<table>
<thead>
<tr>
<th>ASSURE UAS Research and Development Program Research Abstract</th>
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</thead>
<tbody>
<tr>
<td><strong>FAA Research Requirement:</strong> A11L.UAS.22 Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations</td>
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<tr>
<td><strong>UAS Research Focus Area:</strong> Low Altitude Operations Safety</td>
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<tr>
<td>FAA Management Team:</td>
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<tr>
<td>UAS COE PM: Sabrina Saunders-Hodge, ANG-C2</td>
</tr>
<tr>
<td>UAS COE Dep. PM: Paul Rumberger, ANG-C2</td>
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<tr>
<td>ASSURE Co-Principal Investigators (PIs):</td>
</tr>
<tr>
<td>Dr. Mark Askelson, Professor, University of North Dakota, Dallas Brooks, Director, UAS Research &amp; Development, New Mexico State University</td>
</tr>
<tr>
<td>Other ASSURE Performers: None</td>
</tr>
<tr>
<td>Other ASSURE External Advisory Board Principal Investigator (if applicable): N/A</td>
</tr>
<tr>
<td>Other ASSURE External Advisory Board (EAB) Performers: N/A</td>
</tr>
<tr>
<td>Classified or Security Related Work: No</td>
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**EXECUTIVE SUMMARY:**

Currently, there is no Federal Aviation Administration (FAA)-sponsored activity or research focusing on the concept of a limited approach to Unmanned Aircraft Systems (UAS) Detect and Avoid (DAA) (airborne and/or ground-based) that could enable BVLOS operations of small Unmanned Aircraft Systems (sUAS) in the NAS under specific operational limitations. The objective of this project is to provide a research basis for the FAA to potentially expand access for sUAS in limited portions of the National Air Space (NAS) and still achieve a level of safety equivalent to manned aircraft operating in a similar manner. This research and associated operating limitations will facilitate the safe and efficient UAS applications that Association for Unmanned Vehicles Systems International (AUVSI) says will make up to 80% of the future commercial UAS market.

This effort is divided into two primary tasks:

1) **Operational Framework** – Development of an operational framework that defines the environment and conditions under which the recommended requirements will enable sUAS operations BVLOS. This step is informed by identified use cases for sUAS BVLOS operations that fit the assumptions and limitations listed in section 2.2.

2) **Approach Comparison** – Comparison of ground-based and airborne approaches to sUAS DAA systems employed within the operational framework. This comparison will support requirements development for ground-based and/or airborne DAA based upon selection of the most feasible approach. This task will consider both DAA systems and DAA component technologies (e.g. sensors, avoidance algorithms and procedural flight planning/de-confliction tools). The research for this task will consider a variety of criteria such as technology maturity, cost, and size, weight, and power (SWaP) limitations in determining technologies that are an appropriate fit for application within the defined operational framework. The performance of selected systems and component
technologies will be evaluated with appropriate recommendations for configuration and application within the defined operational framework.

1.0 Background

14 CFR § 91.113, Right of Way Rules (except water operations), states that “when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft.”

However, FAA Order 8900.1, Section 16 states that “the absence of an onboard pilot means that the “see-and-avoid” regulations of 14 CFR part 91, § 91.113 cannot be satisfied…consequently, to ensure an Acceptable Level of Safety (ALoS), UAS flight operations require an alternative method of compliance (AMOC) or risk control to address their “see-and-avoid” impediments to safety of flight and any problems they may generate for ATC.”

To address this challenge, the FAA engaged Radio Technical Commission for Aeronautics (RTCA’s) Special Committee 228 (SC-228) to develop a set of minimum operational performance standard (MOPS) for UAS Detect and Avoid. Phase 1 of the DAA MOPS is targeted to address UAS Group 3 and above (> 55 lbs.) and therefore is unlikely to result in a technology that is compatible with small UAS (sUAS, Groups 1 and 2, 0-55 lbs.), particularly when operating at relatively low speeds (< 100 kts) and altitudes (<1,200’ AGL). The SC-228 MOPS may also pose a challenge for sUAS in terms of size, weight, and power requirements.

This shortcoming is partially addressed in the FAA’s notice of proposed rulemaking (NPRM) for small UAS operations (14 CFR Part 107). However, the proposed language is limited to sUAS operated within visual line-of-sight (VLOS) of the UAS pilot during daylight hours. To enable beyond visual line-of-sight (BVLOS) operations, additional criteria must be developed that demonstrate how such operations could be conducted safely.

2.0 Scope

2.1 Research Questions. The proposed research is intended to answer the following research questions and any related questions that may be developed through the research process:

a. What are the requirements for an airborne or ground based Detect and Avoid system compatible with sUAS (55 lbs and less) operating in limited portions of the NAS in order for the sUAS pilot to comply with 14 CFR 91.113 in a manner that does not increase the risk to other aircraft, or persons on the ground, beyond that currently present in the NAS for similar manned aircraft operations?

b. What are the requirements for a software algorithm(s), if any, to implement these requirements?

c. What are the most feasible airborne or ground-based sensors that are capable of meeting these requirements and are compatible with sUAS SWaP and level-of-certification constraints?

This pre-proposal does not obligate the University of North Dakota or New Mexico State University to this project. Upon request of the sponsor, a formal and properly authorized proposal will be submitted.
2.2 **Assumptions and Limitations.** The research will assume the following operating limitations:

a. Day, visual meteorological conditions (VMC) operations only.
b. A potential for night VMC operations enabled by new standards and rules.
c. UAS operations will initially be limited to Class G and Class E airspace. Additional airspace may be evaluated as necessary.
d. UAS operations will be conducted from the surface to 500’ AGL, with additional evaluation of the potential for operations up to 1,000’ AGL.
e. UAS operations will be conducted over other than densely populated areas, unless UAS complies with potential criteria or standard that demonstrates safe flights over populated areas.
f. UAS will not be operated close to airports or heliports. ‘Close’ is initially defined as greater than 3 miles of an airport unless permission is granted from ATC or airport authority. A distance of greater than 5 miles will be examined if needed to support an appropriate level of safety.
g. UAS operations will be restricted to within radio line of sight (RLOS) of a single, fixed ground-based transmitter.
h. Some safety-based design and/or configuration requirements may be specified (aircraft painted in a highly-visible paint scheme to facilitate identification by other aircraft, strobe lights, etc.)
i. Small UAS are potentially designed to an Industry Consensus Standard and issued an FAA Airworthiness Certificate or other FAA approval.

3.0 **Research Framework**

3.1 **Research Requirement.** The PIs will define the research to be executed and present a research task plan (RTP) to the government specifying the proposed research tasks with associated milestones and deliverables for completion. The PIs, in collaboration with identified ASSURE team members (hereinafter referred to collectively as “the researchers”) will identify and apply the necessary expertise to perform the research. The research will focus upon two primary tasks:

a. **Task 1: Development of an Operational Framework.**

The researchers will develop an operational framework that defines the environment and conditions under which the recommended requirements will enable sUAS operations BVLOS. Examples of constraints may include:

1) **Environment:** geographic limitations, population density, altitude, day/night, weather.
2) **Aircraft performance:** UAS min/max airspeeds, climb/descent/turn rates, payload capacity, endurance.
3) **Safety:** risk acceptability, collision avoidance (CA) and self-separation (SS) minima, contingency management.
4) **DAA System Requirements/Performance/Reliability**: size, weight and power restrictions, communications range/reliability, sub-system redundancy, overall system latency, sensor performance, notification/alerting.

The operational framework will be informed by an analysis of actual and proposed use cases for aviation operations (both manned and unmanned) that are primarily conducted from the surface to 500’ AGL. An additional set of use cases that span from the surface to 1,000’ AGL may also be included. The functional and performance requirements of these use cases inform both the functional requirements for the UAS, and the potential threat posed from other users of the operational environment.

**Milestones:**
- 1st COE-Sponsored Industry Technical Exchange Meeting (ITEM)
- Operational Framework Technical Report and Assessment

b. **Task 2: Conduct a Comparison of Approaches.**

The researchers will conduct a comparison of approaches that assesses the feasibility and effectiveness of selected DAA technologies applied within the operational framework specified in 3.1a. The assessment will be informed by OEM-supplied performance data, information gleaned from a series of industry technical exchange meetings (ITEMs) and selected V&V activity results. A range of ground-based and airborne technologies will be assessed separately and in various combinations to determine which best enables the sUAS pilot to comply with 14 CFR 91.113 in a manner that does not increase the risk to other aircraft, or persons on the ground, beyond that currently present in the NAS for similar manned aircraft operations.

Candidate DAA technologies may include active and passive radar (ground or airborne), electro-optical/infra-red (EO/IR), acoustic, and cooperative technologies such as ADS-B. The characteristics that may be considered in this comparison include:

- a) Risk reduction contribution
- b) Technical/performance capabilities, limitations, and reliability
- c) Communication requirements
- d) SWaP for both airborne and ground-based approaches
- e) Feasibility (cost, scalability, ease of installation)
- f) Spectrum usage/limitations
- g) Expected enhancements in the near future

Limited verification and validation (V&V) testing of selected technologies and configurations may be performed within the constraints of the project’s time and budget (to include assistance-in-kind from industry).

**Milestones:**
- 2nd COE-Sponsored Industry Technical Exchange Meeting (ITEM)

This pre-proposal does not obligate the University of North Dakota or New Mexico State University to this project. Upon request of the sponsor, a formal and properly authorized proposal will be submitted.
• Report Comparing DAA Approaches Within the Operational Framework

For this and the previous task (the two primary tasks), significant direct and supporting work enables two additional research phases identified in the “Scope” section of the statement of work:

• The development of proposed minimum performance standards for sUAS Detect and Avoid systems; and
• The development of proposed operating rules, limitations and guidelines

Elements of both of these areas are needed in order to support the recommendations called for in this project. While not deliverables for this effort, this research is expected to substantially inform future work in both areas.

In addition to the primary tasks, the researchers will accomplish two supporting tasks as directed by the SOW:

c. Task 3: Technical Interchange Meetings (TIMs)

The researchers and the FAA will conduct Technical Interchange Meetings (TIMs) throughout the performance of this Task 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. TIMs will be scheduled in accordance with the projected schedule in Section 5 of this proposal.

d. Task 4: Research Task Plan (RTP)

The researchers will provide a research plan for the development and execution of the research to be conducted under two primary sub-tasks. The RTP will include key project milestones, ITEMs, TIMs, reports, and deliverables. The RTP will allocate tasks and responsibilities among the participating universities and identify POCs for each. The plan shall include a kick off meeting to review the task requirements, execution roles and responsibilities and performance expectations.

To perform this research, expertise is required in the following areas:

• UAS operations
• DAA
• Systems engineering
• Requirements development
• Software development

The combined NMSU/UND team provides expertise in all of these areas.

3.3 Research Review.

This pre-proposal does not obligate the University of North Dakota or New Mexico State University to this project. Upon request of the sponsor, a formal and properly authorized proposal will be submitted.
Detect and avoid has been long considered the primary barrier that must be overcome to enable routine operations of UAS in the national airspace system (NAS). Formal efforts to integrate UAS in the NAS have almost universally included some work in DAA, including key multi-agency efforts such as the NASA-sponsored ACCESS 5 (2004-2006), the RTCA Special Committee 203 (SC-203, chartered 2004, disbanded 2013), the RTCA SC-228 (2013-present) ASTM Committee F-38, (2010-present), and the FAA/DoD/NASA/DHS UAS Science and Research Panel (2010-present). All of these groups, and countless other efforts in government, industry and academia, have turned their attention to addressing the challenge of DAA. Many have produced documents that support key functions such as definition of terms, definition of the operating environment, roadmaps to integration, and minimum performance standards. These documents include:


- Federal Aviation Administration, Sense and Avoid (SAA) for Unmanned Aircraft Systems (UAS), October 9, 2009.

- **DO-320 (10 Jun 2010), Operational Services and Environmental Definition (OSED) for UAS, June 10, 2010.**


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While approaches have differed, the fundamental issues are largely agreed upon—most notably defining how UAS can comply with the terms contained in 14 CFR 91.113, *Right of Way Rules: Except Water Operations*.

14 CFR 91.113, paragraph (b), states: “When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.”

The rule pivots on the definition of two terms:

“see and avoid” prescribes a level of vigilance required that is relevant to avoidance of other aircraft. Persons operating an aircraft must “see” an aircraft in time to maneuver sufficiently to avoid a potential collision.

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“well clear” is a non-specific assessment of a safe distance to be maintained from other aircraft.

For aircraft without an on-board pilot, quantification is needed to define threshold values for “see,” “avoid” and “well clear” so that an alternate (electronic) means of compliance may be defined, designed, manufactured and validated. While a large number of papers, symposia and workshops have devoted efforts to defining these terms, two of the most significant are the FAA’s Sense and Avoid (SAA) Workshops and the SAA Science and Research Panel (SARP) Well-Clear Workshops.

In 2009, the FAA’s first SAA Workshop Report summarized the task:

“The ability to ‘see and avoid’ other aircraft is part of the regulations governing the general operation of aircraft in the National Airspace System (NAS) under Title 14 Code of Federal Regulations (14CFR), Part 91, §91.113. Although the requirements stated in the regulations are described as right of way rules, the intent is to avoid collisions and remain “well clear” from other aircraft (emphasis added). While these operating regulations are specific, the concept of “well-clear” is non-specific in nature and allows for a pilot’s subjective assessment when performing maneuvers for this purpose. This is problematic for designing an engineering solution to meet the ‘see and avoid’ requirement. As a result, constructs are required to better describe the functions in terms that can be implemented in a technical solution to meet the regulatory requirements. One such construct is the determination of when an action is needed to comply with those requirements. There are boundaries (or thresholds) that determine when action is needed to remain well clear and avoid collisions with other aircraft. These thresholds are not fixed boundaries in space, but more dependent on time to closest point of approach (CPA), closure rate, maneuverability and other factors. These thresholds are unique for each aircraft being tracked in the vicinity of the UAS and change over time as an encounter progresses.”

In 2013, the second FAA SAA Workshop reached a series of conclusions that suggest an approach to quantifying the key factors supporting a potential DAA system. Those conclusions included:

1. The well clear threshold is fundamentally a separation definition.
2. Horizontal tau, defined as horizontal range/range-rate should be used as the separation measure for evaluating performance of a UAS Self-Separation system.
3. Minimum vertical separation for well clear violation should be consistent with current operational procedures and collision risk (concluded to be within the range of 250 to 500 ft).
4. This guidance would apply to UAS using their SAA Self-Separation capability, and would not be expected to be applied to judge manned aircraft separation performance.

In 2014, the SARP Well-Clear Workshops further refined these recommendations as part of an extensive analysis and recommended a quantified method of compliance for UAS to remain
“well clear.” The SARP adopted five well-clear principles that align significantly with the SAA Workshop report:

1. Well Clear is a separation standard between airborne traffic.
2. A UAS Self-Separation system (i.e., any technical system providing the function of remaining Well Clear to the UA) needs quantitative definitions of the separation minima for this standard, informed by operational acceptability considerations as well as by analytical derivations. This guidance does not apply to manned aircraft separation performance.
3. The quantitative definition of Well Clear separation minima should be based on acceptable collision risks in consideration of its operating environment (e.g., airspace class and associated Air Traffic Control separation standards) and compatibility with aircraft collision avoidance systems.
4. A time-based parameter (time-to-CPA) with minimum separation thresholds (CPA) should be used as the basic separation measure for defining horizontal Well Clear separation minima for a UAS Self-Separation system.
5. Distance, adjusted as needed by closure rate and horizontal separation, should be used as the basic separation measure for defining vertical Well Clear separation minima for a UAS Self-Separation system.

The clear alignment between the FAA Workshops and the SARP Well-Clear Workshops, along with review and concurrence by the RTCA Special Committee 228 (SC-228), indicate broad acceptance that “well clear” is a separation standard, and for UAS should be measured horizontally in terms of time-to-CPA with a minimum distance threshold (expressed as “modified tau”), and vertically in terms of distance. In addition, all supported the conclusion that a quantified method of compliance should be applied only for UAS DAA from other aircraft, and not applied to the pilot of a manned aircraft.

The SARP’s recommendation, supported by member agencies DoD, FAA and NASA, specified a modified tau (τmod) of 35 seconds, a minimum horizontal distance (DMOD) of 4000 ft, and a minimum vertical separation of 700 ft. The SARP’s recommendation was accepted by RTCA SC-228, which with FAA concurrence subsequently reduced the vertical separation minima to 450 ft in order to increase operational acceptability.

Figure 1. SARP Well Clear Recommendation for UAS. Derived from Cook, S., Brooks, D., Cole, R., Hackenburg, D., and Raska, V., Defining Well Clear for Unmanned Aircraft Systems, November 14th, 2014.

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The progress of the FAA Workshops and the SARP Well Clear Workshops represent broad-level acceptance of key assumptions and conclusions regarding DAA for UAS. While these assumptions and conclusions inform the research for this task, they do not fully exploit the advantages and characteristics of the operational framework.

Both the FAA Workshops and the SARP were approaching the DAA problem from a perspective of broad application over multiple classes of airspace and with a goal of standards-based system certification. This perspective effectively limited the potential for near-term fielding (under current technology) to larger UAS platforms—those capable of supporting the size, weight and power (SWaP) requirements of larger and more complex DAA systems. In fact, the SARP’s recommendation specifically applied to aircraft (UAS Group 3/4/5) that are larger and that fly higher and faster than the UAS targeted in the scope of this task.

<table>
<thead>
<tr>
<th>UAS Groups</th>
<th>Maximum Weight (lbs) (MGTOW)</th>
<th>Normal Operating Altitude (ft)</th>
<th>Speed (kts)</th>
<th>Representative UAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>0 – 20</td>
<td>&lt;1200 AGL</td>
<td>100</td>
<td>Raven (RQ-11), WASP</td>
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<tr>
<td>Group 2</td>
<td>21 – 55</td>
<td>&lt;3600 AGL</td>
<td>&lt; 250</td>
<td>ScanEagle</td>
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<tr>
<td>Group 3</td>
<td>&lt; 1320</td>
<td>&lt; FL 180</td>
<td></td>
<td>Shadow (RQ-7B), Tier II / STUAS</td>
</tr>
<tr>
<td>Group 4</td>
<td>&gt;1320</td>
<td>Any Airspeed</td>
<td></td>
<td>Fire Scout (MQ-8B, MQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)</td>
</tr>
<tr>
<td>Group 5</td>
<td></td>
<td>&gt; FL 180</td>
<td></td>
<td>Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)</td>
</tr>
</tbody>
</table>

Figure 2. UAS Groups. Department of Defense, Unmanned Aircraft Systems Airspace Integration Plan, May 29, 2011.

The SARP recommendation also heavily weighted the impact of factors such as the resolution advisory threshold values of TCAS (Traffic Collision Avoidance System) in determining recommended minima. While a key safety system on air-carrier and high-end general aviation aircraft, evidence suggests that TCAS is not widely used on aircraft that routinely operate at extremely low altitudes and away from airports (e.g. agricultural sprayers, Emergency Medical System aircraft).
Furthermore, and perhaps most significantly, the approach of the FAA SAA Workshops and the SARP Well Clear Workshops could not leverage the significant risk-reduction factors available under the assumptions of this study. Specifically, day VFR, low-altitude, lower airspeed UAS operations that are not conducted near airports or over densely-populated areas, all while remaining within radio line-of-sight (RLOS) of a single ground-based transmitter. These factors provide a highly-mitigated risk environment, and thus to some degree reduce the safety mitigation burden assigned to the DAA system in the overall safety equation.

It is noted that these efforts are driven, in part, by significant economic benefits that will be realized when sUAS are integrated into the NAS. AUVSI has estimated that integration of UAS into the NAS would produce an economic impact, in agriculture alone, of > $2 billion/year. Since most agricultural operations would be conducted using sUAS operating at low altitudes and would be greatly enabled by BVLOS capability, the motivation is clearly significant. Moreover, many other operations would be greatly enabled by sUAS DAA, including package delivery, pipeline and bridge inspection, search and rescue, etc. Thus, the need for progress in this area has both economic and humanitarian drivers.

Section 3.4 addresses how the researchers’ approach will attempt to exploit the safety advantages provided by the assumptions of this study, in combination with other potentially beneficial safety mitigations that may be applied through the proposed operational framework. The resulting operational framework is expected to provide a reduction in the safety mitigation burden assigned to DAA systems operated within the framework, potentially enabling near-term BVLOS UAS applications using current or near-horizon DAA technology.

3.4 Research Approach.

The objectives of this effort will be achieved through the following.

- An extensive literature review to identify relevant:
  - UAS, aviation, and other research that supports operational framework establishment and requirements definition (e.g., effectiveness/limitations/safety contribution of visual acquisition and tracking, effective radio line-of-sight limitations at 500’ and 100’ altitudes);
  - Approaches that are being considered for sUAS DAA (e.g. detection/fusion/tracking methods, threat evaluation, avoidance algorithms) by research leaders in government, industry and academia;
- Industry Technical Exchange Meetings (ITEMs) with key stakeholders in industry, government and academia. ITEMS will collect requisite information to support development of the operational framework (e.g., sUAS use cases, existing aviation users in the operational framework space, risk factors and potential mitigations) and to conduction a comparison of DAA approaches (e.g., available technologies/maturity levels for sensors, processing systems and algorithms);
- Limited validation and verification testing (to potentially include simulation) that supports baseline requirements definition for DAA systems within the operational framework. V&V

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focus areas may include performance minima, collision-avoidance and self-separation thresholds, or other criteria;

- An extensive analysis that is divided into the two primary task-driven phases of operational framework definition and comparison of approaches:
  - The operational framework definition will include identification of all relevant assumptions, identification of physical factors such as visual and radio line of sight limitations that impact the operational framework, and delineation of use case characteristics that are relevant to this task.
  - The comparison of approaches will be informed by the operational framework, use cases, existing and emerging approaches to DAA, and supporting V&V efforts (including those conducted by other groups including the SARP and SC0228).
- Presentation of results to gather feedback from stakeholders.

A detailed research/task plan is one of the deliverables, and a detailed spending plan will be provided with the full proposal.

The researchers recognize that this task contains multiple dependencies where key values are yet undefined. For example, selection of a supported risk acceptability level (e.g. acceptable level of safety (ALoS), replacement risk over visual observer, or a risk ratio) drive the performance requirements for both the unmanned aircraft and the associated DAA system. In some cases, research that will define these key values is being conducted by other organizations with complimentary requirements. These include the UAS Science and Research Panel (SARP) sUAS BVLOS workshops, NASA’s Unmanned Traffic Management (UTM) project for sUAS, NASA’s UAS in the NAS project, and FAA’s Pathfinder project. This research will thus ensure tight integration with, and leveraging of the research from, these efforts.

4.0 Government Furnished Information

The government will furnish the following information to the performer:

a) Policy, directives, orders, notices, interim changes, criteria, standards and other operational and technical guidance for UAS operational approval.

b) Policy, directives, orders, notices, interim changes, criteria, standards and other operational and technical guidance for UAS systems safety, qualification, certification and airworthiness.

c) Policy, directives, orders, notices, interim changes criteria, standards or other operational and technical guidance for UAS pilot qualification.

d) Technical reports, assessments, and surveys for relevant government-sponsored and conducted research in the areas of, but not limited to:
   a. Low-altitude use cases (manned and unmanned)
   b. UAS MOPS
   c. DAA

e) Other releasable information, papers, or products that in the view of the FAA may affect the scope of this research.

f) The government will assist the researchers by sanctioning selected meetings with UAS industry, operators and manned aviation stakeholders to enable the gathering and validation of
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5.0 Period of Performance/Projected Schedule

The technical period of performance for this task order is from the Date of Award (listed in table as T) through September 30th, 2016.

<table>
<thead>
<tr>
<th>Proposed Outcomes</th>
<th>Description</th>
<th>Date Due</th>
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<tbody>
<tr>
<td>Kickoff Meeting</td>
<td>NMSU/UND Review task requirements, proposed approaches, execution roles and responsibilities and performance expectations.</td>
<td>NLT T + 15 days</td>
</tr>
<tr>
<td>FAA/COE Technical Interchange Meeting (TIM)</td>
<td>NMSU/UND Review progress via TELCON or Video Teleconference.</td>
<td>Monthly beginning 30 days after kickoff meeting</td>
</tr>
<tr>
<td>TIM Minutes/Notes</td>
<td>NMSU/UND Minutes/Notes capturing the discussions and action items form each Technical Interchange Meetings (TIMS)</td>
<td>3 days after the TIM</td>
</tr>
<tr>
<td>Research Task Plan (RTP)</td>
<td>NMSU/UND A detailed description of research plan for the development and execution of the two primary tasks. Includes key projects milestones, ITEMs, TIMs, reports, and deliverables. The plan will allocate tasks and responsibilities among the participating universities and identify POCs for each. The plan shall include a kick off meeting to review the task requirements, execution roles and responsibilities and performance expectations.</td>
<td>T+ 45 days</td>
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<tr>
<td>COE-Sponsored Industry Technical Exchange Meeting (ITEM)</td>
<td>NMSU/UND Engage industry stakeholders to provide detailed use case information for low-altitude aviation operations (both manned and unmanned) to inform the sUAS operational framework (unmanned) and potential threat environment (manned).</td>
<td>T + 2 months</td>
</tr>
<tr>
<td>COE-Sponsored Industry Technical Exchange Meeting (ITEM)</td>
<td>NMSU/UND Engage industry to provide state-of-the-art on DAA approaches, technologies, and performance data to inform comparative approaches.</td>
<td>T + 3.5 months</td>
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</tbody>
</table>

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Approaches Technical Report and Assessment depends upon the DAA Approaches ITEM. Finally, the Final Report depends upon all of the preceding tasks illustrated in Fig. 3.

Figure 3. Timeline with milestones and activities.

In list form, the outcomes are:
- Kick-off Meeting, 10/15/2015
- TIMS, Monthly
- Research Task Plan, 11/13/2015
- Operational Framework ITEM, 12/1/2015
- DAA Approaches ITEM, 1/13/2016
- DAA Approaches Technical Report and Assessment, 7/1/2016
- Final Report, 9/30/2016

Follow on research is expected. In subsequent effort, the focus is expected to be development of requirements that can, through V&V, eventually be codified in the form of MOPS.
8.0 List of Universities and Individuals Involved in the Project

University of North Dakota:
Mark Askelson, Professor (Atmospheric Sciences & UND UAS Center), PI
Ron Marsh, Assoc. Professor (Computer Sciences), Software Requirements
Hassan Reza, Assoc. Professor (Computer Sciences), Formal Requirements Development
Will Semke, Professor (Mechanical Eng.), DAA
Naima Kaabouch, Assoc. Professor (Electrical Eng.), DAA and Software Requirements
Chris Theisen, NP UAS TS Research Director, DAA
Scott Kroeber, UAS Research Assistant (UND UAS Center), DAA
Doug Olson, Research Assistant (UND UAS Center), DAA & C2
Trevor Woods, UAS Lead Instructor/Airspace Manager (UND UAS Center), UAS Pilot

New Mexico State University:
Dallas Brooks, Director, UAS Research & Development, PI
Henry Cathey Jr., Engineering Director, Physical Science Laboratory
Igor Dolgov, Associate Professor, (VO Performance), Operational Framework Researcher
William Graves, Research Scientist (VO Performance), Operational Framework Researcher
Travis Farley, RF/Electrical (Radar) Engineer: DAA researcher
David Gorman, RF/Electrical (Radar) Engineer, DAA researcher
Tom King, Engineer, Operational Framework/DAA Project Manager
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
Diana Kovar, Conference Coordinator, ITEM Conference Support

9.0 Estimated Level of Effort and Associated Costs

<table>
<thead>
<tr>
<th>Performer: University of North Dakota</th>
<th>Tasks (section 5.0)</th>
</tr>
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<tbody>
<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>
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This pre-proposal does not obligate the University of North Dakota or New Mexico State University to this project. Upon request of the sponsor, a formal and properly authorized proposal will be submitted.