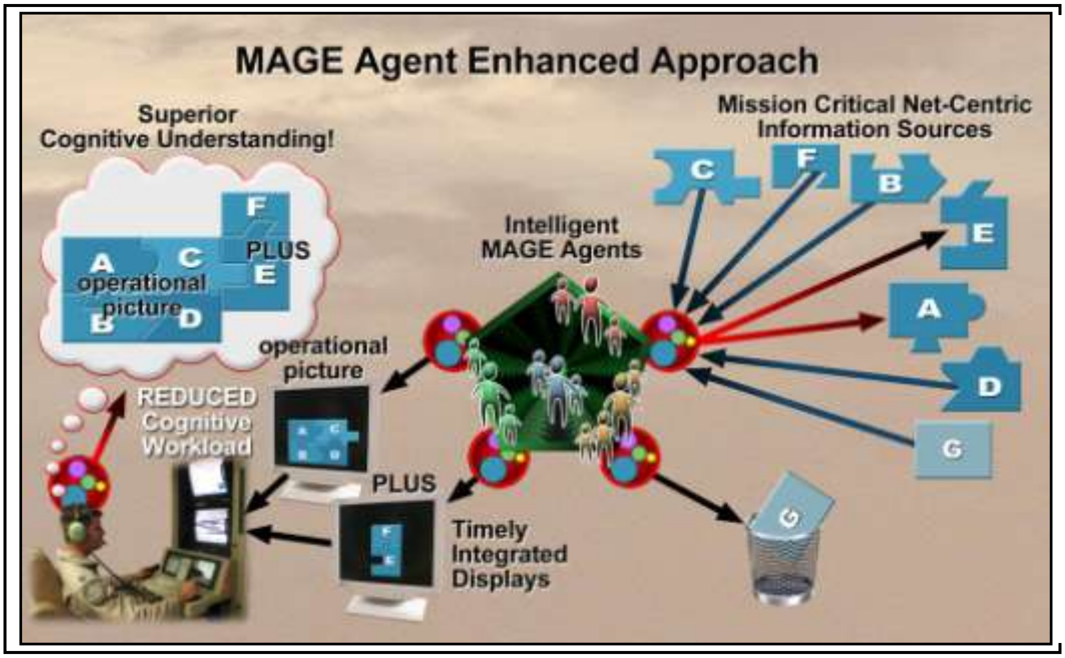

Figure 5: Conceptual representation of an integrated supplemental display system.

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