This proposal addresses four synergistic areas:
1. Function Allocation between UAS Pilot and System Automation;
2. Control Station Standards and Guidelines;
3. Crewmember Training and Certification and

DU will lead the proposed effort. DU and OSU are collaborating on areas 1 and 2; UND and KSU are collaborating on area 3; and NMSU will lead area 4.

DU will complete a systematic review of the function allocation, supervisory control, human-machine systems, and human-computer interaction literature, data sets, incident and accident reports, research studies, discussions, and gap analyses as well as standards, and guidelines with respect to UAS. Identification of functions and tasks for envisioned future systems will be completed. These will guide the development of recommended function allocation strategies for UAS human-machine functions. DU will use the output of the analysis to inform the minimum information requirements and control requirements for operator workstations. DU will also recommend future research related to function allocation strategies and controller station standards and guidelines.

For function allocation and UAS control stations, OSU will focus on technology support for adaptive contingency planning, both pre-flight and enroute, to deal with potential disruptions to
the initial flight plan in order to ensure that off-nominal scenarios can be managed safety and efficiently.

UND will conduct a literature review and a study to inform recommendations for training and certification for those individuals (pilots, sensor operators, others) necessary to operate large unmanned aircraft (55 pounds or greater) in the NAS. The research will identify aeronautical experience profiles that are associated with the efficient learning and retention of UAS piloting skills. The performance will begin to inform the FAA as to the essential competencies for the training and certification requirements for future UAS operations.

KSU will conduct research to inform recommendations for training and certification for those individuals (pilots, sensor operators, others) necessary to operate small unmanned aircraft (less than 55 pounds) in the NAS. This research proposes evaluating such standards for pilots (both external pilots (EPs) and internal pilots) of civil and public operations of sUAS.

NMSU will focus on the establishment of visual observer (VO) training and observer requirements. NMSU will inform training and qualification guidelines for VOs who support UAS operations. The research is guided by an ethnographic analysis of UAS operators and instructors.

1.0 Background

1.1 Function Allocation between UAS Pilot and System Automation

As mentioned in the SOW, function allocation is a process which examines a list of functions that the human-machine system needs to execute in order to achieve operational requirements, and determines whether the human, machine (i.e., automation), or some combination should implement each function. Considerations for function allocation include assumptions of human knowledge, skills, abilities; potential workload; control link performance; information availability; task speed; FAA aircraft certification approval and operational approval; and many other factors.

As mentioned in the SOW, the use of automation is a key enabler for the integration of UAS into the NAS. Due to the remote location of the pilot and the wide array of uses of UAS, control stations may need to facilitate pilot control of a UAS via new and different automated functions (e.g., identifying and providing support for awareness of surrounding traffic and objects, automation to support extremely long duration flights, automation that manages communication functions), as well as more intelligent automation than what is in operation today. Function allocation has many key implications on safety and performance and must be addressed first in order to address control station design, pilot and crew training and certification, and many other standards work. There is a large research base of information about human factors issues associated with automation systems; however, there is a need to review that literature to identify the specific human factors requirements that need to be addressed in certifying civil UAS automation systems. Function allocation strategies will help determine levels of automation across aircraft type, airspace, phase of flight, and normal and non-normal conditions.
1.2 Control Station Standards and Guidelines

As mentioned in the SOW, the UAS control station performs functions normally associated with the aircraft flight deck. There is a need for an evaluation of the regulatory requirements (minimum standards) and guidance for the flight deck of manned aircraft to determine what, if any, of those requirements should be minimum requirements for the control stations for UAS. Areas for evaluation include, but are not limited to, information requirements (as a result of function allocation), control station size and egress capability, and redundant control capabilities such as using another control station or portable device (laptop or tablet) in case the primary control station cannot be utilized due to loss of power, fire, or other emergency. As a result of function allocation research, the information needed by the pilot to perform those functions can be determined and the strategies to display that information via the human-machine interface (HMI) can be developed. As a result of the minimum information required by the pilot, minimum requirements for control station size, habitability, and ingress/egress capability can then be developed. Furthermore, this research can then be leveraged to develop pilot training and certification requirements.

The control of unmanned air systems present a set of human factors related challenges that should be considered in developing the recommended minimum standards and design guidelines for UAS control stations. As UAS pilots receive information regarding the state and health of their aircraft solely through electronic displays, they have reduced sensory cues as compared to pilots of conventional aircraft (Williams, 2008). Auditory information, visual and peripheral vision cues, spatial and vestibular information, proprioceptive and kinesthetic information, smell and related sources useful to conventional pilots are not easily available. This situation makes it difficult for UAS pilots to recognize and diagnose anomalous flight events that could endanger the safety of the flight. In addition information related to loss of data link, an anomalous event associated only with unmanned aircraft, is critical to UAS safety, and thus information such as strength of data link connection, becomes critical.

1.3 Crewmember Training and Certification

As mentioned in 1.1 function allocation has many key implications including pilot and crew training and certification. In 1.2 the aspect of this research related to control stations can be leveraged to develop pilot training and certification requirements. Unfortunately, as mentioned in the SOW, currently there is no general industry pilot training or pilot certification standard for UAS pilots and UAS support personnel (e.g., sensor operators, ground support personnel, mission commanders, visual observers, etc.) to operate in the NAS. Individual organizations in industry and government have implemented their own training programs on an as-needed basis, even though pilot training and certification requirements for manned aircraft are well established. The UAS community has proposed a number of strategies for pilot training and certification, with many arguing that traditional practical test standards and stick-and-rudder skills no longer apply due to the current and potential automation used on UAS. Some argue that “video game” and computer experience is important, or that a UAS pilot needs skills and rules, as opposed to knowledge. Other cases are made that UAS pilots do not need a pilot certificate, or a case is made for a type rating specific to the system and/or the operation. There is a lack of research available to support unique UAS pilot or support personnel training and certification.
requirements. This research will help inform pilot training and certification requirements to support safe operation of UAS in the NAS, and associated standards development efforts.

The Academy of Model Aeronautics (AMA) has developed a Memorandum of Understanding (http://02b954f.netsolhost.com/docs/FAA-AMA_MOU.pdf) that addresses unmanned vehicles in respect to recreational flight operations. The most recent small UAS rule Notice of Proposed Rulemaking (NPRM) (https://www.faa.gov/uas/nprm/) addresses the issues related to unmanned aircraft (under 55 pounds). Other than competencies that have been developed by the military or governmental agencies (NASA and DHS/CBP), no civil training standards exist for unmanned aircraft weighing 55 pounds or greater.

The University of North Dakota (UND) in cooperation with the Air Force Research Laboratory (AFRL), and in conjunction with Aptima and the Group for Organizational Effectiveness, has been addressing UAS training standards for some time. In July 2015, a three-and-a-half year study led to the creation of the Mission Essential CompetenciesSM (MECs), a document identifying those competencies (knowledge, skills, abilities) required for pilots and sensor operators of large UAS. In August 2015, Sinclair College in cooperation with the Air Force Research Laboratory will begin the process for identifying the Mission Essential Competencies for small UAS. Both of these efforts should be leveraged to aid an investigation into FAA requirements for UAS pilots, sensor operators, and other crewmember training and certification standards.

While these may be considered watershed research efforts, they fall short of the generalizable training and certification standards that exist for manned aircraft and do not take into account the function allocation and control station design guidelines that will be developed as a part of this research effort. There needs to be a test of the functions, identified under 1.1, that the human-machine system needs to execute in order to achieve operational requirements. The human factors challenges that affect UAS pilots that are identified under 1.2 also need testing. Changes in control stations whether auditory, visual, spatial or kinesthetic must be tested in order to understand the ramifications for pilot training and certification. Any future innovations have inherent in them a need to examine how those improvements affect training and certification requirements. Therefore, an empirical study needs to examine these new and distinct aspects to better inform the FAA on training and certification requirements and is included as a part of this proposal.

1.4 Visual Observer Requirements.

As mentioned in the SOW, there is also a lack of research to develop visual observer training and certification requirements. Visual observers are used in many current UAS operations to assist in protecting the UAS from other air traffic and hazards. Regulations regarding their use and function were created on a very ad hoc basis. Research is required that will help establish clearly defined limitations for the use of visual observers and to assist in the creation of procedures and training for their effective employment. Questions regarding the need for certification of visual observers require answers. There needs to be clearly defined rules for a variety of environmental (e.g., clouds, fog, dust), lighting (e.g., day, night, dusk) conditions, and type of operations. More
clearly defined guidelines for the use of visual observers will benefit rule makers in establishing and approving new UAS operations.

Although VOs have been a critical component of the vast majority UAS operations in the United States, detailed definition of VO roles, responsibilities and performance expectations have yet to be crystalized. As stated in the Unmanned Aircraft Systems (UAS) Operational Approval policy notice (publication N8900.227, FAA, 2013), VOs are expected to be responsible for: 1) helping UAS pilots keep the aircraft with visual line of sight (VLOS), 2) exercising see-and-avoid responsibilities by maintaining compliance with 14 CFR § 91.111, 91.113, 91.115, and 3) preventing the unmanned aircraft (UA) from creating a collision hazard. To ensure that these functions can be performed adequately in VOs must be able to scan the airspace effectively and make accurate and reliable estimates of relative aircraft position, assess the need for a potential avoidance maneuver, and communicate that need to the UAS pilot in a timely manner. To date, VO training curricula and qualification criteria vary depending on type of aircraft, the operating environment, and the experience of the UAS operating organization.

The demand for standardized and effective VO training has become more important with the announcement of the FAA’s recent notice of proposed rulemaking (NPRM; 14 CFR Part 107) for civil UAS operations. The proposed language states that flights are limited to small UAS (sUAS) operated within VLOS for the UAS pilot during daylight hours in visual meteorological conditions (VMC). While the nature of some simple operational tasks allows sUAS pilots to maintain the unmanned aircraft (UA) in their line of sight throughout flight, as task difficulty increases so does the cognitive load on the pilot. This can result in fewer opportunities to maintain visual contact with the UA and perform see-and-avoid tasks. So, in the following scenarios, and perhaps others, civil UAS operations will necessitate a visual observer (14 CFR Part 107, as cited in Williams & Gildea, 2014):

a. Operations conducted above 400 feet AGL OR beyond 1500 feet laterally from the pilot-in-command must have at least one dedicated visual observer, even if VLOS can be maintained by the pilot-in-command (PIC).

b. Operations conducted above 400 feet AGL AND beyond 1500 feet laterally from the pilot-in-command must have at least one dedicated visual observer, even if VLOS can be maintained by the PIC.

c. When the PIC determines that one or more VOs are necessary flight crewmember to maintain the safety of the operation.

d. When the PIC is (expected to be) in a “heads-down” or any situation that precludes the ability to perform see-and-avoid duties.

e. When the PIC is within an enclosure, at least two VOs are required.

f. Any Group C, D, or E aircraft operations and all operations conducted within Class B airspace.

The NPRM also specifies the following guidelines for visual observers (14 CFR Part 107, as cited in Williams & Gildea, 2014):

a. Medical standards and operational limitations in this proposed rule ensure that the pilot and VO are capable of scanning the airspace of intended operations. Aids to vision, such as binoculars, must be used with care to ensure that the total overall viewing of the airspace
isn’t inadvertently limited. An FAA second-class medical certificate is required for commercial operations.

b. In order to be certified, applicants for a Visual Observer Certificate would be required to pass a practical test with either a certified sUAS pilot or instructor.

c. The VO will be required to always know where the sUAS is and to discern the attitude and trajectory in relation to conflicting traffic, weather, or obstacles. Because of the level of vigilance that would be required in scanning the surrounding airspace, a visual observer would be prohibited from supporting more than one aircraft operation at a time.

d. The VO will need to be in close proximity (within 10 feet) to the PIC and should be able to communicate directly, exchange non-verbal signals, and share the same relative visual references. A backup communications system is required for operations where the PIC is in an enclosure and cannot directly see at least one visual observer.

e. §107.77 Visual observation. Notwithstanding §107.53(c), the PIC must be able to see or ensure that a VO is able to see the aircraft throughout the entire flight well enough to: Know its location, determine its attitude and direction to exercise effective control, observe the airspace for other air traffic or hazards, and determine its altitude.

f. Operations, sometimes referred to as “daisy-chain,” “relay,” or “leap-frogging,” would not be authorized under this proposed rule.

g. Operations conducted under this subpart must fly no farther laterally from the pilot-in-command and/or visual observer, whichever is less, for each Group identified in §107.13: (1) Group A or B: 1500 feet (2) Group C, D, or E: 2640 feet (½ statute mile).

2.0 Scope

2.1 Research questions

As per the SOW the main research questions are:

- What are the recommended function allocation strategies for UAS human-machine functions?
- What are the recommended minimum standards and design guidelines for UAS control stations?
- What are the recommended crewmember training and certification requirements, to include pilots and other crewmembers?
- What are the recommended visual observer training and certification requirements?

The main research questions are refined in Section 3.2.

3.0 Research Framework

3.1 Research Requirements

The work is requested by the FAA via a Statement of Work A7 (FAA COE Task: A11L.UAS.24 UAS Human Factors Control Station Design Standards). The questions are listed in Section 2.1 and the requirements are listed here.
Requirement 1: Develop recommended function allocation strategies for UAS human-machine functions.

Requirement 2: Develop recommended minimum standards and design guidelines for UAS control stations.

Requirement 3: Develop recommended crewmember training and certification requirements, to include pilots and other crewmembers.

Requirement 4: Develop recommended minimum standards and design guidelines for visual observers.

3.2 Research Mapping.
The mapping of the research questions to be answered in this proposed work follow.

3.2.1 Function Allocation between UAS Pilot and System Automation:

a) What are the recommended function allocation strategies for UAS human-machine functions?
b) What measures should be used for making strategy tradeoffs?
c) What context related to the human operator, the automation, the task(s) to be completed, and the external environment may limit the efficacy of each function allocation strategy?
d) What are alternative conceptual approaches for allocation of pre-flight and enroute contingency planning and management tasks to different people? Should there be the equivalent of dispatchers (for larger commercial operations) and/or flight planning services (to support smaller operations) who are distinct from pilots, or should some of the functions that are today allocated to these individuals be changed (for example with the pilot taking on more dispatcher functions)?

3.2.2 Control Station Standards and Guidelines:

a) What are the recommended minimum standards and design guidelines for UAS control stations?
b) What are the function allocation strategies that support those standards and guidelines?
c) What task contexts require different sets of information for UAS supervisory control?
d) What task contexts require different control designs for UAS supervisory control?
e) What interaction schemes support multi-tasking contexts for UAS operators?
f) What environmental contexts require different sets of information for UAS supervisory control?
g) What environmental contexts require different control designs for UAS supervisory control?
h) What workstation functions and interaction designs are necessary to support new associated roles?

3.2.3 Crewmember Training and Certification:
a) What are the recommended training and certification requirements for pilots of UAS that would allow for the safe and efficient operation of those platforms in the NAS on a par with what is currently permitted in the NAS for similar manned aircraft operations?
b) What are the recommended training and certification requirements for other crewmembers of UAS that impact the safe and efficient operation of those platforms in the NAS?

3.2.4 Visual Observer Requirements:

a) What are the recommended training and certification requirements for VOs to effectively assist sUAS pilots with see-and-avoid (in order to comply with 14 CFR § 91.111, 91.113, 91.115) in a manner that optimally mitigates the risk of conducting civil UAS operations to other aircraft or persons on the ground, on par with what is currently permitted in the NAS for similar manned aircraft operations?
b) What are the UAS pilots’ and VOs’ functional roles and relationship in various operational settings and scenarios, including flights at different times of day and in varying meteorological conditions?
c) To what degree do VOs typically maintain VLOS with the UAS in various environmental conditions? Can VOs successfully scan the airspace for other traffic when tasked with this requirement?
d) At what point do VOs typically advise UAS pilots of incoming air traffic and of the potential for collision? How well do they perform at these tasks?

3.2.5 Limitations. The research will have the following limitations:

a) The research samples for the large UAS studies will be drawn from University of North Dakota students, which may not reflect the larger population of pilots, sensor operators, or other crewmembers who operate large UAS.
b) The research for the large UAS studies will not include actual UAS flights in large UAS platforms. Only simulators will be used.
c) The ethnographic study for VO will involve a sample of UAS pilots, VOs, and instructors, since an exhaustive sample is not feasible or practical.

3.3 Research Review.

3.3.1 Function Allocation between UAS Pilot and System Automation

Function allocation is the design decision where functions are assigned to humans and automation. Automation to support operators comes in many forms (e.g. information acquisition; information analysis; decision and action selection; and action implementation) and the way it can be coupled with a human operator also varies (Parasuraman, Sheridan, & Wickens, 2000). For example with respect to information acquisition, with more automation remote sensing systems can run autonomously or operators can set parameters or constraints to guide the process while at the more manual end, operators can more manually direct sensing using a human-computer interface. Varying automation levels have been applied across systems incorporating information analysis; decision and action selection; and action implementation. Different systems integrate different types of automation in the same system (such as TCAS II which
automatically acquires traffic information, analyzes it, and recommends a control action but does not execute it) and employ multiple levels of automation for the same task (such as the many ways navigation can be implemented on a modern glass cockpit).

For years, researchers have known that UASs require function allocation considerations that conventional aircraft do not. For example, the latency in the control of a UAS means that manual control is problematic. Bates & Hilliard (1997) and Worsch et al. (1996) showed that response delays even close to 1 second do not allow for satisfactory manual control of aircraft and thus responsive automation is required.

Different types and levels of automation vary across the task operators need to achieve (see for example Lee & Mueller, 2013; Consiglio, Chamberlain, Munoz, & Hoffler, 2007; Wing, et al., 2013). For UAS operators, the tasks automation can support range from path planning (pre-flight and enroute), flight control, navigation, guidance, communication, monitoring and managing systems, and detecting and avoiding aircraft and other entities (FAA, 2013; JPDO, 2012; Barnes, et al, 2000) as well as those related to more specialized activities such as search and rescue (Adams, et al, 2009).

Failure modes including engine loss and data link loss and non-normal conditions including stalls and unusual attitude come into play. In addition the external environment including traffic and atmospheric conditions such as wind, weather, turbulence, and icing as well as lighting and noise are important to consider.

In assessing recommended function allocation strategies for UAS human-machine functions, one must consider the methodology to evaluate options. Current human factors descriptions of function allocation can be too abstract or conceptual to guide specific design decisions. Sometimes only response times and heuristics are used to evaluate the criteria, such as how automation can decrease or increase workload depending on circumstances, rather than a detailed analysis in context. Thus an analysis of function allocation must necessarily consider the metrics to be used to measure performance and the function allocation strategies need to be compared using those metrics. As described in Pritchett, Kim and Feigh (2014), measuring function allocation strategies can be evaluated using eight categories: (a) workload/taskload arising from all sources, (b) mismatches between responsibility and authority, (c) stability of the humans’ work environment, (d) coherency of the function allocation, (e) interruptions, (f) automation boundary conditions, (g) system cost and performance, and (h) humans’ ability to adapt to context.

Taskload metrics include immediate workload or taskload relative to thresholds, as well as considering workload spikes or longer-duration periods of workload saturation. Methods to assess the workload associated with a given function allocation can include subjective ratings in multiple dimensions, such as measuring via psychophysical scaling (Dixon, Wickens, & Chang, 2005) and multidimensional rating systems (Hart & Staveland, 1998; Potter & Bressler, 1989). Mismatches between responsibility and authority can be quantified statically by the number of functions with mismatches between responsibility and authority and dynamically by the number and combined duration of the induced monitoring actions (Lee & Bass, 2015). Stability of the work environment can be measured by the extent to which the function allocation allows human
team members to predict (and potentially plan for) upcoming actions. A particular function allocation strategy may distribute functions in a way such that one agent will trigger the requirement for another to act. Thus, a person’s ability to predict his or her activities can have great value for system stability; although some unpredictability may be inherent to the work environment, a function allocation should not limit the person’s ability to predict and schedule his or her own activities. Coherency addresses the interleaving of functions assigned to humans and automation that creates obstacles to each agent’s being able to perform assigned functions. An allocation may require significant coordination or idling as one waits on another, or when workload may accumulate. Interruptions is another important measure, particularly when unexpected situations require immediate action or when one operator is interrupting another. Function allocations should not divide functions between agents such that they create the need for interruptions. Another metric, automation boundary conditions, recognizes when the immediate situation violates the fixed set of boundary conditions in which the automation is operable and thus is appropriate to use. Cost is dependent on the domain objectives such as fuel burn. Adaptation addresses situations where the human’s behavior does not meet what is expected by the function allocation.

There is a literature on approaches to contingency planning for military applications of UASs and for limited applications of UASs in the NAS. There is a more substantial literature on human factors issues associated with the roles of dispatchers, flight service providers and traffic managers dealing with traditional aircraft in the NAS. The literature review will catalog known approaches and considerations, and leverage the existing identification of relevant gaps in 14 Code of Federal Regulations (CFR).

Whether an operation assigns ultimate responsibility for the contingency planning to an individual UAS pilot who then flies the UAS, creates a new position such as the UAS planning pilot who is distinct from the real time pilot, or creates non-pilot positions analogous to dispatchers and flight planners in current aircraft operations, the necessary functions need to be defined and will be strongly influenced by the capabilities of the automation. Thus, research is needed to define these necessary contingency planning and adaptive planning functions and to identify and evaluate alternative strategies for allocating those functions to people and automation. One additional important component of this work is the need to define the interactions between the UAS contingency planner and FAA Traffic Flow Management (TFM) functions, as TFM advisories will have a strong impact on contingency planning for UAS operations.

3.3.2 Control Station Standards and Guidelines

UASs currently lack key capabilities required to routinely integrate with the current Air Traffic Management (ATM) system and minimum standards and guidelines do not exist for civil UAS control stations. There is a need to develop new and/or modified regulations, standards, and guidance for control stations to support safe integration of UAS into the NAS. In particular focused attention is required for situations unique to UAS including the reduced level of sensory information (Williams, 2008) and managing off nominal or contingency events, especially those that are specifically related the unique UAS communications architecture (Fern, Rorie & Shively, 2014a; 2014b) and related functions.
Researchers have proposed various ways to augment sensory information for UAS pilots. Design interventions to address the loss or degradation of sensory information is the use of other sensory modes or by the enhancement of visual displays. Many advocate design concepts regarding the incorporation of multisensory alert and warning systems into UAS control stations. Researchers such as Sklar and Sarter (1999) and Calhoun and Draper (2006) and others discuss the possibility for an enhanced use of cues from multiple modalities such as tactile feedback and this research should identify such enhancements necessary with respect to minimum requirements. The use of force feedback through a haptic control device is hypothesized to increase situation awareness, especially in situations where visual information is insufficient (Lam, Mulder, & van Paassen, 2007).

Considerable work has already been invested in developing display concepts for vehicle mission management. For example primary displays to support horizontal and vertical situation awareness, as well as other summary and alerting displays have been incorporated into many systems (see for example, Rowe, et al., 2009). Display navigation concerns have been addressed with filtering and other design concepts. Integrated displays using features such as timelines (Cummings & Guerlain, 2007) and perspective displays (AGI, 2006) have been implemented. However identifying the minimal required information is not completed.

Other display concepts are being investigated. For example auditory display technologies such as spatial auditory displays could be integrated for UAS operations (Simpson, Bolia, & Draper, 2004). Synthetic vision systems (SVS) integrated with camera information also show promise (Calhoun, Draper, Abernathy, et al., 2005; Draper, Nelson, Abernathy, & Calhoun, 2004).

With respect to guidelines, there are design choices that need to be made for the display of control of information. In addition care needs to be taken to reduce display clutter. One approach involves mapping variables for a given entity to attributes of a particular multi-attribute graphical shape or symbol so as to conserve display space and support monitoring. Standards such as MIL-STD-2525B (DoD 2005) suggest symbology for this convention. Researchers such as Smallman and colleagues (2005) are tailoring symbology for UAS control to enhance information presentation.

However these solutions may exceed the minimum requirements for UAS operations in the NAS. To provide support for standards, (1) relevant use cases need to be identified, (2) alternative human/automation design solutions need to identified, (3) cognitive task analyses (CTA) need to be completed, and (4) empirical evaluations and field studies need to be conducted. This proposed work focuses on use cases and design solutions with a limited focus on CTA emphasizing the most critical use cases and design solutions that have implications for standards.

3.3.3 Crewmember Training and Certification

Crewmember training and certification requirements do not exist for civil and public use UAS operations. The goal of this research effort is to provide recommendations to the FAA to help establish training and certification requirements for UAS pilots, sensor operators, or other crewmembers.
Most people would agree that pilots with previous knowledge and experience will learn and retain related information to a greater degree than individuals with less background knowledge and experience. A critical question today, with the expanding importance of UAS, is the degree to which previous pilot training will facilitate the acquisition of expertise in piloting a UAS platform. Do the expectations of future UAS pilot knowledge and skills and the function of future control stations change the training and certification requirements for future pilots? An empirical study, taking into account the function allocation and control station design guidelines as determined in this study, will better answer these questions and allow for training and certification recommendations to allow for the safe and efficient operation of UAS platforms in the NAS.

While the proposed research will examine the impact of previous flight experience on the acquisition of UAS flight skills it is important to tie those experiences into scenario-based exercises. UND has a pool of approximately 1600 aviation students ranging from no experience to Airline Transport Pilots with thousands of hours of flight experience. Differences between groups of pilots can inform researchers as to the impact of their previous flight experiences on the acquisition of UAS skills. Observation of choke points and the analysis of performance data, as discovered through experimentation, will better help to inform the training and certification requirements of future UAS pilots.

The scenarios will be developed after considering the findings of the previous function allocation and control station research efforts in this study. UND has the ability to develop task appropriate scenarios and the infrastructure to test the findings from DU and OSU. The development and testing of these scenarios will be delayed until later in the study to allow for the fullest assimilation of the findings from the function allocation and control station analyses.

3.3.4 Visual Observer Requirements.

The initial minimal set of VO requirements were published in 2005 (AFS-400, UAS Policy 05-01) and have since evolved to include the responsibility assisting the UAS pilot with the task of see-and-avoid (in compliance with 14 CFR § 91.111, 91.113, 91.115; publication N8900.277, FAA, 2013) (Williams and Gildea, 2014). While VOs ability to effectively detect incoming air traffic has been verified empirically, their performance in predicting imminent mid-air collisions has been mixed (Crognale, 2009; Dolgov, Brooks, & Hudson, 2015; Dolgov et al., 2012).

To better understand VOs’ capabilities, the three aforementioned studies can be supplemented by earlier forward-facing observer research conducted in the context of manned aircraft operations. Although much has been done in this domain (see Baldwin, 1973), Williams and Gildea (2014) elucidate that models of visual aircraft detection, such as the Spatial Standard Observer (Watson, Ramized, & Salud, 2009), are doomed to fall short. This is due to the overall complexity of the problem and the extreme variance in operational scenarios. Factors negatively affecting see-and-avoid include the small visual angle of air traffic, inadequate visual accommodation, poor visual acuity at distance, as well as poor contrast against simple and complex backgrounds. Thus, despite knowing the extent of human perceptual (e.g., acuity, depth perception) and cognitive abilities (e.g., vigilance, collision estimation), Williams and Gildea (2014) conclude that “It is not...
possible to [predict] the visible range of an aircraft without [reliably] knowing its size, shape, orientation, brightness, and the brightness of the background sky.” Moreover, knowing that a VO is capable of detecting an aircraft, does not guarantee they will actually see it in some future scenario.

In addition to detecting incoming aircraft and maintaining VLOS with the UA, the safety of UAS operations is also greatly impacted by UAS pilots’ and VOs’ ability to reliably predict imminent mid-air collisions. This is illustrated by VOs’ struggles in predicting mid-air collisions despite nearly perfect intruder aircraft detection rates, as reported by Crognale (2009) and Dolgov et al. (2012). However, the latest empirical findings from Dolgov, Brooks, and Hudson (2015) demonstrate that VOs can predict imminent collisions with high rates of accuracy, achieved by: 1) augmenting the their responsibilities to include the prediction of incoming aircraft intrusions into progressively larger zones centered on the area of UAS operations, 2) reducing the search area to one quarter of the total airspace, and 3) relaxing the requirement to maintain constant VLOS with the UA. Moreover, VOs’ performance remained high for sUAS platforms of multiple sizes (Raven and Puma), at operations at altitudes varying from 500 feet AGL to 1500 feet AGL, during various times of day (morning, dusk, night), and with the introduction of artificial light pollution during night operations.

While predicting mid-air collisions is a highly specialized task, in the realm of experimental psychology, the general phenomenon of predicting the arrival of a moving object at a specific place has been called coincidence anticipation (e.g., Gottsdanker, 1952). While this line of research reaches back more than sixty years, no laboratory studies have been devoted to the prediction of the coincidence of two moving objects. Thus, the aforementioned empirical UAS observer studies are the initial forays into this phenomenon, which demands more scholarly attention in the form of laboratory and field research.

In addition to see-and-avoid related responsibilities, VOs roles in UAS operations are further clarified in documents such as the standard certificate of authorization (COA) template and the recent civil UAS operations NPRM. Furthermore, the discussion section of Williams and Gildea’s (2014) recommends a series of VO guidelines that establish a foundation for further clarifying VOs’ role in UAS operations, and specifies pre-operational activities, operational recommendations, and observer certification and training recommendations. Notably, they also state that it is unclear whether VOs can effectively perform the tasks of scanning the sky for incoming traffic and predicting imminent mid-air collisions while simultaneously maintaining visual contact with the UAS, as is required by the NPRM. Thus, as Williams and Gildea shrewdly identify, it is uncertain whether all of the proposed guidelines align with industry practices and the needs of civilian stakeholders. Furthermore, the NPRM specifies that VOs are to inform the pilot every time they visually disengage from the UA. If VOs consistently disengage in order to scan the sky for incoming traffic, the likely result of the above requirement is a very noisy “cockpit.” Taken together, these observations necessitate a new approach that investigates VOs in their natural settings rather than in contrived experimental scenarios.

The publications cited in Williams and Gildea’s (2014) and others will inform the proposed research.
3.4 Research Approach.

Numbering reflects task numbers in institutional PI documentation. Not every institutional PI has each planning and documentation task listed.

3.4.1 Research Task Plan (RTP) (all DU Task 1, OSU Task 1)

The researchers will provide a research plan for the development and execution of the research to be conducted. The RTP will include key project milestones, TIMs, reports, and deliverables. The RTP will allocate tasks and responsibilities among the participating universities and identify a point of contact (POC) for each. The plan shall include a kick off meeting to review the task requirements, execution roles and responsibilities and performance expectations.

3.4.2 Technical Interchange Meetings (all DU Task 2))

The researchers and the FAA will conduct Technical Interchange Meetings (TIMs) throughout the performance of this work as needed to review progress. TIMs may include an overview of task progress and milestones against the RTP, candidate approaches and technologies identified and/or assessed, evaluation criteria, preliminary results from evaluations, initial assessment of data collected, and discussion of lessons learned.

3.4.3 Quarterly reports (all DU Task 3)

In quarters where technical reports are not already due, quarterly reports will be delivered highlighting progress for the quarter and plans for the next quarter.

3.4.4 Function allocation literature review (DU Task 4).

DU will conduct a search of the literature for relevant papers related to UAS function allocation and related terms. The literature will include fielded systems, systems under development, research studies, incidents, accidents, pilot observations, discussion forums, and existing regulatory gap analyses of the Federal Aviation Regulations. In addition task specific searches will also be conducted. Databases and citation indexes searched as well as any hand-searched individual sources will be documented.

The titles and the abstracts of the identified articles will checked against pre-determined criteria for eligibility and relevance. Taxonomies are useful for guiding the findings (see for example Nehme, Crandall & Cummings, 2007). To organize the findings, a taxonomy will be developed based on the type of aircraft, the function allocation, the demographics of the participants, the tasks included, the procedures and training, any associated the apparatus, the external context, the measures collected, and the experimental design (if any). With respect to the type of aircraft, features may differ not only based on general categories but may differ due to any manipulations included as part of the study. Features of focus include the types of automation included, the automation modes of operation tested (including degraded modes), and the function allocation(s) tested automation as well as the measures considered. With respect to the demographics, features include what experience participants before the study as well as what training was included in
the study. With respect to the task environment, critical features include what tasks are included and which include automation support. The task environment also relates to the frequency of tasks as well as their overlap. For simulated operations with UASs, it will include additional features about the simulation environment as well as features associated with the experimental design. With respect to the environment the taxonomy will address external factors such as traffic and lighting. Benefits, limitations and open issues related to the function allocation will be documented.

DU will use two researchers for the development of the taxonomy, the screening of documents and the assignment of document using the taxonomy.

3.4.5 Function allocation strategy and future research recommendations (DU Task 5 and OSU Task 3).

Based on the reviewed literature DU will develop recommended function allocation strategies for UAS human-machine functions. This will include preliminary task analyses for function allocated to pilots. When there are gaps in the literature that preclude making a definitive recommendation, DU will suggest areas for future research.

3.4.6 Planning literature review (OSU Task 2)

OSU will conduct a literature review focusing on pre-flight contingency planning and adaptive planning.

3.4.7 Control Station literature review (DU Task 6)

DU will conduct a search of the literature for relevant papers related to UAS control stations and human-computer interaction. The literature will include fielded systems, systems under development, research studies, incidents, accidents, pilot observations, discussion forums, and existing regulatory gap analyses of the Federal Aviation Regulations. In addition task specific searches for UAS pilot tasks will also be conducted. Databases and citation indexes searched as well as any hand-searched individual sources will be documented.

As with the function allocation review, a taxonomy will be developed to organize the findings. DU will use two researchers for the development of the taxonomy, the screening of documents and the assignment of document using the taxonomy.

3.4.8 Control Station Standards and Guidelines and recommendations for future research (DU Task 7)

Based on the results of the function allocation recommendations and on the control stations literature review, DU will develop recommendations for control station standards and guidelines. When there are gaps in the literature that preclude making a definitive recommendation, DU will suggest areas for future research.

3.4.9 Crewmember Training and Certification literature review (UND literature review)
A comprehensive UAS literature review will be performed including Parts 61 and 67 of the FARs, United States Code (Public Laws/Acts), Advisory Circulars (including draft AC), AIM, FAA Orders, manuals and Policy statements, other Federal sources (i.e. USAF, Army, Navy, NASA), foreign Treatment/reports on these topics (UK, Australia, New Zealand, Germany, NATO, ICAO, etc.), Judicial Treatment (court decisions from litigation, if any), Private and Industry Sources, AIAA, Elsevier, ASTM, SAE, IEEE, AOPA, NOAA, ATCA, Inc. and MITRE. After this portion of the literature is assembled, the function allocation findings and the control station design guidelines, developed as a part of this research effort, will be used to qualify and expand upon the literature review. A careful analysis will help determine the probable impact of the information on future training and certification needs of UAS pilots and associated crewmembers.

3.4.10 Phase 1 Literature review (KSU)
KSU has proposed to inventory 14 CFR Part 61 for relevance to sUAS operations by both public and civil entities. This phase will address each sub-part and will address whether each one is relevant, with justification provided. KSU personnel that are FAA-certificated pilots will complete this effort. These personnel are also experienced UAS operators with a diverse background in remote control and sUAS operations. One of the researchers is a former instructor and evaluator of the DoD’s largest UAS, the RQ-4 Global Hawk. Once 14 CFR Part 61 is analyzed, KSU researchers will identify gaps in existing manned training and certification standards for VLOS operations. This phase will culminate in a report providing the review and gap analysis results.

3.4.11 Empirical study of pilot procedures for UAS (UND)
A study of UAS pilots will be conducted using students at the University of North Dakota’s John D. Odegard School of Aerospace Sciences. Each pilot participant will receive training in a UAS simulator to the extent that each pilot can fly a scenario created to explore future intelligence, reconnaissance, and surveillance UAS procedures as determined by the previous findings from the function allocation and control station design portions of this study. This could include, but not be limited to, mission planning, use of checklists, aircraft handling, navigation procedures, new methods of presenting information to pilots, etc.

3.4.12 Ethnographic Study of UAS Operators. (NMSU Task 1)
While three recent efforts empirically studied visual observers’ see-and-avoid abilities (Crognale, 2009; Dolgov et. al, 2012; Dolgov, Brooks, and Hudson, 2015), none have been aimed at clarifying their role in civil UAS operations nor evaluated training regimens. Furthermore, although the cited studies measure VO performance in various experimental settings, they do not investigate how see-and-avoid and other operational tasks are divided between UAS pilots and VOs in real-world settings. To address this R&D gap, the proposed research will recommend guidelines for the role VOs should play in UAS operations by reviewing relevant existing/forthcoming literature and executing an ethnographic analysis of UAS VOs, pilots, and instructors/trainers.
Ethnography is an immersive, qualitative research protocol that involves observing a group of people in their natural settings. Through the use of field notes, recordings, and interviews, data about UAS pilots’ and VOs’ training and functions during operations in various contexts will be collected, analyzed, and interpreted; trainers and instructors will also be investigated. To ensure a broad sample of UAS operators, the sites of where ethnographic study will occur will include the NMSU Flight Test Center (Las Cruces, NM), the Jornada Experimental Range (Las Cruces, NM); Holloman Air Force Base (Alamogordo, NM), UND’s Center for Unmanned Aircraft Systems (Grand Forks, ND), AeroVironment, Inc. (Monrovia, CA), the Mesilla Valley Model Airplane Club (Las Cruces, NM), and among others. The findings from the ethnographic study will be used to design the protocol for Task 2, and will also be relayed to PIs of the other sub-projects, allowing for more informed control station design standards.

3.4.13 Final report (all (Drexel Task 8))

A final report at the end of the project period will be delivered. Institutions that complete their work before the end of the project period will deliver the institution’s final report within 30 days of the end of the institution’s project period.

4.0 Government Furnished Information

The government will provide pointers to FAA Technical Reports related to:

a) Function Allocation between UAS Pilot and System Automation
b) Control Station Standards and Guidelines
c) Crewmember Training and Certification
d) Visual Observer Requirements.
e) Policy, directives, orders, notices, interim changes, criteria, standards and other operational and technical guidance for UAS operational approval.
f) Policy, directives, orders, notices, interim changes, criteria, standards and other operational and technical guidance for UAS systems safety, qualification, certification and airworthiness.
g) Policy, directives, orders, notices, interim changes criteria, standards or other operational and technical guidance for UAS pilot and visual observer qualification.
h) Technical reports, assessments, and surveys for relevant government-sponsored and conducted research in the areas of, but not limited to:
   a. UAS pilot and VOs’ performance, training, and certification requirements
   b. UAS MOPS
i) Other releasable information, papers, or products that in the view of the FAA may affect the scope of this research.
j) The government will assist the researchers by sanctioning selected meetings with UAS industry partners, operators and manned aviation stakeholders to enable the gathering and validation of needed data.
k) The government will assist researchers, where necessary, by designating the ASSURE researchers as FAA-sponsored SMEs to the appropriate organizations, working groups and symposia as needed to ensure access.

5.0 Period of Performance/Projected Schedule
The technical period of performance for this task order is from the Date of Award to September 30, 2017 (as award is expected Sept. 1, 2015, the performance period is expected to be 25 months).

### 6.0 Proposed Outcomes

This section includes the schedule and a list of desired products.

<table>
<thead>
<tr>
<th>Proposed Outcomes</th>
<th>Description</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kickoff Meeting</td>
<td>A kick-off meeting to review the task requirements, execution roles and responsibilities and performance expectations.</td>
<td>T + 15 days</td>
</tr>
<tr>
<td>Research Task Plan</td>
<td>Task 1 (all). Description of research plan for the development and execution of the task.</td>
<td>T+ 45 days</td>
</tr>
<tr>
<td>Technical Interchange Meeting (TIM)</td>
<td>The UAS COE performer and FAA will conduct Technical Interchange Meetings (TIMs) throughout the performance of this work as needed to review progress via TELCON or Video Teleconference. Minimum monthly.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Minutes/Notes</td>
<td>Minutes/Notes capturing the discussions and action items form each Technical Interchange Meetings (TIMS)</td>
<td>3 business days after the TIM</td>
</tr>
<tr>
<td>Quarterly Status Report</td>
<td>The report will provide the status of the research desired products, schedule, budget and risks.</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Draft Technical Report</td>
<td>DU and OSU. Function allocation and controller station initial draft.</td>
<td>T + 6 months</td>
</tr>
<tr>
<td>Technical Report</td>
<td>DU and OSU. Function allocation and controller station literature review.</td>
<td>T + 12 months</td>
</tr>
<tr>
<td>Technical Report</td>
<td>DU and OSU. Function allocation recommendations and workstations guidelines</td>
<td>T + 24 months</td>
</tr>
<tr>
<td>Technical Report</td>
<td>NMSU. Ethnographic Study of UAS Operators and Trainers.</td>
<td>T + 15 months</td>
</tr>
<tr>
<td>Technical Report</td>
<td>OSU. Literature review with recommendations</td>
<td>T + 12 months</td>
</tr>
<tr>
<td>Technical Report</td>
<td>UND. Literature review begins at T+45 and continues until the UND Empirical Study begins. Empirical study begins after an analysis and inclusion of the Function allocation recommendations and the control station guidelines.</td>
<td>T + 24 months</td>
</tr>
<tr>
<td>Final Report</td>
<td>Final report for all 4 areas</td>
<td>T+ 25 months</td>
</tr>
</tbody>
</table>

In addition to support new research, the following is beyond the current scope:
- Refinement of task analyses
- Development of storyboards to capture the broader range of scenarios that merit deeper investigation.
- Completion of cognitive walkthroughs using these additional storyboards.
- Implementation of a functional prototype to empirically evaluate alternative function allocations, automation capabilities and control station design features.
- Empirical evaluation of competing function allocations, forms of coordination, automation capabilities and control station design features
- Refinement of guidelines and the development of requirements that can, through V&V, eventually be codified in the form of MOPS.
- Formation of a decision model (using principles explored in this proposal) to simulate UAS pilots to enable optimal function allocation
- Use of a decision model to improve control station design in early-design stages
- Formation of games for UAS users to improve task-related processes
- A follow on to UND’s Phase 1: Phase 2 of the proposed research will include undergraduate students attending the University of North Dakota. Up to 10 participants will have received a Private Pilot Certificate. The private pilot participants will have accumulated fewer than 100 flight hours at the time of their entry into the study. The assumption is that the commercial/instrument/CFI group from phase 1 will have a level of aeronautical knowledge, judgment, and skill that exceeds the participants with a Private Pilot Certificates.
- A follow on to UND’s Phase 2: The participants for the proposed research will include up to 10 commercial pilots with more than 500 total flight hours.
- To verify and validate the findings of NMSU’s ethnographic study of UAS operators, a series of field studies will be conducted that will focus on the efficacy of different VO training regimens and VO’s performance in various lighting and meteorological conditions. Additionally, a series of laboratory experiments will further evaluate people’s ability to successfully predict the coincidence of two moving objects.

7.0 List of Universities and Individuals Involved in the Project

Please list the Universities and individuals from those universities involved in the project.

**DU**
Ellen Bass, Professor,  
Patrick Craven, Research Faculty  
Douglas Lee, Research Engineer  
Graduate Research Assistant (TBD)

**NSMU**
Igor Dolgov, Associate Professor, Engineering Psychology  
Dallas Brooks, Director, UAS Research & Development, Physical Science Laboratory  
Tim Lower, Chief Pilot, UAS Flight Test Center  
Robert McCoy, Systems Integration Lead, UAS Flight Test Center
Joseph Millette, Flight Operations, UAS Flight Test Center
LeeAnna Covey, Graduate Research Assistant, Engineering Psychology
Elizabeth Kaltenbach, Graduate Research Assistant, Engineering Psychology

OSU
Phil Smith, Professor
Post-doc (TBD)

UND
John B. Bridewell, Professor of Aviation
Thomas Petros, Professor of Psychology

KSU
Mark Blanks

8.0 Estimated Level of Effort and Associated Costs

<table>
<thead>
<tr>
<th>Performer: Drexel University</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td><strong>Performance Period</strong></td>
</tr>
<tr>
<td>Sept 1 2015- Aug 31, 2016</td>
<td>12 months</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Sept 1 2016- Aug 31, 2017</td>
<td>12 months</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Sept 1 2017- Sep 30, 2017</td>
<td>1 month</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25 months</strong></td>
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<table>
<thead>
<tr>
<th>Performer: University of North Dakota</th>
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<tr>
<td><strong>2015</strong></td>
<td><strong>12 months</strong></td>
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<tr>
<td><strong>2016</strong></td>
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<td><strong>Total</strong></td>
<td><strong>15 months</strong></td>
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<tr>
<td>Performer: New Mexico State University</td>
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<tr>
<td>----------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Year</td>
<td>Performance Period</td>
</tr>
<tr>
<td>2015</td>
<td>3 months</td>
</tr>
<tr>
<td>2016</td>
<td>12 months</td>
</tr>
<tr>
<td>Total</td>
<td>15 months</td>
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<table>
<thead>
<tr>
<th>Performer: Ohio State University (24 months)</th>
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</thead>
<tbody>
<tr>
<td>Year</td>
<td>Performance Period</td>
<td>Tasks</td>
</tr>
<tr>
<td>Sept 1, 2015- Aug 31, 2016</td>
<td>12 months</td>
<td>OSU Task 1 – RTP; OSU Task 2 - Literature review</td>
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<tr>
<td>Sept 1, 2016- Sept 30, 2017</td>
<td>13 months</td>
<td>OSU Task 3 – Phase 1 Function allocation strategy and future research recommendations OSU Task 3 Phase 2 - Function allocation strategy and future research recommendations</td>
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<tr>
<td>Total</td>
<td>25 months</td>
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<th>Performer: Kansas State University</th>
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<tr>
<td>Year</td>
<td>Performance Period</td>
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</tr>
<tr>
<td>2016</td>
<td>9 months</td>
<td>Lit. review; Phase 1</td>
</tr>
<tr>
<td>2017</td>
<td>9 months</td>
<td>Phase 1 Final Report</td>
</tr>
<tr>
<td>Total</td>
<td>24 months</td>
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</tr>
</tbody>
</table>

3 References


Dolgov, I., Brooks, D. & Hudson, B. (2015). Report of the evaluation of the safety of small unmanned aircraft system (sUAS) operations in the national airspace system (NAS) at night, Year 2. Report delivered to the Federal Aviation Administration, Unmanned Aircraft Systems Integration Office.

Dolgov, I., Marshall, D. M., Davis, D., Wierzbanowski, T., & Hudson, B. (2012). Final report of the evaluation of the safety of small unmanned aircraft system (sUAS) operations in the national airspace system (NAS) at night. Report delivered to the Federal Aviation Administration, Unmanned Aircraft Systems Integration Office.


