Unmanned System Autonomy, Situation Awareness, and System Safety

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Abstract

The future will provide an increasing number of autonomous unmanned systems; e.g. weapons and vehicles, to be deployed by the nation's military. There are a large number of safety issues that such systems will pose, one such safety concern is the ability of the autonomous unmanned system to accurately identify environmental elements and make the appropriate decisions based upon the situation. Human's have an innate ability to interpret the environment and determine the appropriate action to take in order to ensure mission success while minimizing the danger to friendly forces and innocent bystanders. Current autonomous systems do not have capabilities at the same level as their human counter-parts, thus raising concern regarding their ability to ensure safety and still be effective. This paper discusses how current autonomy is insufficient to guarantee system safety and how incorporating the concept of situation awareness into the unmanned system can improve safety.

Introduction

Humans are capable of understanding highly dynamic and complex environments and situations. Humans' cognitive capabilities permit this understanding and the ability to successfully complete missions in such environments. Future fully autonomous unmanned systems e.g. weapons and unmanned vehicles are planned to execute similar tasks in identical domains. However, current unmanned system (UMS) technology either depends heavily on a human operator's cognitive capabilities for task completion or relies on very fragile autonomous technology that typically is unable to function in today's highly dynamic and complex military theaters. One may tout the need for better artificial intelligence to improve autonomous capabilities; however, if unmanned systems with human-level capabilities are to be developed, UMSs require more human-like cognitive capabilities. One such capability is situation awareness, the human's ability to perceive the environment, comprehend the situation, and project that comprehension into the near future in order to determine the best action to execute (ref. 2, 3).

Currently deployed UMSs are teleoperated or semi-autonomous, thus requiring a human to be an integral component for mission success. However, many individuals are working towards the deployment of fully autonomous systems that will be deployed with human partners or will be deployed to complete missions with little or no human intervention. This vision will require UMSs to have a high level of situation awareness in order to be able to accurately perceive the environment, understand the situation, locate the target, engage and fire weapons, provide battle damage assessment, and maintain communication with team members or a superior (human or machine). Each of these activities, when executed by humans, requires situation awareness; however, there is no similar concept of awareness for an automated unmanned system. The future safe and successful deployment of autonomous unmanned systems will require that such systems possess situation awareness.

Situation Awareness

Many human situation awareness (SA) definitions exist (refs. 1, 2, 3, 4, 5, 6); however, all of the definitions pertain to the human's ability to understand the environment in order to carry out appropriate actions. Endsley's definition is a commonly accepted definition: "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (refs. 2, 3). This definition encompasses three levels of SA. Level 1 represents the perception of information from the environment; Level 2 is the comprehension of the perceived information; and Level 3 is the projection of the information into the near future for the purpose of guiding actions. This paper adopts Endsley's SA definition.

Situation awareness was originally defined for the aviation domain (refs. 6, 7, 8, 9, 10, 11); however, over time the concept has been expanded to a number of domains such as military infantry operations (refs. 12, 13), process control (ref. 14), and air traffic control (refs. 15, 16, 17).

Typical environments in which SA is discussed encompass a number of characteristics that include (refs. 11, 18):

- The environment is dynamic and information dense.
- The human may encounter high cognitive workload situations.
- Training is an integral and required element for mission completion.
- The domain problems are ill-structured.
- There are time constraints on missions.

The SA processes require comprehension of the dynamic situation/mission that is often multifaceted (ref. 19). Generally speaking, awareness can be characterized as the human's knowledge of a particular environmental state that must be updated as the environment changes (ref. 20). This awareness maintenance requires the human to interact with the environment (ref. 20). As the mission or situation becomes increasingly complicated, the human often encounters increased mental workload in order to achieve high quality Level 3 SA (ref. 20). SA can be thought to result from the acquisition of external information that is integrated with working memory and long-term memory in order to form an internal representation (e.g. a mental model) (ref. 21).

Fracker (ref. 4) indicates that the quality of the human's SA is dependent on his or her knowledge stored in long-term memory and the completeness of that knowledge. If the stored knowledge related to the particular activity is "sufficiently complete", then working memory capacity should have less of an effect on the human's SA quality. However, situations exist in which having complete SA does not result in good decision making (ref. 22). Endsley and Jones point out that the resulting decision-making outcome can also be affected by the human's level of SA and corresponding confidence level in the SA (ref. 20). If the human has good SA and is highly confident in that SA, then generally there is a good decision making and future projection. If the human's SA level is poor while the human is over confident in his or her SA, then the resulting decision making and projection is often bad. If the human possesses good SA but has a low confidence in that SA, the human will often not make decisions and projections, but rather will continue to collect additional information. Finally an individual with poor SA and low confidence in that SA often chooses not to take any actions and continues to gather information. The potentially most dangerous combination is an individual with poor SA and high confidence since there is a high likelihood that this individual will make highly incorrect decisions and projections, thus leading to bad actions.

Sarter and Woods (ref. 5) argue whether or not awareness is "synonymous with expressions such as knowledge or integrated understanding." A question they raise is whether or not awareness is equivalent to conscious knowledge (working memory) or to any retrievable knowledge (working and long-term memory). Further they suggest that if SA is equivalent to the information in working memory, then one can only be aware of the information in working memory. If awareness is only composed of information from working memory, the implication is that consciousness equals awareness; however, this cannot be the case since SA also requires temporal components that are not maintainable in working memory (ref. 5). Additionally, preattentively processed information contributes to SA when it is brought into working memory due to attention allocation (ref. 5). Sarter and Woods conclude that SA is a distinct and unique phenomenon.

SA is a grouping and description of processes working to form human cognition (ref. 23). The portions of these processes that handle incoming data and then compute higher level constructs can be grouped together by SA. Endsley modeled these higher level constructs via the three levels (ref. 3).

Level 1 SA is the perception of the environment relative to the assigned mission, including the environmental status, attributes, and dynamics, which involves acquiring raw environmental information based upon the human's visual, auditory, tactile, taste, and olfactory senses (ref. 3). Various combinations of sensory capabilities are necessary to perceive the relevant aspects that vary across application domains. Human's perception is guided by directing attention to the relevant elements based upon the current goals, objectives, working memory, and long-term memories. Example environmental elements that may be relevant in an aircraft domain include: own and other aircraft location, altitude, heading; system status; and weather.

Humans achieve level 2 SA by integrating their disjoint perceptions from level 1 in order to form an understanding of the current situation, including the significance of the perceptions given the human's current goals (ref. 3). This comprehension level integrates the perceptions into information and prioritizes the importance of the information relative to the goals (ref. 11, 24). Examples of information that may be relevant in an aircraft domain include: the mission status and timing; remaining flight time and distance given fuel levels; and the potential impact of system failures and degradations.

The projection step, Level 3, utilizes the constructs of both Levels 1 and 2 to predict future environmental states and possible actions to undertake (refs. 3, 25). The ability to form sound projections depends upon the human possessing an excellent understanding of the domain (e.g. mental model) and is frequently a highly demanding cognitive activity (ref. 24). Various cognitive aspects such as workload, mental capacity, and environmental stressors can limit the humans' Level 3 SA. An example of a Level 3 projection for the aircraft domain would be the projected aircraft tactics and maneuvers.

Figure 1 represents Wickens et al.'s model of human information processing (ref. 26) with an overlay correlating the three levels of SA to the information processing model (ref. 27). Human information processing requires that the human register the sensory information, perceive the information based upon the sensory input and memory, allocate attentional resources, make decisions, select the appropriate action, and execute the selected action. This model varies slightly from Endsley's model of dynamic decision making (ref. 3) in that a portion of decision making is represented as a small element of the Level 3 projection activity. The development of SA combines the environment state with the current goals; long term memory stores; and any available (and relevant) information processing mechanisms to form a continuous series of decisions. These decisions either directly or indirectly affect the environment, thus modifying the SA inputs.

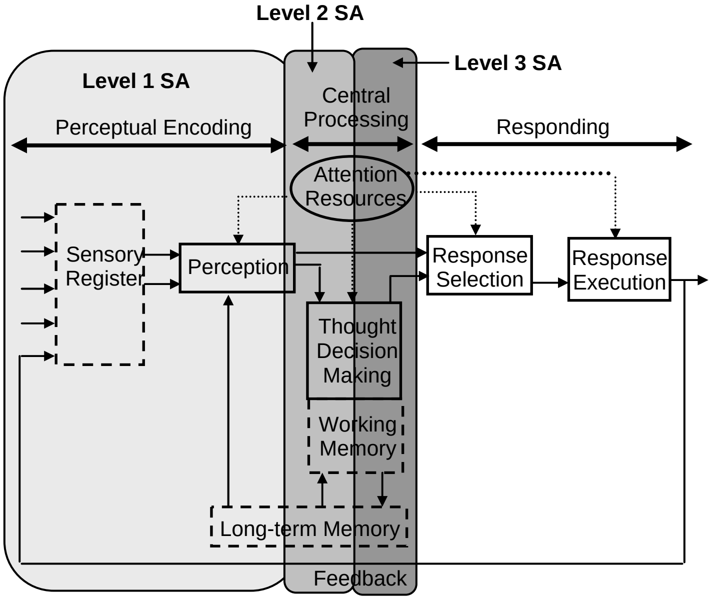

Figure 1 — Endsley's levels of SA overlaid onto Wickens et al.'s (ref. 26) model of information processing.

Autonomy

Human SA is highly sensitive and can be affected by any number of external (e.g. automation, environmental stressors, salience) or internal (e.g. cognitive workload, vigilance, fatigue, stress) factors. Automation, in particular, was originally touted as a mechanism to reduce the cognitive demands placed on humans; however it has been demonstrated that SA can be reduced as the level of system automation increases (refs. 28, 29, 20).

A current working assumption is that the level of required UMS SA correlates to the system's level of autonomy. Parasuraman et al. (ref. 28) revised Sheridan and Verplank's (ref. 31) ten levels of autonomy. Similarly, Endsley and Kaber (ref. 32) and the Army scale for the Future Combat System (ref. 33) each provide ten slightly different levels of autonomy. Irrespective of the definitional differences, at the lowest autonomy level the human has full control of the system and the system has no autonomy, thus the system may have little, if any SA capability (today most UMSs have no SA or very limited Level 1 SA). A fully autonomous UMS will require significant SA capabilities to ensure safe and successful mission completion. The intermediary levels of automation will result in varying relationships between the human and the UMS, potentially resulting in varying the SA quality levels for each entity. UMS SA must delineate the characteristics required for varying levels of autonomy in addition to how the level of UMS SA influences human SA.

Figure 2 provides a potential representation of the required UMS SA levels as the level of autonomy spans from full human control to fully autonomous UMS control. At the lowest autonomy level, the human possesses the SA required for mission success, while at the highest level the UMS possesses the required SA. As the level of autonomy transitions from low to high, the UMS will increase its level of SA while the human's level of SA decreases. This preliminary representation indicates that the lowest level of autonomy is similar to current systems, where the onus for possessing SA is placed on the human. However, it may be important for the UMS to possess some SA in order to improve the human's SA. Additionally, at the highest level of autonomy, the human may not require a high SA level throughout the entire mission; but situations may exist during which the human must possess a high SA level.

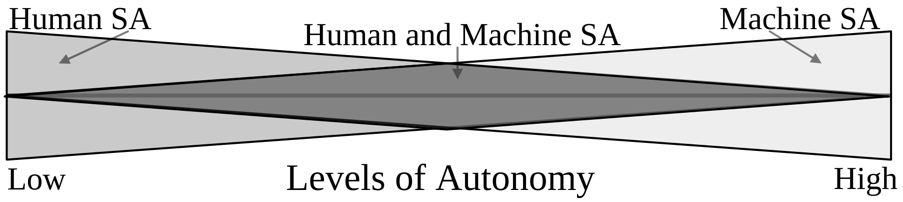

Figure 2 — An allocation of human and UMS SA across the levels of autonomy.

Unmanned System Situation Awareness

Existing knowledge of human situation awareness in individuals and teams is the basis for a preliminary representation of the UMS SA concept. Human SA typically focuses on a single human interacting with a system and is commonly improved by providing better interfaces between the human and system. Human SA does not represent the system's ability to possess SA; therefore a new formalization that represents each entity's contribution to SA has been developed (ref. 27).

Generally speaking, Endsley's SA definition can be adopted for defining the UMS SA concept since this definition is not specific to human SA (refs. 2, 3). The UMS SA formalization delineates system SA and system team SA. System SA simply represents a single human interacting with a single UMS and the combination of the two entities represents the system SA. The individual entities contribute to the system SA based upon the UMS's level of automation and SA. The concept of system SA is similar to Endsley's definition of human team SA (ref. 3), which relies upon Salas et al.'s definition of a team (ref 34). Salas et al. (ref. 34) define a team as: "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership." Based upon this definition, team SA was defined as (ref. 3): "the degree to which every team member possesses the SA required for his or her responsibilities."

System team SA extends the notion of system SA to any combination of multiple humans and UMSs. The system team SA representation is based upon the system SA representation but must represent individual entity SA in addition to the SA across sub-teams and the overall team.

The UMS's SA requirements are influenced by the system's level of automation. There are a number of characteristics, other than the autonomy level, that determine UMS SA, including characteristics specific to the environment and those unrelated to the level of autonomy or the environment. Examples of characteristics associated with the level of autonomy include workload, stress, attention, perception, memory, and vigilance. Weather, terrain, location, and operational requirements represent items included in the environmental characteristic set, while the set of other characteristics may include training, capabilities, task complexity, and communication errors.

The preliminary UMS SA representation provides an understanding of the relationships between humans and systems based on the existing definitions of human SA. Full details of the current formalization are provided in Adams (ref. 27). The preliminary UMS SA representation is intended to provide an understanding of the interconnections between humans and UMSs based on the existing definitions of human SA (refs. 2, 3), team SA (ref. 3), and shared SA (ref. 3). These interconnections and the delineation of the UMS SA characteristics are driving the development of the UMS SA concept.

Inherent Autonomous Unmanned Systems Situation Awareness Components

A large portion of our UMS SA work has focused on identifying SA components specific to unmanned systems. There are a number of human SA components and factors that apply to UMS SA. Two groups of components have been defined: inherent and non-inherent. Inherent SA components are defined by the features and limitations of the UMS hardware and software. The non-inherent SA components are introduced by the UMS designer as a result of the humans' natural biases and design decisions. This section focuses on the inherent SA components for UMSs.

The inherent SA components for UMSs are defined by the hardware and software capabilities of the systems with correlating elements of human SA, many of which are often difficult to measure. Table 1 provides a list of the identified inherent SA components that are analyzed for inclusion in the UMS SA framework for UMSs. Each component will be discussed in turn.

Table 1 — A list of the inherent SA components for unmanned systems.

Attention
Explicit Focus
Working Memory
Long Term Memory
Stress
Workload
Failures
Uncertainty/Confidence
Ideal/Achievable/Actual SA
Vigilance

Attention management affects a human's ability to sense and understand the surrounding environment. While attending to a particular sensory channel does not guarantee perception, generally speaking, attention is required to attain perception (ref. 26), which is critical to Level 1 SA. Humans are able to divide, direct, and select their attentional capabilities. Human perception is limited and finite; while UMS attention is also limited, it may be able to surpass human limitations. Human attentional resources are limited by the demands of the sensory channels and complex, dynamic environments can quickly overload the human's attentive abilities, as a result humans selectively sample their sensory channels. UMSs are able perceive the environment based upon their available sensors and the associated sensor processing; however, these capabilities are also limited. Humans typically manage their attentional focus based upon the frequency that percepts must be updated or the information update rate. Future autonomous UMSs will suffer similar limitations; however, the UMS's saturation point for information collection may surpass humans'. Human perception is also limited by the human's ability to parallel process sensor percepts due to sensor modalities and working memory constraints. UMSs may encounter similar situations and must be able to manage attention or the processing of percepts; UMS SA will need to direct attention and percept processing appropriately. Current UMS technology does not necessarily consider these aspects of attention, in particular how they affect awareness.

Humans are able to direct their attention, and potentially the sensory channels that they are relying on, based upon the surrounding environment and the dynamics of the associated tasks. The ability to rapidly redirect human attention is critical for Level 1 SA and as a result has an effect on Level 2 and 3 SA. UMSs currently are unable to rapidly adapt or redirect their attention, via their sensory capabilities (e.g. hardware and software), to developing situations. In fact, UMSs will frequently "ignore" information that would cause a human to redirect their attention. This limitation is due to the currently available hardware and associated software that are designed to gather particular data and process that data in a predefined manner. UMS SA will require the development of adaptable sensory capabilities along with the associated attentional capabilities that redirect attention appropriately.

Humans possess working (short-term) memory and long-term memory that are directly relevant to developing SA. Short-term memory suffers from limited capacity and humans have unreliable long-term memory recall. Random access memory is an inherent UMS component that can potentially be employed to simulate or replicate human working memory while a persistent storage device can be employed as a representation of long-term memory. The result may be that the UMS can possess a larger working memory that may facilitate SA. Additionally, the accuracy of UMS's long term memory recall may also improve all levels of SA because persistent storage can be more reliable and does not degrade over time.

Due to the limitations associated with human memory, humans tend to rely upon mental models, schemas, scripts, and heuristics. Specifically, heuristics allow humans to react with a fairly good probability of success based upon their prior experience. Humans tend to generalize existing mental models, schemas, scripts, and heuristics to unknown or similar situations often resulting in less than optimal performance (ref. 26). UMS memory may contain structures that are composed of mental models, schemas, and scripts as the underlying memory constructs. These constructs can be incorporated into the UMS and facilitate longer-term memory recall, which in turn can influence overall SA. UMSs may also have the memory and processing capacity to rely less on heuristics than their human counterparts, thus increasing the likelihood that the UMS will provide a high probability of mission success. Memory constructs of this nature will be necessary for UMS SA.

Human SA tends to suffer as the human's stress level increases. Often the discussion of human stress focuses on internal, cognitive stressors. UMSs do not encounter stress in this same manner. Humans can also encounter stress due to physical (e.g. fatigue) and environmental (e.g. bright light, intense heat) demands. A similar parallel exists for UMSs that can suffer from stressors that arise due to system and algorithmic limitations. System stress may be mechanically oriented and can occur when the UMS is stressed due to heat, wear, or inferior design and construction. Algorithmic stress may occur when the computation complexity reduces the ability to process information in a timely manner or results in a fragmentation of the UMS's memory. Both types of stress can result in reduced perceptual capabilities (Level 1 SA) and reduced ability to comprehend the situation (Level 2 SA).

Human SA is affected by both cognitive and physical workload. Similarly, workload will affect UMS SA. UMSs, like humans, have limited physical abilities that vary dramatically across systems. UMSs that are unable to obtain a particular physical configuration in order to obtain particular sensory percepts will encounter limitations in their SA. UMSs may also suffer from cognitive tunneling (ref. 26), like humans, when the system sensors focus attention on a particular percept set or on a demanding physical task, thus entirely consuming the systems available resources. UMSs may also suffer from a notion similar to cognitive workload due to limited processing capabilities and algorithmic limitations that hinder the system's ability to properly understand the perceived information. These limitations will arise as a result of the system's sensors, actuators, and software capabilities.

Humans are prone to a number of physical and cognitive errors, mistakes, and failures; similarly UMSs will suffer from physical and computational errors, mistakes, and failures. Currently, UMSs frequently suffer from any number of failures. Often failures are physical in nature and include situations where a sensor or actuator fails, the system's power source expires, the system's capabilities do not provide the physical capabilities to complete the assigned task, etc. UMS algorithmic failures may be considered similar in concept to human cognitive failures. UMS algorithms currently are very fragile and sensor data oscillation can result in an algorithm incorrectly classifying and processing the data. Human failures can result in reduced SA and often are a result of inaccurate or insufficient sensor/perceptual information; system failures will have similar implications for UMS SA.

Uncertainty and confidence play a pivotal role in the relationship between human SA and performance. Human uncertainty often manifests itself in the human's hesitation or failure to act. Frequently humans will continue to gather additional information in order to improve their awareness and confidence in their selected action in order to achieve the desired objective. UMSs must rely on their sensors, actuators, and software capabilities in order to modify their SA, hence the system's confidence and certainty levels. However, sensors and actuators introduce uncertainty into the perception (Level 1 SA) that is then integrated into the Level 2 and 3 SA. UMS sensor capabilities have considerably narrower field of views than human sensory capabilities thus further increasing the uncertainty associated with the UMS's SA. Finally, the software and algorithms may also introduce additional uncertainty. For example, algorithms may abstract the percept data prior to processing and then employ heuristics to generate further data abstractions. This process may introduce noise or lost data that result in higher uncertainty and lower confidence in the results.

Pew (ref. 11) classifies human SA into three categories; ideal, achievable, and actual SA. Ideal SA is an awareness of the entire situation. It is often unachievable with the given sensor capabilities. Achievable SA, a subset of ideal SA, captures the best level of SA for a given situation that is possible with the human's limited cognitive and perceptual capabilities. Actual SA represents the human's current SA, which is often a subset of achievable SA. This classification can be extended for UMS SA. Achievable SA may be defined and limited based upon the UMS's existing configuration. UMS achievable SA may also refer to all the potential information the system can attain to develop SA, whether or not that information is necessary given the current situation. A system with limited sensory, actuator, and software capabilities will have a narrower achievable SA that will result in a narrower actual SA. A narrow achievable SA may or may not result in a narrower actual SA. However, the ability to improve the achievable and ideal SA spaces by adding additional UMS capabilities may, but not necessarily, result in improved overall SA. There are, however, tradeoffs. Simply increasing the UMS's sensory and actuator capabilities may result in software/algorithmic stressors that result in limited or decreased overall SA. The new capabilities may result in additional information that is ignored due to limitations of the UMS's software capabilities, thus not improving actual SA. For example, the system is unable to process and interpret the newly available information, thus resulting in no improvement to overall SA.

It is well known that human vigilance levels drop dramatically over time and have an affect on overall SA. Human vigilance levels often drop due to boredom or fatigue, fortunately, UMSs do not suffer from such limitations. UMSs can inherently maintain persistent vigilance levels, levels that are necessary for tasks such as persistent surveillance, unless power or resource failures occur.

Similarities in the concepts of the inherent components of SA between humans and UMSs exist, however the underlying considerations tend to be dramatically different. As a result, UMS SA must accommodate these differences based upon the system's inherent capabilities and the components necessary to achieve UMS SA.

System Safety Implications

This paper has, thus far, presented an overview of human SA, how autonomy affects and can be affected by SA, and the notion of UMS SA. At this point, the discussion turns to the system safety implications pertaining to current autonomous unmanned systems and future systems that possess UMS SA.

As previously noted, humans are an integral component of currently deployed military systems, independent of autonomy level. Current semi-autonomous or "autonomous" UMSs are unable to fully understand their surrounding environment, assess the status of that environment, and execute appropriate actions. Therefore, humans are left to make the critical decisions. Humans, however, are not perfect and human SA is frequently affected by a number of external and internal factors that lead to humans taking short-cuts through the use of heuristics or to simply make sub-optimal decisions, thus carrying out sub-optimal actions. Frequently these issues are not severe enough to result in dire consequences.

The military theater is one in which humans must rely on their extensive training and experience in order to overcome the cognitive limitations this domain places on their capabilities. However, training and experience are often insufficient in the ever changing military theater and/or accidents occur, often as a result of high cognitive demands. While poor SA typically results in poor decisions and inappropriate actions, good SA cannot guarantee good outcomes. Although humans are not perfect, they are able to outperform many, if not most, current automated UMSs when the environment is sufficiently dynamic and complex.

While there have been a number of very important advances in the autonomous capabilities of UMSs, often the autonomous capabilities are limited in their applicability. For example, programming a target coordinate into a missile and the missile flying to that target once the human fires it. It is unusual with today's technology for the missile to fail at flying to the target location. However, the missile is not sensing the entire environment, including the target in order to determine if that target is legitimate; it is focusing, because it is programmed to do so, on the target location. For example, if the target is a school filled with children, the missile is unable to autonomously abort its mission. However, humans given a mission of transporting themselves to the same target location and destroying their target will likely abort their mission or seek additional feedback from their commanding officers once they learn that the target is a school filled with children. UMS SA has the potential to provide the missile with the capability to abort the strike and seek mission reassignment, thus leading to a higher level of safety.

UMS SA is intended to provide the system with the ability to improve its environmental perception in order to inform the decision making and projection processes such that the system will not blindly carry out actions. The ability for the UMS to understand the situation in order to override and seek guidance from a commanding human or system will be a safety critical consideration in order to ensure that friendly forces and civilians do not become casualties.

UMS SA will also address a number of safety concerns associated with autonomous systems. For example, if the UMS becomes disabled or is captured in enemy territory, the UMS must ensure that it returns itself to a safe state from which it cannot be manipulated or mined for classified information by the adversary. The UMS must have an understanding of its internal status as well as its environmental circumstances at a level that ensures the UMS does not enter the safe state during inopportune situations, but does enter the safe state when necessary. UMSs may have multiple levels of safe states that range from disarming itself to destroying all saved data and capabilities. The UMS's ability to disarm itself may be considered a low safety level example to ensure that the system does not cause undue harm to other entities, such as when the UMS returns from a mission and is entering camp. At the other end of the safe state spectrum, the UMS may need to essentially destroy itself to ensure the adversary does not access the system to garner classified information or turn the system into an enemy of the friendly forces.

UMS SA may be critical to the ever increasingly congested military theater communication spectrum that may result in future UMSs and the remote human supervisor's inability to communicate. Today's technology leaves the human with the ultimate control of the system, thus requiring established communication channels through which the human can safely direct the system. A system with SA should have the capabilities to direct its own actions when communications with the home base are lost. Thus the UMS will be able to return to its home base or continue the assigned mission. The result may be a higher level of mission completions and a reduced number of lost systems that cannot be remotely guided back to a safe location for recovery.

Future UMS deployments will likely involve deploying multiple systems with or without humans to complete a mission. These types of missions introduce new safety concerns that may be addressed by requiring UMSs have SA. Often missions are highly coordinated and multiple entities must work closely to ensure proper sequences of activities are carried out at the appropriate times and with the appropriate level of completion before additional activities can be completed. UMSs that are unable to perceive and understand their counterparts' activities (either human or unmanned) will be unable to act appropriately towards the successful completion of the mission's goals, thus placing the mission and the associated team members at risk. UMS SA may allow the system to understand the critical elements of the mission in order to assure appropriate coordination and mission success.

As the level of UMS automation increases, the human's role will become more of a supervisory role in which control and interaction with the UMS decreases. At the same time, it is anticipated that this same human operator will be required to supervise simultaneously an ever increasing number of UMSs. As the number of systems increases, it will become increasingly difficult for the human to maintain SA of each system's activities and mission status. The human's inability to maintain a complete awareness of all systems will lead to safety issues. For example, if the human is required to intervene or verify that a target has been acquired with inadequate information, unsafe decisions can result. UMS SA can facilitate the human supervisor's understanding of the remote situation, thus lowering the likelihood the human will make an ill-informed decision. An UMS with SA may be able to provide historical information that allows the human to understand how the current state of affairs was attained; the current environmental status; the system's status; etc. This information should be the result of the system's integration of the perceptions thus leading to the presentation of higher-level information in a format that is easily understood by the human. An UMS with SA may be able to communicate to the human supervisor a) a verification that the target location has been attained, b) a verification that the target is properly identified, c) a verification that the system possesses tactical situation awareness before releasing the munitions, c) an assessment of the battle damage, and d) a report of the mission status.

Conclusions

The purpose of this paper is to present the position that the development of situation awareness in unmanned systems is critical to the future safe deployment of such systems. Current unmanned systems rely heavily on the human element's situation awareness to ensure safe and successful mission completion. Unmanned systems continue to incorporate more autonomous capabilities; however, such capabilities tend to be specialized capabilities that do not afford the ability for the system to understand its environment, make safe and accurate decisions, and determine what actions to complete. Future unmanned systems will require capabilities beyond the specialized autonomous capabilities currently under development in order to ensure successful missions. Unmanned system situation awareness is a concept based upon incorporating the notion of human situation awareness into the unmanned system. Unmanned systems that incorporate situation awareness will be aware of their environment, mission goals, and rules of safe engagement.

The paper presented an overview of human situation awareness, including a discussion of elements that affect the human's level of situation awareness. The paper also presented a review of autonomy and a proposed interaction between the level of system autonomy, human interaction, and situation awareness levels across the unmanned system and human entities. The unmanned system situation awareness concept was briefly defined and elements that are inherent to unmanned system situation awareness were presented with regard to their effect on humans and unmanned systems. Finally, a number of safety implications were discussed relative to the deployment of future autonomous unmanned systems.

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