APPENDIX E—TASK CS-5: REFINEMENT AND EXTENSION OF WORKSTATION DESIGN REQUIREMENTS AND GUIDELINES BASED ON COGNITIVE WALKTHROUGHS

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EXECUTIVE SUMMARY

The objective of the work was to support the development of recommendations for minimum unmanned aircraft system (UAS) control station standards and guidelines. These recommendations focus on operation of fixed-wing unmanned aircraft (UA) larger than 55 lb. operated beyond visual line of sight in an integrated National Airspace System (NAS).

Prior to this research task (CS-5) which focused on cognitive walkthroughs, recommendations for minimum human-automation function allocation were developed and minimum information requirements for safe UAS operation in the NAS were identified (CS-1, CS-2, and CS-3). The goal of the cognitive walkthroughs was to provide further validation and refinement of the recommendations generated in the function allocation and information requirements research tasks.

In addition to presenting the SMEs with the storyboards produced in CS-4 to structure the cognitive walkthroughs, in CS-5 a set of probes was presented in order to trigger inputs beyond those that would have been generated by the SMEs simply by reviewing the contexts provided by the storyboards.

These prompts included aviation-specific prompts such as:

> In reviewing the scenario and three associated variations to generate ideas for **pre-flight, ground and taxi operations, takeoff, enroute operations and landing,** please consider the following questions.
>
> **Can you envision <u>threats</u> that could contribute to an incident, near miss or accident?**
>
> For instance, for the following <u>environmental threats</u>, can you envision scenarios involving:

- unexpected adverse weather that could arise even though the forecast was for visual meteorological conditions (VMC),
- terrain,
- airport conditions,
- other ground or air traffic, or
- other environmental conditions?

They also included probes focused on human performance such as:

> **Does consideration of any of the following cognitive processes that could contribute to an incident, near miss or accident help you to generate any additional scenarios?**

- <u>Slips</u> (the person has the necessary expertise, but fails to apply it for a given instance),
- <u>Ineffective attention management</u> (the person does not look at and/or process relevant information),
- <u>Incorrect or incomplete mental model of the situation</u>,

- Inadequate vigilance (failure to maintain a sufficient level of alertness and attentiveness in order to detect and respond to some problem in a timely manner),
- Fatigue, or
- Inadequate training or experience
  - with automation of other equipment,
  - with procedures,
  - with critical scenarios, or
  - with effective teamwork (communication and coordination).

Results and conclusions from cognitive walkthroughs with three subject matter experts (SMEs) are reported. The results include one recommendation that differs from a recommendation proposed from the prior information requirements research task (CS-3), six recommendations that are consistent with recommendations proposed from the function allocation and information requirements research tasks (CS-1, CS-2, and CS-3), and four new recommendations that were not covered in the function allocation and information requirements tasks (CS-1, CS-2, and CS-3). The results also provide additional input for efforts that extend beyond the scope of A10.

1. INTRODUCTION

As indicated in the section on CS-4, we used the above three storyboards as the basis for the cognitive walkthroughs. The Methods and Results are detailed below.

2. METHODS

This exercise was conducted asynchronously, asking via email that each subject matter expert (SME) review the storyboards individually. Below are the general instructions.

Thanks for agreeing to assist as an SME for this effort. The goal is to collect your insights regarding scenarios that could lead an incident, near miss or accident under operations meeting minimum human factors standards for unmanned aircraft systems (UASs) in order to provide insights for helping to determine those minimum standards.

Step 1. Please print out the attached slideshow.

Step 2. Please read the introductory material at the beginning of this slideshow.

Step 3. Please read through the description of Scenario 1 contained in this slideshow.

Step 4. Please use the attached Word document to help generate scenario ideas and to describe them, referring to the description of the scenario on the printed slides as necessary. Please focus your scenario ideas and recommendations on examples involving UASs.

Step 5. Repeat Steps 3-4 for Scenarios 2 and 3.

The word document provided further instructions and the full set of prompts presented to the SMEs. The full contents of this document are provided below in order to indicate the range of prompts used to help trigger ideas as the SMEs reviewed the storyboards.

2.1 INSTRUCTIONS FOR SME INPUT

In reviewing the scenario and three associated variations to generate ideas for **pre-flight, ground and taxi operations, takeoff, enroute operations and landing,** please consider the following questions.

Can you envision threats that could contribute to an incident, near miss or accident?

For instance, for the following environmental threats, can you envision scenarios involving:

- unexpected adverse weather that could arise even though there had been a forecast for Visual Meteorological Conditions (VMC),
- terrain,
- airport conditions,
- other ground or air traffic, or
- other environmental conditions?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

For instance, for the following airline/aircraft threats can you envision specific related examples involving:

- operational pressure,
- aircraft malfunctions,
- ground maintenance,
- ground/ramp operations,
- manuals/charts, or
- other airline/aircraft threats?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

Can you envision pilot ground control workstation related errors that could contribute to an incident, near miss or accident? If so, please describe scenarios where they could arise.

For instance, for the following factors that could influence pilot ground control workstation related errors, can you envision specific related examples involving:

- manual flying,
- instruments/radio communications/phone communications, or
- other pilot ground control workstation based errors?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

For instance, for the following procedural errors, can you envision specific related examples involving:

- checklist completion,
- briefing and callout (i.e., remote pilot in command (RPIC)/visual observer (VO) coordination),
- documentation, or
- other procedural errors?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

For instance, for the following flight deck based communication and coordination errors, can you envision specific related examples involving:

- RPIC communication and coordination with air traffic control (ATC),
- crew resource management/coordination and communication (RPIC and VO),
- RPIC communication and coordination with other aircraft (manned and unmanned), or
- other communication and coordination errors?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

Can you envision airport/airspace based threats that could contribute to an incident, near miss or accident? If so, please describe examples of scenarios where they could arise.

For instance, for the following airport/airspace based external threats, can you envision specific examples related to:

- airport layout,
- navigation aids,
- airspace infrastructure/design, or
- other airport/airspace based external threats?

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

Does consideration of any of the following cognitive processes that could contribute to an incident, near miss or accident help you to generate any additional scenarios? If so, please describe examples of scenarios where they could arise.

- Slips (the person has the necessary expertise, but fails to apply it in a given instance),
- Mistakes (the person does not have the necessary expertise to perform appropriately),
- Ineffective attention management (the person does not look at and/or process relevant information),
- Incorrect or incomplete mental model of the situation,
- Inadequate knowledge of intent (Lack of awareness or understanding of one agent regarding the goals, plans or intended actions of other agents - automation or human),
- Inadequate vigilance (failure to maintain a sufficient level of alertness and attentiveness in order to detect and respond to some problem in a timely manner),
- Information overload (too many competing sources of information, making it difficult for the person to focus attention on all of the relevant information that is being displayed),
- High mental workload (excessive demands due to too many competing tasks or tasks that are too complex),
- Inadequate resource management (failure to manage or make adequate use of the full range of resources – human and automated – available to detect and/or deal with a problem. This includes inadequate teamwork.), or

- Excessive communication/response latency (the rate at which some action is initiated or completed is delayed relative to requirements for effective performance).

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

Does consideration of any of the following additional factors that could contribute to an incident, near miss or accident help you to generate any additional scenarios? If so, please describe examples of scenarios where they could arise.

- Fatigue,
- Inadequate training or experience
  - with automation of other equipment,
  - with procedures,
  - with critical scenarios, or
  - with effective teamwork (communication and coordination),
- Stress (including time stress), or
- Language barriers.

Enter Scenario(s) here. Also please indicate any changes in capabilities or procedures as described in this scenario that you think could eliminate or reduce the likelihood of such a scenario arising.

2.2 SME QUALIFICATIONS

The most relevant credentials of the three SMEs who completed the cognitive walkthrough are summarized below:

ID	Professional Experience
1	MS Systems Engineering MA Management BS Mechanical Engineering Remotely Piloted Aircraft/Unmanned Aerospace Systems Pilot (Approx. 500 RQ-4 hours) FAA Commercial/Instrument Pilot (264 hours); Master Navigator (2,476 total hours) 2008 – 2010: Commanded US Air Force's RQ-4 Global Hawk combat unit Global Hawk instructor and evaluator pilot certified in 5 unified Command theaters UAS Flight Operations Manager 2014 – 2016 UAS Executive Director, Kansas State University 07 / 2016 – Present.

2	Ph.D. in Business Administration Master of Aeronautical Science Assistant Professor, Embry-Riddle Aeronautical University 2015 – Present (teaching core technologies of unmanned aircraft systems (UAS); governmental and private sector applications of UAS to meet mission needs) AAI Corporation – Senior Program Manager 2011 – 2015 • Developed a UAS crewmember transition program of instruction for the US Army Shadow UAS fleet of aircraft to transition from RQ-7Bv1 to RQ-7Bv2 aircraft models • Responsible for the Shadow UAS Government Owned Contractor Operated (GOCO) program, including synthetic aperture radar capabilities, to expand organizational Intelligence, Surveillance, and Reconnaissance (ISR) fee-for-services strategic objective requirements • Co-authored the technical volume proposal development for logistics, training, and deployed labor execution plans for the Aerosonde UAS used in the Special Operations Command Mid-Endurance UAS (MEUAS) and Navy ISR Services fee-for-services programs • Planned and executed the MEUAS and Navy ISR Services fee-for-services programs including UAS crewmember training for more than 200 crewmembers, deployment of nine systems to Iraq, Afghanistan, and Africa AAI Corporation – Program Manager 2007 – 2011 • Program Manager for the GOCO ISR project to the US Special Operations Command (USSOCOM) • Planned and executed the MEUAS and Navy ISR Services fee-for-services programs including UAS crewmember training for more than 200 crewmembers, deployment of nine systems to Iraq, Afghanistan, and Africa • Designed and implemented Tactics, Techniques, and Procedures (TTPs) to provide persistent surveillance with 200% increase in ISR coverage and a 44% reduction in mishap rates compared to deployed Army and Marine Corps UAS units AAI Corporation – New Equipment Training Project Manager 2002 – 2007 • Established a UAS crewmember training program of instruction to transition the USMC from the RQ-2 Pioneer to the RQ-7A Shadow UAS, which trained over 150 US Marines • Developed an instructor program of instruction for US Army Soldiers for the RQ-7A/B Shadow UAS, which trained over 30 instructors • Developed a New Equipment Training (NET) program of instruction, which trained 117 Shadow 200 units from the US Army, Marine Corps, and Special Operations United States Army – UAS Institutional Training Program Director 1996 – 2002 • Chief Instructor Pilot for the US Army’s Unmanned Aircraft System (UAS) crewmember training program as the proponent UAS • Standardization Instructor Pilot and Program Director, while transforming the US Army training strategy to the RQ-7A Shadow 200 UAS

	• Integrated new methods of UAS instruction, coordinated schedules and resources with the government Program Office, US Army
3	Instructor/Evaluator Pilot, RQ-4 UAS (Global Hawk) Weapons Instructor Officer/Evaluator Pilot C-130/T-38/T-1 FAA Commercial Instrument Rating FAA Single and Multi-Engine Rating AIR FORCE RESEARCH LAB 2012-2016 • Infoscitex - UAS Research Lead Multi Role Control Station (Vigilant Spirit) - development of next generation operator interfaces for single and multiple aircraft control operations AERONAUTICAL SYSTEMS CENTER 2007- 2012 • Booz Allen Hamilton - UAS Operation Lead Navy Broad Area Maritime Surveillance Airspace Integration and Safety Case Modeling and Simulation Integration Lead examining world-wide employment analysis • Lead UAS integrator for OSD Unmanned Aircraft System Airspace Integration into National Airspace Space, Joint Integrated Product Team (utilization of constructive and virtual modeling) • Global Hawk Ground Segment Re-architecture integration of next generation interfaces including electronic flight manual development, pilot map requirements, sensor operator upgrades and updated CONOPS • AF and Navy Joint Cockpit Evaluation Team member – evaluated and developed next generation ground station interfaces working directly with current qualified warfighters

3. RESULTS

As indicated above, three SMEs participated in the cognitive walkthroughs. They provided their input in writing, providing the following kinds of responses:

- detailed sample scenarios that served to illustrate situations that they think could arise that would differ from the normative paths described in the three scenarios described in Appendix D, and that would introduce additional cognitive complexity and the potential for error that could result in an incident, near miss or accident; and
- inputs regarding information requirements and recommendations for minimum human factors requirements.

Since responses from the three SMEs frequently clustered around specific topics, we have grouped them by topic in the presentation of the results below. For example, there were several inputs regarding the need for an airport surface display that dynamically indicates the current location of the unmanned aircraft (UA) on the airport surface, as well as three sample scenarios generated by one of the SMEs illustrating the complexities that could arise during landing and taxi in. These inputs and sample scenarios are grouped in the presentation below under the header of "Category 1. Airport Surface Displays".

Thus, within each such category, we report the relevant "Inputs" and "Sample Scenarios" as provided by the SMEs. At the end of this presentation of the results relevant to each category, we then provide "Recommendations" guided by these inputs.

In addition, because the responses provided by the SMEs sometimes went beyond the scope of A10 (due to the open-ended nature of this knowledge elicitation task), we have reported the findings under three major headings:

- inputs and sample scenarios that have implications for potential minimum human factors requirements within the scope of A10, with associated recommendations,
- inputs and sample scenarios relevant to non-human factors requirements and a scope broader than A10, and
- storyboard improvements.

These inputs, along with associated recommendations and comments are provided below.

3.1 INPUTS WITH RELEVANCE TO RECOMMENDATIONS FOR MINIMUM HUMAN FACTORS REQUIREMENTS WITHIN THE SCOPE OF A10

3.1.1 Category 1. Airport Surface Displays

The SMEs provided the following inputs and sample scenarios relevant to this category.

Input 1a. "Recommend a minimum requirement to have a top-down view of the airport surface area with the UA depiction on that view."

Input 1b. "Risk area. UA position should also include on the airport surface area as a minimum requirement."

Input 1c. "With a 2D display showing the UAs location on the surface, the RPIC would have awareness of the UAs movement."

Input 1d. Sample Scenario:

"Non-standard VO integration:

- Tiger 33 (a UA) is flying into Wilmington Airport (KILN) [GPS 22R final approach] during hours when the ATC tower is not open (so the RPIC must rely completely on a VO because RPIC is at a remote site).
- RPIC is manually flying the approach until 1 NM:
    - At 1 NM the VO will identify the aircraft.

- After positive identification, the VO will start issue commands for final approach and landing.

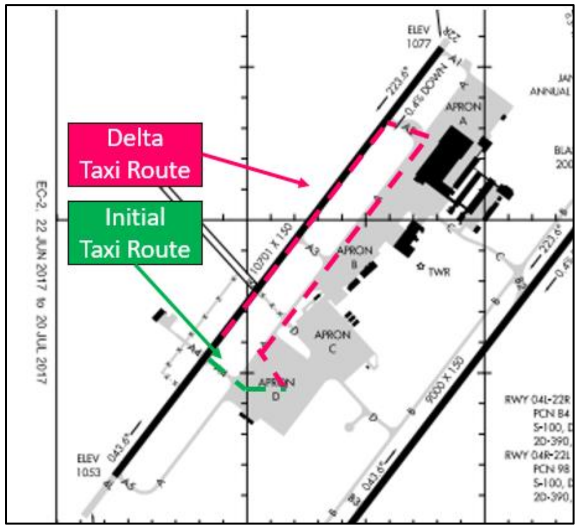
- Variation 1 - VO identifies Tiger 33 at 1.5 NM:
  - VO starts to tell the RPIC to make a “slight left turn.”
    - RPIC makes a 5-degree left turn.
    - This correction is too large, the RPIC should have only turned 2-degrees [final approach and landing will require a high fidelity of corrections].

- Variation 2 - VO identifies Tiger 33 is off course to the right of centerline:
  - VO then tells the RPIC to “get back to course.”
  - RPIC turns to wind correct course heading.
  - RPIC thinks he is back on course while VO still sees him right of centerline [an understanding of positional awareness is important during critical phases of flight].”

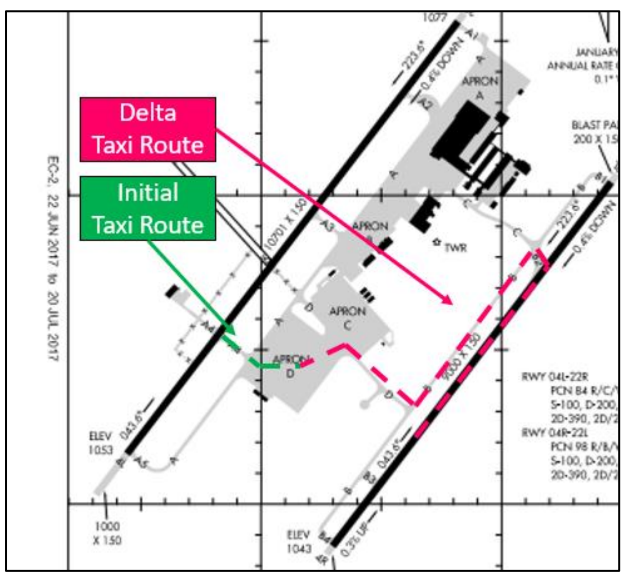
Input 1e. Sample Scenario:

“Taxi Changes with Complex Common Operating Picture

- Eagle 65 is preparing to land 04L at Wilmington Airport (KILN) during hours when the ATC tower is not open (so the RPIC must rely completely on a VO because RPIC is at a remote site):
  - Parking location is Apron C.
  - Taxi plan is A4 to Apron D.
  - Taxiway A3 is closed.
- Variation 1 - Aircraft lands slightly long, RPIC is slow to engage brakes:
  - Aircraft stops 200 feet past A4.
  - 180s turns on the runway are non-standard and could delay other aircraft.
  - Long taxi to A2 could also cause delays to inbound aircraft.
  - Long taxi through two additional aprons could be challenging.



- Variation 2 – Eagle 65 is directly to land on parallel runway 04R:
    - VO may have to give commands in potentially less than optimum pre-planned position.
    - Both options to taxi back to Apron D will be much more involved."

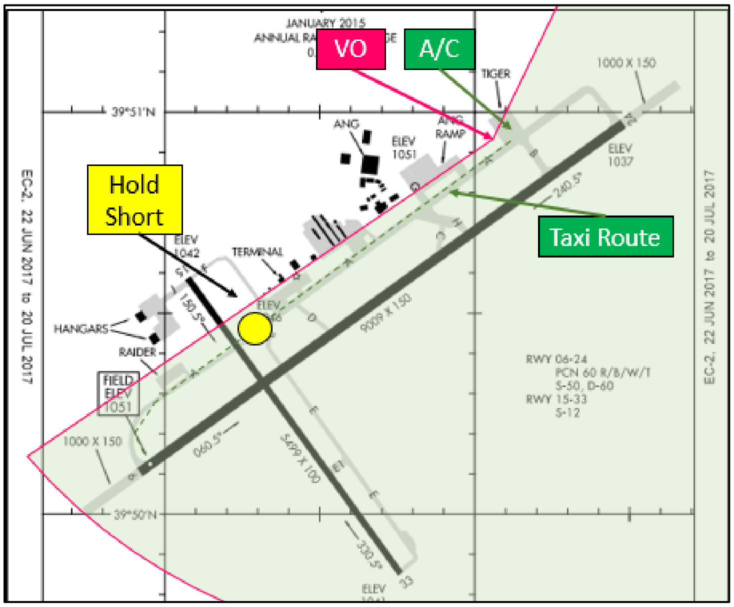


Input 1f. Sample Scenario –

"Runway Incursion:

- Robin 17 (an UA) is taxing to RWY 06 from Tiger Ramp via Taxiway A during hours when the ATC tower is not open (so the RPIC must rely completely on a VO because RPIC is at a remote site).
- Both runways are active (RWY 06 and RWY 15).
- Airfield is uncontrolled so aircrew are responsible for crossing both active runways.
- After taxi has commenced, VO hears Penguin 52 report 1 NM short final for RWY 15.

- Robin 17 is approaching RWY 15, due to the VO angle they can't tell exact position.
- VO directs the RPIC to stop taxi (instead of continuing and crossing RWY 15).
- Robin 17 stops just past the hold short line for RWY 15.
- Penguin sees Robin 17 stop and decides it is too close to the runway so they go-around."



Based on these data, we make the following recommendation:

> **Recommendation 1.** Require GS to include a display showing a top-down view of the airport surface with the UA's current position indicated dynamically on this surface display. Note that this requirement is more stringent than the one proposed in CS-3. CS-3 indicates that the relevant CS-3 information elements are:
>
> - UA latitude and longitude—required to be displayed at all times
> - Airport configuration—obtained from source outside control station
> - UA position relative to taxiway centerline—obtained from source outside control station

Thus, in CS-3 the minimum information requirements do not require a top-down view of the airport surface; rather, airport configuration is expected to be obtained from a source outside the control station (such as an airport diagram); similarly, the minimum requirement in CS-3 for UA position relative to centerline is that it should be obtained from a source outside the control station, such as via communication with the visual observer.

Based on these additional inputs and our human factors judgment, our recommendation is that the more stringent input described above in Recommendation 1 be required.

Note that the above scenarios have relevance for Category 2. Certification Requirements for VOs and Category 3. Phraseology for VOs and RPICs (below) as well.

3.1.2 Category 2. Certification Requirements for VOs

The SMEs provided the following inputs and sample scenarios relevant to this category.

Input 2a. "There is currently no certification for Visual Observers. This is a risk area."

Input 2b. "Given the basic assumptions and potential limitations of a VO, there is a risk of an incursion between the intersecting runways."

Input 2c. "Further, without two-way radio communication, the VO may not be able to communicate vectors to the RPIC/ OAC."

Input 2d. Sample Scenario –

"Non-Standard Visual Observer (VO) Integration:

- Tiger 33 is flying into Wilmington Airport (KILN) [GPS 22R final approach] during hours when the ATC tower is not open (so the RPIC must rely completely on a VO because RPIC is at a remote site).
- RPIC is manually flying the approach until 1 NM:
  - At 1 NM the VO will identify the aircraft.
  - After positive identification, the VO will start issue commands for final approach and landing.

- Variation 1 - VO identifies Tiger 33 at 1.5 NM:
  - VO starts to tell the RPIC to make a "slight left turn."
  - RPIC makes a 5-degree left turn.
  - This correction is too large, the RPIC should have only turned 2-degrees [final approach and landing will require a high fidelity of corrections].

- Variation 2 - VO identifies Tiger 33 is off course to the right of centerline:
  - VO then tells the RPIC to "get back to course."
  - RPIC turns to wind correct course heading.
  - RPIC thinks he is back on course while VO still sees him right of centerline [common understanding of positional awareness should be standard during critical phases of flight]."

Input 2e. Sample Scenario –

"Standardized Terminology with VO:

- Robin 17 is taxing to RWY 06 from Tiger Ramp via Taxiway A during hours when the ATC tower is not open (so the RPIC must rely completely on a VO because RPIC is at a remote site).
- Final turn at the end of Taxiway A is a long gradual turn.

- VO directs RPIC to start a gradual turn entering initial curve.
- RPIC turns more than the VO is expecting.
- Due to the VOs angle at the far side of the field aircraft departs the taxi surface.

VO issues to be addressed:

- non-standardized terminology,
- delayed instructions for high fidelity inputs,
- lack of training,
- lack of 'currency' requirements,
- too many perspective angles to give appropriate instructions
  - pilots usually have a cockpit angle or north up angle,
- terminology definitions
  - heading vs left/right,
  - braking effort,
- line of sight issues
  - (that is why we have tall ATC towers), and
- taxi speeds
  - worse communication between RPIC/VO will result in lower taxi speeds
  - VO will not have a speed indication to make estimates."

Based on these data, we make the following recommendations:

Recommendation 2a. Require certification for VOs to ensure clear understanding of communication protocols, roles and responsibilities and an understanding of scenarios where risks are higher in order to increase vigilance for such scenarios. Note that, although CS-1 and CS-2 do not develop procedures or training/certification recommendations, the VO should be competent in the following tasks, to which our recommendations expect the VO to contribute:

- ensure instruments, avionics, and navigation equipment are working properly,
- monitor UA trajectory for obstacles (on the ground),
- check for proper flight control surface movement,
- ensure UA maintains runway centerline,
- ensure UA is above runway surface before touch down, and
- ensure separation during climb out and approach.

Recommendation 2b. Require reliable two way communication between the RPIC and VO. Note that the technological solutions to this are not directly human factors issues. Note also that the input "without two-way radio communication, the VO may not be able to communicate vectors to the RPIC/ OAC" indicates a particular technological solution, which may not be the best for all scenarios (such as when the RPIC is at a site remote from the departure or arrival airport). Thus, we have worded this more generally as a requirement for two-way communication and assume that the technological solution(s) will be specified in other forums. Note that this is consistent with the function allocation and control station work reported in CS-1 through CS-3, which includes assumptions stating that there is a direct line of communication between the VO and RPIC and that two-way communication is essential for all of the tasks that need to be performed by the VO, particularly separation responsibility.

Note that the above scenarios have relevance for Category 3. Phraseology for VOs and RPICs (below) as well.

3.1.3 Category 3. Phraseology for VOs and RPICs

The SMEs provided the following input relevant to this category:

Input 3: "The RPIC/OAC and VO must use standardized terminology when communication processes are being used. It may add risk to describe intruder aircraft callouts with regard to direction because the direction of the UA may be different than the direction of the VO."

Based on these data, we make the following recommendation:

Recommendation 3. Establish and train RPICs and VOs on standardized vocabulary. Note that CS-1 through CS-3 do not address the subject of establishing standardized vocabulary between RPIC and VO.

3.1.4 Category 4. Backup Communication Channel

The SMEs provided the following inputs relevant to this category:

Input 4a. "Having two-way radio communications between the RPIC/OAC and the VO is better than no communications; however primary communications can fail and procedures for secondary communications may be required here."

Input 4b. "The communications between RPIC/VO may be lost after the final go ahead for launch or landing and then an abort may become necessary. An open line that indicates communications is lost could serve as an automatic abort/wave off in this scenario."

Input 4c. "Regarding crewmembers, the RPIC is ultimately responsible for the operation; however the RPIC may have operators at the controls at a launch and recovery site while the RPIC may be collocated with en-route operations site. Communications between the RPIC and Operator at the Controls is a risk area."

Based on these data, we make the following recommendation:

> **Recommendation 4.** Require procedures and/or technological solutions that ensure that the detection of a loss of the primary communication channel between the RPIC and VO is noted and handled in a timely and appropriate fashion. Note that CS-2 covers recommendations for contingency planning for loss of VO, which includes loss of communication with the VO. The recommendation states that a plan must be created before takeoff, but does not require the use of advanced automation; i.e., the contingency plan could simply be a procedural solution, as opposed to a technological solution.

3.1.5 Category 5. Procedures to Handle Loss of Visibility

The SMEs provided the following inputs and sample scenario relevant to this category:

Input 5a. "VO LOS is subject to the movement of other aircraft/vehicles at the airport. Putting the VO in the tower might improve LOS, but not eliminate this possibility."

Input 5b. "This assumes that the VO can see the UA throughout procedures requiring the VO. For example, the VO may not be able to observe the proximity of the UA on the airport surface area (during taxi)."

Input 5c. "The VO may not be able to observe the UA on the taxiway well enough to separate from other aircraft on larger airports".

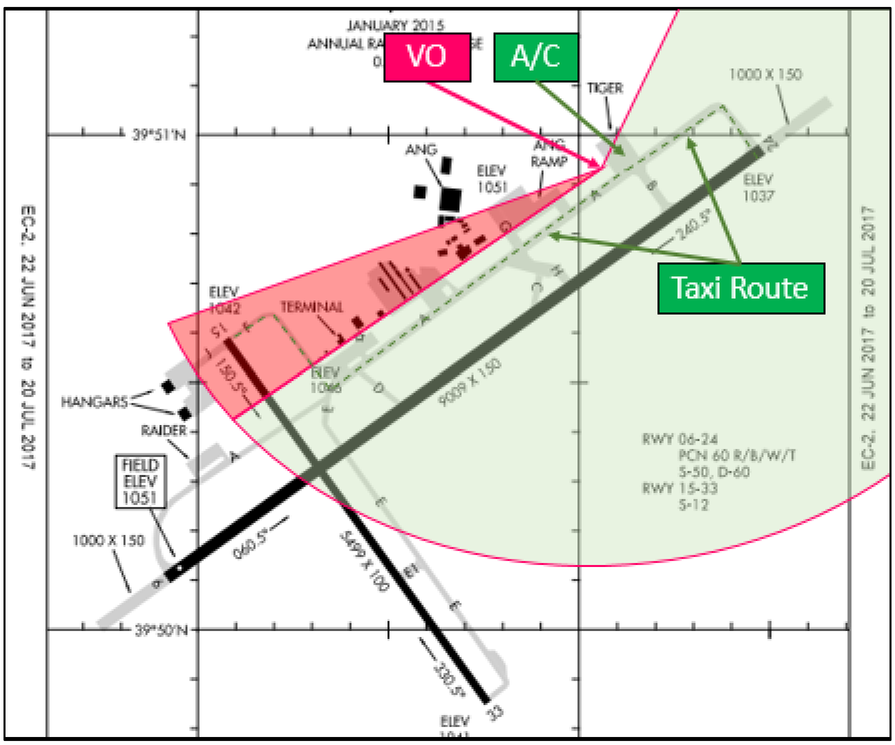
Input 5d. Sample Scenario:

"Visual Observer (VO) Limited Visibility on the Taxiway:

- Falcon 87 is preparing to taxi at Springfield Airport (KSGH).
    - Parking location is Tiger ramp.
    - Initial planned takeoff was RWY 24.

- VO is located on the corner of Taxiway A/B right near the Tiger ramp.
  - VO has a clear view from parking to RWY 24.
- Winds have changed during the last hour.
  - RPIC reviews the winds (140/10 gust 150.
  - RPIC recognizes these crosswinds are out of limits if utilizing RWY 33.
  - RWY 15 is the only option to takeoff within limits.
- Instead of a short taxi path from Tiger to RWY 24, there will be a long taxi to RWY 15.
- VO cannot see the final portion of the taxiway.

- Options are limited:
  - Wait until winds change (delayed mission).
  - Move VO to new position (pre-coordination required).
  - 2 VO for full taxi (personnel manning issues)."



Based on these data, we make the following recommendations:

Recommendation 5a. The VO must be placed so as to have full visibility of the airport surface as well as departure and arrival airspace. Since changes in runway configuration are a routine practice, such placement of the VO must take this into consideration.

Recommendation 5b. Since the VO (as a non-FAA function) is not likely to be located in the ATC Tower and since many of the airports involved do not have airline ramp towers, the possibility of another aircraft or vehicle blocking the line of sight must be considered a possibility. Procedures need to be defined to guide VO and RPIC responses when this happens, likely involving stopping the UA until visibility is regained. Note that CS-2 recommends that contingency planning be performed for "VO failure", which could include VO loss of visual contact with the UA. The minimum function allocation recommendation states that this process can be done without automation (i.e., it could be simply a procedural solution), which is in agreement with Recommendation 5.

3.1.6 Category 6. Requirements for Alternate Airports

The SMEs provided the following inputs relevant to this category.

Input 6a: "Due to liability issues and the potential level of distraction, I question how realistic it is for an ATC controller to be a VO on a UAS crew." (The scenario assumed that a requirement for filing a particular alternate airport would be the presence of a VO, and that one way to achieve this would be to train ATC Tower controllers as VOs for such cases in order to have a sufficient number of acceptable alternate airports.)

Input 6b. "The ACT controller may not have the time/ certification to perform duties as a VO."

Input 6c. "The schedule could change because of weather or in-flight emergencies."

Based on these data, we make the following recommendation.

Recommendation 6. Requiring the flight operator to staff a VO at the filed alternate airport would be a significant additional cost. Having ATC Tower controllers certified as VOs would be one approach to deal with this (recognizing that this has a training cost). Having a VO staffed by flight operators as a whole at "certified" alternate airports might be another (with a different set of attendant costs.) The recommendation is that requirements be established to ensure that there is a VO available at a filed alternate airport without specifying the required method to achieve this. Note that this topic is not covered by the function allocation or control station information requirements work.

3.1.7 Category 7. Information Requirements for RPIC

The SMEs provided the following input relevant to this category.

Input 7a. "The maps given do not show terrain elevation, but should be a GS requirement."

Based on these data, we make the following recommendation.

Recommendation 7. Given the scope of A10, information regarding planned or current altitude above terrain should be required. Note that CS-3 recommends that terrain/obstacle height is optional, but that is because CS-3 recommends requiring UA altitude above ground level (AGL) to be displayed at all times in the control station. RPICs do not have the out-the-window visual cues to judge aircraft height above terrain that manned pilots have, so they require some information in the control station that conveys UA clearance over terrain. Altitude AGL is a variable that can be quickly processed by the RPIC to mitigate the risk of CFIT.

3.1.8 Category 8. Access to Camera Views

The SMEs provided the following inputs relevant to this category.

Input 8a. "Nose camera: It offers some mitigation and enhances SA, but it can also create a false sense of security if that's the closes thing to sense and avoid. There could be conflicts not on the camera. Even if flying at a high AoA, there could be co-altitude hazards that the camera may not detect. It can definitely help if there are objects in front of the UA's taxi/flight paths."

Input 8b. "This would increase situational awareness provided this capability doesn't degrade. It may degrade because of equipment failure, weather, of obscurations between the camera and UA (i.e. birds form a next in front of the camera). Additionally, the camera equipment should have a night operational capability (i.e. FLIR)."

Input 8c. "A forward-looking camera may not have a field of view equivalent to a manned pilot in the cockpit; whereas the manned pilot can turn his/her head to improve the situational awareness or widen the field of view."

Input 8d. "A better variation for a minimum requirement to this scenario would be to have a 360 degree field of view to determine the location of other traffic. This field of view may not necessarily be optical as an ADSB in may also provide information. Still, VOs will be required for aircraft without transponders also operating within the area."

Input 8e. "With a forward POV camera the RPIC will not have improved situational awareness during surface operations."

Input 8f. "With a multi-directional POV camera, the RPIC may be capable of independent operations during surface operations."

Input 8g. "With fixed cameras showing the airport surface (ramp, taxiway and runways), the RPIC will have improved situational awareness."

Input 8h. "Airport cameras can help with SA and can help the RPIC identify hazards during taxi, takeoff, and landing. But they can also be distracting to monitor. As I picture this, I'm thinking of something like a security officer would have in a mall. Lots of cameras to monitor, each potentially distracting, and each one adds to complexity in terms of understanding the location of that camera to discern potential ramifications on UA operations. Unless there's a way for the system to only show feeds for areas in the vicinity of the UA, I don't think I like this idea."

Input8i. "Better real-time video transmission from the UA, perhaps going so far as to allow a 360 degree view."

Based on these data, we make the following recommendation.

> **Recommendation 8.** While views from cameras might be useful in some situations, within the scope of A10, there was no strong argument to require them as minimum human factors requirements. Note that SME feedback in CS-1 and CS-2 indicated that cameras are not necessary to safely operate a UA in the NAS, as long as information is being delivered to the control station with minimal delay and a high degree of accuracy. For example, SME comments from CS-1 include: "I disagree with the assumption about [requiring] the nose camera. I have operated UAS that do not need this to be able to fly safely. The FAA has not allowed cameras as a safe separation method either. I could use VO or millimeter wavelength radar to do something similar. I would recommend that we remove the assumption." Similarly, another SME commented as input to the preparation of CS-1: "I personally feel there is a bit too much emphasis placed on the nose camera. Don't get me wrong, it's a great tool for SA, but I think in some cases it's over emphasized." On the other hand, a third SME commented: "With today's technologies regarding VR and 360-degree cameras, there is no reason that this functionality cannot be added to UAS larger than 55 lb. This can allow the pilot/operator to have more visibility of the environment the UAS is operating in (such as an airport)." Note the emphasis of the third SME's comments was not on requiring a camera, but the fact that camera technology is relatively inexpensive and unsophisticated compared to the technology on a UAS larger than 55 lb so that there is little reason to exclude a camera.

3.1.9 Category 9. ADSB Equipage

The SMEs provided the following input relevant to this category.

Input 9a. "ADSB out may not provide the RPIC/OAC with the situation awareness necessary to manually operate the UA to avoid other aircraft. Recommend an ADSB in/Out capable transponder."

Based on these data, we make the following recommendation.

> **Recommendation 9.** For an IFR flight landing and departing in Class G and Class D airspace, there will be aircraft that do not have ADSB/Out and furthermore do not have a transponder and radio. ADSB will not provide information regarding the presence of these aircraft. The recommendations for requirements for a Visual Observer to support taxi, arrival and departure operations along with required interaction with ATC to fly IFR once airborne, as documented in the report for CS-1, provide adequate minimum standards for taxi, departure and arrival operations without requiring ADSB/In.
>
> For enroute operations where all aircraft will be flying IFR, procedures to fly under positive control by ATC while enroute could benefit from ADSB/In, but within the scope of A10 it

is not required. Note that the FAA UAS Integration into the NAS Roadmap states the UAS will be required to have ADSB/Out to operate in the NAS. Beyond stating this as an assumption, CS-1 through CS-3 do not address any other requirements for ADSB capability.

For enroute operations in Class D and G airspace there could be manned aircraft that are not equipped with ADSB/Out and are even without a transponder and radio. Standards/procedures for response when an unequipped manned aircraft is on a trajectory that is in conflict with a UA need to be defined. However, detect and avoid was not addressed in CS-1 through CS-3 as it was not in scope.

3.1.10 Category 10. Training of Manned Pilots

The SMEs provided the following input relevant to this category.

Input 10a. "Manned Pilots not accustomed to looking carefully enough to visually locate smaller, more agile aircraft."

Based on these data, we make the following recommendation.

Recommendation 10. This consideration needs to be added to the training of pilots for manned aircraft.

3.2 INPUTS WITH RELEVANCE TO NON-HUMAN FACTORS REQUIREMENTS AND A SCOPE BROADER THAN A10

Note that some of these recommendations are outside the scope of A10 but apply to expansions beyond that scope.

The SMEs provided the following inputs (each followed by a note indicating potential considerations associated with that input. Recommendations are not provided because these inputs are outside of the scope of A10.

Input: "Frequency deconfliction must be accounted for." (Note, however, that to the extent that this isn't achieved, procedures need to be defined.)

Input: "UAs must be programmed so that in a lost signal situation, it would avoid infrastructure on their way to the specified loiter point. This path would not be part of the filed flight plan. Other aircraft in the area would need to be alert to this possibility. Does the NOTAM cover this possibility from all angles?" (Note that if the RPIC or the supporting flight operator has responsibility to do this for each flight, then this has human factors implications in terms of information requirements.)

Input: "Need to overlay as much information as possible onto a single visual source. For example, the inability to overlay (or remove) weather or other aircraft information on the same screen where the flight control/path is being monitored/manipulated has been mentioned repeatedly as an issue. When the information is presented on separate displays or in separate windows on the same display, this creates too much work for the pilot especially if they have a more complex control system (and increasingly complex if peddles are involved which usually seems to indicate a more dated system)." (Note: Within the scope of A10, much of this information is assumed to be accessed external to the GS.)

Input: "ATC sometimes will talk in terms of land marks, (i.e. report when abeam the water tower). RPIC may not have this marked on available maps." (Relevant to ATC training?)

Input: "Automating the checklists and other aspects in flight that remove cognitive load or that simply having an understanding of when the pilot can get overloaded is important to acknowledge in the minimums." (This input is more relevant for other more complex airspace and airport operations.)

Input: "Assumption of a roadway inspection of 1000 feet may not be accurate. Many UAS with EO/IR sensors are capable of performing this inspection from 4000-6000 ft. above ground level (AGL). This potentially adds risk as many other aircraft may be operating at this altitude compared to 1000' AGL. Also, depending on the topography, at 1,000' AGL the electronic line-of-sight may be obscured causing the UA to implement its lost link logic." (This may have implications for the technology used to support these operations.)

Input: Sample Scenario –

"Intermittent command and control (C2) link malfunction:

- Tiger 33 is flying into Wilmington Airport (KILN) [5 NM from Wizard for GPS 22R approach].
- RPIC is manually flying the approach.
    - RPIC is manipulating stick control and throttle.
    - Tiger 33 has an auto rudder system and is not required for flight.
- C2 display page is to the right side of the ground station.
    - It is NOT located with the primary flight display (PFD) which the pilot is focusing on during the approach.
- Maintenance malfunction – the C2 link to Tiger 33 has become intermittent.
    - Ground station indication for C2 link is on a non-integrated display.
    - C2 link is outside the primary PFD field of view (FOV) the RPIC utilizes for the approach and landing.
- RPIC attempts to turn aircraft to final.
    - PFD does not indicate a turn.
    - RPIC attempts the turn a second time again and the aircraft does turn.
    - RPIC scans the ground station displays and does not see any problem indications.

- RPIC attempts to level off the aircraft on the final approach.
  - PFD does not indicate a nose pitch up to capture the required altitude.
  - RPIC attempt to level the aircraft a second time and the aircraft does not respond.
  - RPIC scans the ground station displays and sees a C2 link ‘yellow’ light.
  - While examining the C2 link ‘yellow’ light, the light extinguishes.
  - RPIC returns to the PFD in the ground station, now the aircraft is descending below the targeted altitude.

- Since the C2 link indications are outside the PFD FOV the following could be an issue:
  - Delayed notification of C2 issues.
  - Pilot induced oscillations (PIO):
    - Potentially missed altitude assignments.
    - Heading misalignment.
  - Incorrect diagnosis of a flight control malfunction.”

3.3 STORYBOARD IMPROVEMENTS

The SMEs also noted two improvements that could be made to the three storyboards that were presented as part of this knowledge elicitation exercise.

Input: “There was no basic assumption about two-way radio capabilities. Although not required for Class G airspace, I recommend two-way radio capability as a minimum requirement/assumption.” (This was inadvertently left out of the assumptions indicated in the storyboards and should be added.)

Input: “Is there a point in 18,000 ft.? It doesn't seem practical for the length of ferry.” (The intention was to get the participants in the cognitive walkthrough to think about RPIC/ATC interactions at higher altitudes. This topic merits further investigation.)

In summary, above we have presented the results (“Inputs” and “Sample Scenarios”) generated by this knowledge elicitation exercise and, based on these data as well as the data considered as part of CS-1 through CS-3, have presented recommendations.

4. CONCLUSIONS

This exercise involved:

- The development of storyboards illustrating normative performance under nominal conditions (CS-4).
- Using these storyboards to conduct a knowledge elicitation exercise using cognitive walkthroughs in which SMEs were asked to walk through the storyboards, to consider alternative versions of these scenarios where a near miss, incident or accident could occur, and to suggest changes in the relevant human factors minimal requirements that could have prevented the occurrence of these hypothetical scenarios or scenario branches.

- Using these data to develop recommendations.
- Contrasting these recommendations with those developed thus far by CS-1, CS-2, and CS-3 without the benefit of these data.

In many cases, the data from the cognitive walkthroughs provided additional validation for the recommendations developed in CS-1 through CS-3. And in other cases, the resultant data indicated additional recommendations to add to those documented as part of CS-1 through CS-3. However, in one case, the presentation of the specific contexts provided by the storyboards triggered input from the SMEs that was not consistent with the recommendations in CS-3. These consistencies and inconsistencies with CS-1 through CS-3 are specifically noted in the results section.