APPENDIX C—PLANNING LITERATURE REVIEW

Philip J. Smith and Amy Spencer

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Task 4 report on relevant considerations from the planning literature emphasizes the importance of developing technological capabilities and procedures to support contingency planning in order to deal with possible anticipated scenarios as well as adaptive planning and response to deal with unanticipated scenarios. This review emphasizes the need to consider such planning and adaptive responses within the framework of a distributed work system, where coordination among a number of different actors must be achieved. This framework emphasizes that such anticipation and coordination applies not only to real time operational staff (pilots, visual observers, dispatchers and flight followers, ramp controllers, ATC and air traffic managers), but also to across technology, airspace and procedure developers.

1. INTRODUCTION

The literature on planning can be found in a number of varied application contexts, including military planning, homeland defense, supply chain management, energy management and healthcare (Juttner et al., 2003; Knight, 2001; Lentzos and Rose, 2009; U.S. Army, 2012; World Healthcare Organization, 2011). The discussion of planning in these different contexts, as well as the literature on planning in aviation, emphasizes a number of overlapping themes that will be used to organize this review on planning in aviation as relevant to the design of UASs:

- System designs focusing on distributed planning that incorporate individuals with different roles, responsibilities and expertise into both preparatory planning and adaptive planning. In the aviation system, such distributed planning not only distributes task requirements impacting individual requirements in terms of workload and expertise, it also provides a variety of safety nets that provide the benefits of partial redundancies and brings to bear a broader range of expertise and perspectives to increase the chances of effective plan development and implementation. Note that such distributed planning includes the work of the technology developers and the designers of procedures who anticipate conditions that could arise and, through their technologies or procedures, provide cognitive tools to detect anomalies that require deviation from a current plan and provide contingency plans to help deal with these situations as they arise.
- Such contingency planning is a second major theme in the planning literature. It involves anticipating possible events and circumstances that could require a change in the current plan, and providing an alternative plan if needed. This anticipation includes specification of a process for detecting such events as well as defining a response at some level of abstraction. This response could be implemented by humans or automation, or some combination of the two.
- System designs focusing on resilience, or the ability to detect and respond effectively to some unanticipated or only partially anticipated situation. This requires incorporating within a system design resources that enable a flexible, uniquely developed response in dealing with some novel scenario.

2. OVERVIEW

This review is intended to be one of our starting points for developing recommendations for human factors guidelines for the design and use of UASs (Valavanis and Vachtsevanos, 2004). In order to focus attention on the most informative contents in the literature, we have taken two approaches. The first is to limit the review of the literature to documents focusing on aviation. Aviation has long been at the forefront in developing approaches to both preplanning and adaptive, real-time re-planning. Hence, this literature (and actual practice in current aviation operations) does an excellent job of highlighting key issues that need to be addressed as part of the incorporation of UASs into the NAS.

The second strategy we have adopted to focus our discussion on relevant issues has been to develop concrete scenarios characterizing UAS operations and to then, within the context of these scenarios, to highlight important planning issues. In addition to reviewing the aviation planning literature, as part of our scenario development activity, we interviewed two recently retired Global Hawk/Predator pilots, a business aviation pilot, a retired controller/traffic manager for DTW/D21, a retired controller/traffic manager for ZOB, two dispatchers, a certified Visual Observer for small UASs, three pilots for small UASs, and three flight planners working for flight service providers.

This review is organized using the following sections:

- Planning within a distributed work system.
- Contingency planning and resilience.
- Scenario-based implications for planning in UAS operations.
- Conclusion.

Note again that this work is intended to help provide a foundation for our further work on the development of human factors recommendations for UASs (Gawron, 1998; McCarley & Wickens, 2004; Tvaryanas, 2006; Williams, 2006). Thus, in many cases, we use this analysis to highlight questions that require further analysis in order to ultimately propose recommendations.

3. PLANNING WITHIN A DISTRIBUTED WORK SYSTEM

The current aviation system relies heavily on strategies for distributing work in order to ensure safety and efficiency (Borgman et al. 2010; Fernandes & Smith 2011; Obradovich & Smith, 2003; Smith et al., 1997a, 1997b, 2000a, 2000b, 2007, 2008, 2010, 2012; Wickens, Mavor, & McGee, 1997). This applies to pre-flight planning and enroute replanning (Out to In) as well as to the implementation of these plans. From the flight operator perspective, depending on the nature of the operation, such distributed planning could include pilots, crew schedulers, maintenance schedulers, ramp controllers and dispatchers or other flight planning specialists working for flight service providers (with the individuals within each category playing a variety of different specialized roles within their organizations). From the FAA perspective this includes controllers and traffic managers working at a number of different facilities, also in a range of different roles.

The designers of the aircraft and avionics software and automation, as well as the developers of procedures associated with the use of this equipment, are also a critical part of this distributed work system, as their designs help define the capabilities that can be considered in planning and replanning. In addition, the developers of the FARs and of FAA procedures play an important role in this distributed work system, as they similarly have a strong impact on capabilities and constraints that impact planning.

The aviation planning literature addresses the distributed nature of this work along the full continuum from strategic to tactical planning and replanning. In this review we focus primarily on day-of planning, but longer term planning in terms of airport and airspace design (such as the layout of runways and landing pads) relative to the expected demand in terms of volume and the mix of equipage also has a major effect on planning to ensure safety and efficiency. These strategic design decisions (for instance, if an airport has been designed so that a UAS has to cross an active runway while taxiing out for departure) have important human factors implications as they affect decisions about function allocation as well as the information requirements and the functional and interface design requirements for the pilot ground control workstation and the capabilities of the automation embedded in the design of the UASs.

3.1 DISTRIBUTED WORK IN PREFLIGHT PLANNING

A primary question that needs to be addressed in terms of function allocation focuses on the distribution of pre-flight responsibilities across multiple agents.

3.1.1 Dispatchers and Flight Planning Specialists

At the one end of the spectrum, FAR Part 121 carriers are required to employ certified dispatchers (with significant additional in-house training requirements) as well as pilots to sign off on flight releases developed prior to departure. This includes consideration of weather, NOTAMS, ATCSCC advisories, MELs, aircraft capabilities, etc. The dispatcher, pilot and co-pilot are all required to review conditions and approve the flight plan, and all have the responsibility to request significant changes (adding extra fuel, changing the route, etc.) if deemed necessary. In between are Part 135 operators who employ flight planning specialists (some companies like NetJets voluntarily require them to be certified dispatchers) and flight planning specialists at flight planning service providers (some like ARINC require them to be certified dispatchers). At the other end in terms of staffing are individual general aviation pilots who may use services that provide access to flight planning tools and information (such as FlightPlan.com) or may do the flight planning without the benefit of such a service.

The decision about whether to require a given UAS flight operator to use dispatchers or flight planning specialists (Prats, 2008) will need to consider issues such as payload, mission, type of aircraft, airspace utilization and airport utilization, addressing the question:

> When do flights merit mandating the extra level of safety provided by the inclusion of flight planning specialists? (As with current manned operations, there is not likely to be a one size fits all solution.)

From a human factors perspective, the inclusion of certified dispatchers (with associated in-house training requirements) in the flight planning process introduces a number of benefits in terms of increased safety and efficiency (from both a flight operator and FAA perspective). First, shared responsibility by a dispatcher adds a second pair of eyes (and a second mind) to the pre-flight planning effort, increasing the chances that important issues will be recognized and dealt with. Second, the dispatcher provides a perspective based on different training, experience, access to decision support tools and motivations, introducing not simply a level of redundancy but actually increasing the range of expertise and experience applied to developing a preflight plan. Among other things, the dispatcher "experiences" a far greater number of flights and therefore has developed a different range of expertise (recognition-based decision making ala Klein, 1998; Orasanu and Strauch, 1994) than a pilot. Third, the dispatcher represents additional "processing capacity" or an increase in collective mental workload and attentional capacity.

> Are there certain types of flight operations (payload, mission, type of aircraft, airspace utilization and airport utilization) for which a certified dispatcher should be mandated and given shared responsibility for pre-flight planning?

> Given expected unique characteristics of UASs (single remote pilot; automation with increased level of authority under certain circumstances), are there additional certification

or training responsibilities that need to be mandated for dispatchers, flight planners and/or pilots relevant to pre-flight planning?

Given the UAS pilot will also be at a fixed location on the ground, what changes can and should be made in terms access to information and decision support tools for pilots relative to the tools available only to dispatchers today for preflight planning? (This will need to take into consideration implications in terms of the development of expertise and in terms of workload/attentional demands, as well as the integration of any such information and tools into the pilot's ground control workstation, as simply providing access to information and tools is not sufficient – it has to be in a form that is useful, useable and used effectively.)

3.1.2 Traffic Flow Management

One fundamental question that needs to be addressed is under what circumstances UASs need to file IFR vs. VFR. This has implications for the degree to which the FAA has the information necessary to manage flights relative to constraints resulting from traffic volume and complexity. This is important in terms of system throughput and safety, especially if there are circumstances where UASs need to be handled differently (analogous to the segregation of props from jets).

Are there circumstances that merit requiring UASs to file IFR under conditions where a manned aircraft could fly VFR?

In what cases should a NOTAM be issued as part of pre-flight planning when such aircraft are flying VFR?

Are there circumstances that merit planning for UASs differently in terms of traffic management constraints and airspace procedures? (Central to this is the consideration of aircraft performance characteristics, including fixed wing, hybrid and rotorcraft UASs.)

Note that, from a human factors perspective, these considerations are important in terms of task requirements and training for pilots (and dispatchers or flight planning specialists if they are involved with any VFR flights), and in terms of situation awareness for controllers and traffic managers.

Designers of Automation and Procedures for Off-Nominals. When the designers of the automation and procedures intended to deal with off-nominal events and emergencies develop new automation or procedures to handle the unique issues that arise with UASs, they are essentially coordinating asynchronously with operational staff.

Although they are preplanned, many of these capabilities and procedures are simply triggered or applied when some event or situation arises, and will be discussed in the later section on Contingency Planning. However, there are some flight dependent preparations that do arise during preflight. In particular, decisions about whether and when to file and fuel for an alternate airport need to be considered for each flight. The advance preparation associated with filing of an alternate airport may seem routine, but if there is uncertainty in the weather or if the aircraft is flying (in compliance with regulatory requirements) with an MEL item placarded (such as an anti-skid inop), then it is advantageous to prepare preflight for an acceptable alternate.

3.2 DISTRIBUTED WORK FROM OUT TO IN

The next section on contingency planning emphasizes that the system design needs to ensure that relevant events and conditions will be detected so that the contingency plans are implemented in a timely fashion. Manned operations in the current NAS rely heavily on distributed responsibilities for such monitoring, including a number of different roles for people (pilot, co-pilot, ramp controller, ATC Coordinator, line dispatcher or other flight follower, controller, traffic manager, etc.) as well technological support tools (such as automatic alerts to inform a dispatcher when a flight deviates significantly from its filed or amended route).

> How should plans specify the manner in which roles and responsibilities for monitoring be distributed across people and technology for UAS operations in order to provide equivalent safety by ensuring that contingency plans are implemented when necessary?

4. CONTINGENCY PLANNING AND RESILIENCE

In an analysis of contingency planning for ATC (Eurocontrol, 2009; FAA, 2013; Transportation Research Board, 2012) that is equally applicable to pilots and dispatchers, Malais et al. (2010) note that: “Planning enables controllers to employ standard and contingency planning for the unfolding situation. Depending on the situation, a minimal set of prescribed action-scripts in documented forms (e.g., checklists) is normally available” (p 621). They further emphasize that there are different complementary approaches to planning, including developing plans that minimize uncertainty, preparing contingency plans for predicted possible situations, and ensuring the resources to manage unpredicted scenarios. Kontogiannis (1999) similarly discusses planning ahead for contingencies and emphasizes the need to be vigilant to system changes in order to detect a situation that requires the application of a contingency plan, as well as the value of consulting external advice.

Pastor et al. (2009) specifically discuss “In-Flight Contingency Management for Unmanned Aerial Vehicles” cautioning that “managing contingencies on a UAS is a much more complex problem basically due to the automated nature of the vehicle and the lack of situational awareness that pilot's in command should face. It is well known from the short history of UAS accidents that many of them are directly imputable to pilot errors when trying to manage an unexpected contingency … without an adequate situation awareness.” (p. 1).

What studies like these emphasize is that the effectiveness of contingency plans (Smith et al., 2003; Vigeant-Langlois & Hansman, 2003) depends not only on the ability to predict and prepare potentially effective contingency plans to deal with possible scenarios, but also the importance of designing to support the detection and assessment of such situations, the ability to adapt the contingency plan as necessary to deal with variations on the predicted circumstances, and the value of accessing additional resources to increase resilience. Note that this applies whether the implementation of the contingency plan involves input by the human operator or involves the autonomous implementation of a contingency plan by software. In addition, studies indicate that there are significant human factors issues associated with the use of checklists as a process to employ a contingency plan (Berman & Dismukes, 2010; Degani & Wiener, 1990a; 1990b).

Thus, this literature emphasizes the need to ask the following question:

> How will UASs operating in the NAS ensure equivalent safety in the development and application of contingency plans through changes in the allocation of roles and responsibilities across different people and through the introduction of new technologies (information displays, decision support systems and automation)? This includes changes to support both the detection of a situation that requires application of a contingency plan and the actual implementation of this plan.

To address this question in a detailed manner, a next step would be to review a range of contingency plans and emergency procedures for existing manual aircraft and to ask the following questions about how the design and operation of UASs will compensate for the following changes that could impact either monitoring performance, contingency plan implementation or both:

- How do we make up for the changed nature of the sensory input for the pilot in terms of
    - The semantic content of this input (or lack of it)?
    - The form of this input (visual, auditory and kinesthetic)?
    - The impact of this content and form on top-down and data-driven attentional, vigilance, perceptual, memory and decision making processes and on perception-action cycles?
    - The impact of this content and form on mental workload?

    Note that this is important to adaptive planning as the pilot needs to detect and assess situations that require replanning.

- What is the impact of new forms of aircraft and aircraft system control available to a pilot, flight planner or Visual Observer (VO)?
    - The semantic content of this input (or lack of it)?
    - The form of this input?
    - The impact of this content and form on top-down and data-driven attentional, vigilance, perceptual, memory and decision making processes and on perception-action cycles?
    - The impact of this content and form on mental workload?

    Note that this is important to planning as such control capabilities help define some of the actions that can be specified in a contingency plan.

- How do we make up for the changed nature of the social, organizational and physical environments in which a pilot, VO and flight planner operate? (including new types of distractions and behaviors)

    Note that this is important to planning as the distribution of roles and responsibilities across organizations has an important impact on the effectiveness of planning as a safety net.

- How do we expect a pilot, VO or flight planner to adapt his behaviors? How do we influence this through the design of training, technologies and procedures?

Under workload and time stress, we can expect pilots and flight planners to sometimes adapt and abbreviate procedures. How do we develop procedures and contingency plans to detect situations where this could lead to undesirable consequences? (The strategies for distributing work and developing contingency plans need to anticipate how the humans in the system will actually behave.)

- Assuming only one pilot per UAS rather than two:
  - How do we make up for the loss of the contributions of the pilot not flying in terms of
    - The loss of a second human sensor, monitor, information processor, communicator, decision maker and actor?
    - The lack of human-human call-outs and cross checks?
    - The lack of a second human to monitor the state of the pilot flying?
    - The impact of the presence of the pilot not flying on the pilot flying?
    - Changes in mental workload?
    - The elimination of the processes involved in distributed and shared problem solving and decision making, including communications?
    - The availability of a second human as a redundant capability to take over the duties of the pilot flying?

  Note that this is important to adaptive planning as the pilot needs to detect, assess and respond to situations that require replanning.

- If a dispatcher/flight service provider isn't given shared responsibility for flight following, how do we compensate for the lack of this safety net?

  Effective plans require effective monitoring to determine when replanning is needed.
  Within the NAS today, some types of operations have mandated flight following, others have voluntary flight following, and yet others have no flight following (other than the pilot or pilots onboard). What is appropriate for different types of UAS missions in different classes of airspace and airports?

- What can we assume about the range of understanding (mental models) that we can expect from different pilots (as well as controllers, flight followers, etc.) in terms of the sensing, communication, navigation and other computational processes embedded in the UAS and the control workstation, and resultant behaviors in different scenarios?

  These mental models are critical in two senses. First, in order to "stay ahead of the aircraft", pilots, controllers, etc. need to have an accurate understanding of how the automation will behave when certain contingency plans are initiated by the automation. Second, these individuals need to understand what the UAS is capable of and how it will respond when they need to initiate some novel plan for an unanticipated situation.

- What can we assume about the effectiveness of the UAS and control workstation software in communicating the current state of the software, the intent/plans of the software, the options available to the pilot, VO or flight planner and the resultant implications of such design features and capabilities in terms of monitoring, planning, decision making and the execution of plans and actions?

  This is an extension of the point made by the previous bullet, emphasizing the need to introduce good affordances into the design of the interface with the software.

- What are the predictable classes of scenarios where the UAS automation and/or control workstation may be brittle, where human error could arise or where the "approximate adjustments [made by human operators] in order to try to successfully adapt to varying conditions" could fail? This includes the impacts of possible changes in the perception of risk.

  These situations need to be anticipated as much as possible so that contingency plans can be developed.

- What does the controller know about the capabilities and intentions of the UAS, the UAS ground control station capabilities and associated pilot, flight planner and VO performance?
- How do pilot, controller and traffic managers coordinate with each other in different off-nominal scenarios to help implement contingency plans?

In short, in order to help ensure equivalent safety, a valuable exercise would be to review existing contingency plans and emergency procedures for manned aircraft and ask the above questions to explicitly specify how the design and operation of UASs will compensate for differences from manned operations.

4.1 RESILIENCE

We defined contingency plans to be the design of explicit instructions on how to deal with a *predicted* off-nominal event or situation. A resilient system (Boring, 2008; Hollnagel et al., 2006; Hollnagel et al., 2011; Smith and Billings, 2006) extends the safety envelope in a different sense: A resilient system is one that has the capability to respond in a flexible and effective manner to unpredicted situations for which contingency plans were not prepared ahead of time (keeping in mind that "unpredicted" is a relative term – a problem might be anticipated at an abstract level and still require a sufficiently resilient design to find a solution for some specific instance that has arisen). Generally speaking, this requires a design that provides resource buffers that increase the flexibility and capacity of the system to detect and assess a problem in a timely manner and to develop and apply a unique context-sensitive solution to this problem. This can include:

- Developing an initial plan that leaves many flexible options open should some unanticipated situation arise. A simple example here is to prefer a route that provides access to many alternative airports/landing strips for a diversion, instead of planning a route that has very few alternates. Another important example is adding extra fuel when there is a high level of uncertainty about weather or traffic constraints so that more options (such as increased airborne holding or diversion to a more distant airport) are available should they become necessary.

- Providing access to additional human resources to provide the extra processing capability (mental workload; additional software support) and expertise necessary to evaluate and deal with a problem. An example is the ability of the pilot to get a dispatcher and maintenance on the line quickly if, for example, there is an indication of an oil pressure problem during takeoff.
- Designing software that provides the flexibility for the human operator to implement a novel solution, including the information displays necessary to assess a situation and envision the impacts of alternative solutions (Smith et al., 2006) as well as control functions that allow the implementation of some novel solution.

5. SCENARIO-BASED IMPLICATIONS FOR PLANNING IN UAS OPERATIONS

Below we describe three scenarios that should help focus attention on human factors requirements concerned with preflight planning, adaptive replanning, function allocation and ground control workstation design:

- Scenario 1. Low Volume, Company Owned Landing Strip (CTH) Used for Transporting Cargo to KILN Using Fixed Wing UASs
- Scenario 2. Low Volume UAS Traffic From KSGH and Back to KSGH Using Fixed Wing UASs
- Scenario 3. High Volume UAS and Manned Vehicle Traffic Departing KSBD; UAS Flight from KSBD to KILN Using Fixed Wing Aircraft.

Note that this set is far from complete. Future work will, for instance, need to focus on the use of rotorcraft in a variety of importantly different situations.

Since this document focuses on Task 4 (literature review on planning), we primarily highlight the issues these scenarios raise regarding:

Implications for Initial Pre-Flight Planning
Implications for Contingency Planning (preplanned adaptive replanning)
Implications for Resilience (novel adaptive replanning)

We have also included some observations regarding:

Implications for Function Allocation
Implications for Pilot Ground Control Station Design
Implications for UAS Automation
Implications for Airport/Airspace Design

The set of implications contained here is not meant to be complete. A more thorough analysis will be completed later in this project. We include some examples here simply because it is useful to capture them whenever we think of them.

Ultimately then, these scenarios are designed to provide coverage of *the relevant situations that need to be considered in developing human factors requirements for the design and use of UASs, with a primary focus on issues concerning function allocation (including preplanning and adaptive planning) and the design and use of pilot ground control stations*. For example, some of the human factors issues that arise in the use of fixed wing UASs over moderate to long distances flying to and from towered airports are different from those that need to be considered in using unmanned rotorcraft to replace helicopter operations for flying cargo from EWR to New York in order to meet tight schedule constraints.

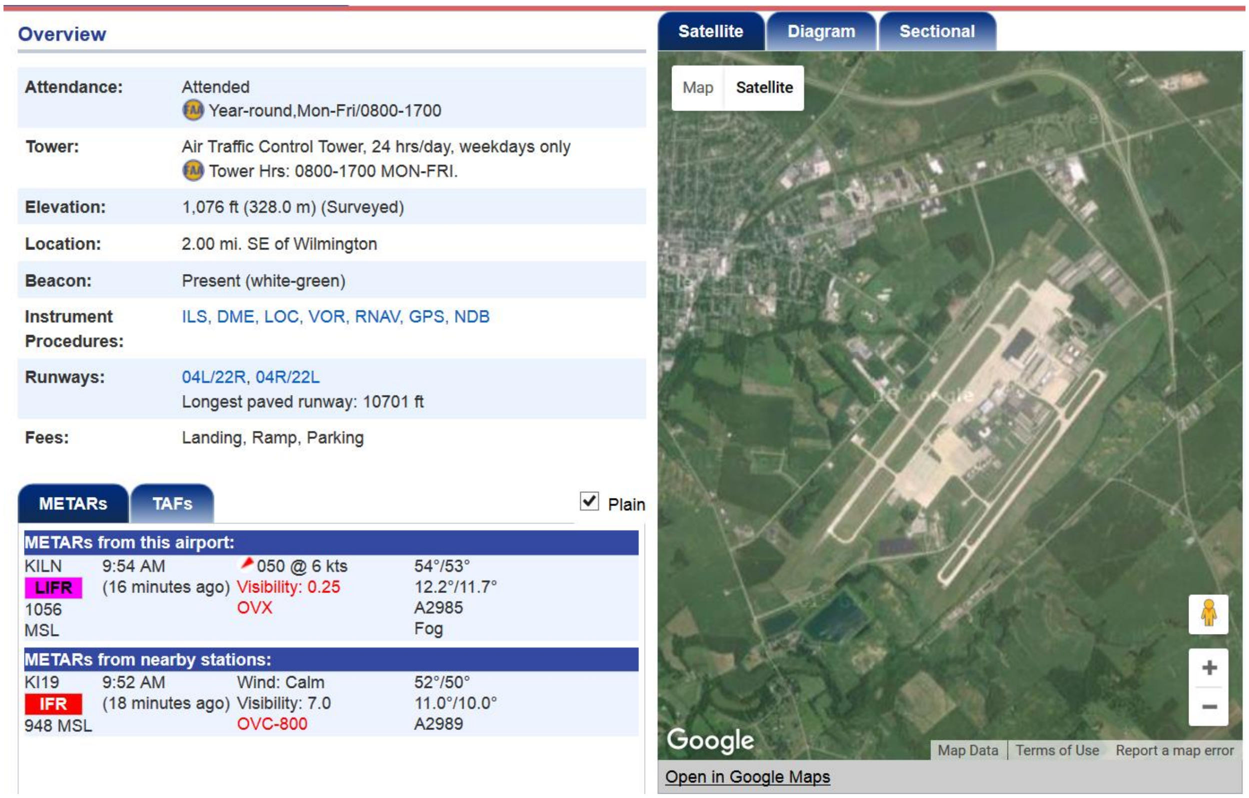
More specifically, the goal of such scenarios is to help focus attention on the important issues that need to be considered assuming a single pilot flies a UAS from a remote location, as contrasted with flight operations involving either a single pilot flying a manned aircraft or a team of two pilots together flying a manned aircraft.

In these scenarios, we have provided a sample description of performance in order to structure the consideration of alternatives and to evaluate them in terms of human factor issues. Some of these considerations have planning implications, which are highlighted in this document. Others have implications for function allocation and control workstation design. Some of the latter implications are noted in this document (since it was convenient to consider them now). Additional implications will be highlighted at a later date as this project progresses.

5.1 SCENARIO 1—LOW VOLUME, COMPANY OWNED LANDING STRIP USE FOR TRANSPORTING CARGO USING FIXED WING UAS

For this scenario, the goal is to characterize flights to and from:

- A company owned landing strip located at a ground shipping hub at a site outside of Detroit near Jackson Michigan that is used to transport a small number of high value packages on an as needed basis (1-2 packages per hour).
- The towered airport at Wilmington OH (KILN) serving manned general aviation flights, as well as manned and unmanned cargo flights using fixed wing aircraft operated by a number of different flight operators. For this airport, it is assumed that there is substantial arrival and departure traffic that requires management of traffic on the airport surface as well as in the terminal airspace and that the hours during which the tower is open will be increased to serve the demand. Information on KILN is provided in the figure below.



CTH is designed to handle the arrival and departure of fixed-wing UASs carrying cargo, all of them equipped with ADSB-OUT. There is a single runway to handle both arrivals and departures, and a tarmac designed to provide flexibility in taxiing aircraft or temporarily staging aircraft away from the ramp/loading area. There is no ATC Tower.

This hub is used primarily for ground shipping, but high value packages that need rapid delivery are shipped out of this hub using fixed wing UASs. On a typical day, 1-2 UASs depart per hour, and 1-2 arrive per hour.

For this scenario, we focus on a flight departing CTH. The flight pushes back at 2100Z and is filed to land at KILN (Wilmington Air Park in Ohio). There are no arrivals during this time period. However, a second aircraft has pushed back at the same time and is filed to land at a towered airport in Indiana.

CTH has a single runway that runs northeast to southwest. Given this simple layout, the ramp area feeds a taxiway that takes aircraft to and from either end of the runway without the need to cross it. A tug operator, who is in communication with the pilot, pushes the plane back from the loading area and moves it to a spot where the pilot takes control and taxis it into the active movement area. All of the aircraft are ADSB-OUT equipped so that the pilot can see the other aircraft in the active movement area on a surface display and maneuver appropriately (and there is a video camera at the landing strip showing a view of the active movement area that the pilot can see).

Given this process, under normal operations only ADSB-OUT equipped aircraft should be in the active movement area (no other vehicles). However, there will be times when other vehicles will have to enter the active movement area (for snow plowing, removal of FOD, etc.). When this occurs, the tug operator has the responsibility to act as a certified VO and coordinate with the pilot to ensure separation of aircraft and other vehicles. As a VO, the tug operator also has responsibility to confirm with the pilot that the runway is clear of FOD, animals, etc. before an aircraft lands or departs. Certification is required for this role by the tug operator.

KILN has two runways that run parallel, with the terminal area between the two runways (see figure above), and has an active tower 24 hours a day. Depending upon the mix of arrivals and departures, based on the impact on throughput, different runways may be reserved for arrivals, departures or mixed arrivals and departures, or one runway may be reserved for UASs and one for manned aircraft. This is determined not only by the numbers of arrivals vs. departures, but also based on the spacing and performance requirements of the different manned and unmanned aircraft. (For example, if the inclusion of UASs in a arrival stream increases spacing when using visual approaches (due to controller or pilot comfort levels or differences in performance characteristics), then there may be times when it is desirable to segregate manned and unmanned aircraft on separate runways.)

Since the UAS pilot cannot truly establish visual contact with surrounding aircraft, when a UAS pilot requests a visual approach while 20 miles out ("Request visual approach"; "Traffic is at 10 o'clock, 5 miles out SE bound 737"; "Traffic in sight"; "Roger, cleared visual approach to RW 21L") the pilot is actually confirming that he is "seeing" the aircraft on a radar display.

Certified UAS pilots working for the company are located at an operations center located at KILN in Wilmington OH. Thus, they do not have direct visibility of the runways, taxiways or ramp area at CTH.

> **Implications for Function Allocation:** A tug operator, who is in communication with the pilot, moves the aircraft from the loading area to a spot where control is transferred to the pilot. The pilot then uses a display of the aircraft on the airport surface and the image of a forward looking camera to control the aircraft as it moves from the spot to the departure queue to the runway. This tug operator also has responsibilities as a certified VO coordinating with the pilot.
>
> **Implications for Pilot Ground Control Station Design:** The pilot has a surface display that shows the locations and movement of all aircraft on the airport surface.
>
> **Implications for Pilot Ground Control Station Design:** The pilot has a view from a forward looking camera that shows other aircraft and objects on the airport surface that are in front of his aircraft, as well as a view from a fixed camera showing a lateral view of the active movement area on the airport surface.
>
> **Implications for Automation:** As an additional safety net, the UAS automation has a collision avoidance system the acts to prevent collisions on the surface.
>
> **Implications for Pilot Ground Control Station Design:** The pilot needs access to a control to quickly stop an aircraft on a taxiway or in the ramp area.

> **Implications for Pilot Ground Control Station Design:** Since there is no ATC, the pilot needs have a display with a view showing arriving and departing aircraft in the terminal area, with an associated alerting system to help detect a potential runway incursion.

> **Implications for Pilot Ground Control Station Design:** The pilot needs be able to quickly stop an aircraft or maneuver it off an active runway if a runway incursion is imminent.

> **Implications for Contingency Planning:** In case of a blunder or some other issue, the pilot of the arriving aircraft needs to be able to quickly initiate a go-around for an arriving UAS if the ground control station displays or alerts indicate a need in order to avoid a runway incursion with a departing UAS. A contingency plan has been developed for go-arounds and the details are described on an arrival plate that the pilot has reviewed before takeoff.

> **Implications for Pilot Ground Control Station Design:** The pilot and tug operator need an effective, means of communication for the handoff of control.

For this scenario we assume a blue sky day with winds from the west at 15 kts for the entire flight. It is a winter operation, however, and there has been some precipitation at KILN earlier in the day. These flights depart IFR southwest from CTH. They are cleared to depart by Lansing Approach.

5.1.1 Preflight Planning

(Global Hawk Pilot: "Contingency planning is everything. You have to stay ahead of the aircraft, so you need to plan for what you are going to do when something goes wrong or you have to deviate from the plan.")

After the aircraft for these two flights have arrived, maintenance inspects them. Both aircraft are prepped for departure. There are no MEL issues identified, so the aircraft are loaded.

> **Implications for Function Allocation:** There are new items included on the MEL for UASs that have to be checked.

In parallel, the pilots use a commercial flight planning service as support to prepare the flight releases. To do this, the dispatchers/flight planners at these services check:

- Weather.
- NOTAMS.
- Taxiway and runway conditions.
- Active MOAs.
- ATCSCC advisories.
- Maintenance release (MELs) and any associated implications (such as a restriction from flying into an area where icing could occur if the deicing is inop, or a restriction from landing at certain airports with wet short runways if the anti-skid is inop).

The dispatcher/flight planner at the flight planning service provides a flight plan. If the conditions at the destination airport warrant it, an alternate airport and associated fuel requirements are indicated. The dispatcher/flight planner also completes a quick check of the status for other possible alternate landing areas along the route, should something go wrong like an engine problem. (Business Jet Pilot: "I always check for other alternates along the way when I'm planning just to be safe. With a drone, it seems like this would be even more important since you don't have a pilot up there to look for a safe place to get the plane down if something goes wrong.")

> **Implications for Pre-Flight Planning.** An important question that needs to be addressed is whether, under some conditions such as flight into a congested airport or congested airspace, to increase safety, the FARs should require use of a flight planner, and whether this flight planner needs to be a certified dispatcher. (This is requirement for FAR 121 carriers, and is a voluntary practice for some business aviation operations and for some flight planning services.)

> **Implications for Resilience:** If there was a lot of uncertainty about the weather, as appropriate the dispatcher/flight planner should add extra fuel beyond the required reserve and alternate airport fuel loads in order to provide additional flexibility to deal with the weather.

The pilots review the materials provided by the flight planning service and file their flight plans (IFR).

> **Implications for Pre-Flight Planning.** To provide a second pair of eyes with a different background, and to ensure the pilot is familiar with the conditions for the flight, the pilot has responsibility for reviewing and accepting or modifying the flight plan he has received from the dispatcher/flight planner, including the alternate airport if any, weather forecast, fuel load, the implications of any MELs, etc.

The pilots (and dispatchers if applicable in some variations on this scenario) for these two flights note that there is no reason to expect ATC delays with either of these flights, so there are no concerns about compliance with FAR 117 or the equivalent for UASs.

40 minutes before ptime, the responsible traffic manager notes that the flight plans for these two flights are ok relative to any ATC constraints.

> **Implications for Pre-Flight Planning.** This is the first of several safety nets, distributing certain responsibilities to a traffic manager to ensure that the flight plan does not conflict with any ATC constraints. It assumes that a flight plan is filed (that the UAS is flying IFR). The traffic manager could amend the route. Current system: This amendment would be communicated from Flight Data to the pilot when the pilot calls for a clearance to depart. Current system for some flight operators: As soon as an amendment is made, it is communicated as an alert to the dispatcher who communicates with the pilot (and considers refueling or negotiation of an alternative route if necessary). Future System: The amended route is used in the PDC.

Each pilot checks out his workstation to ensure everything is working properly (comm check, etc.). In preparation for their flights, the pilots also review the relevant departure and approach procedures, etc.

As departure time approaches for each of the 2 flights, maintenance does a walk around to make sure there are no dings in the fuselage, etc. and informs the pilots (who are at the remote operations center) that everything looks good. (Global Hawk Pilot: "Maintenance has a better eye for problems with the plane than most pilots anyway.") When the final numbers are in, the pilot checks the weight and balance, and determines whether additional fuel is required (or whether cargo needs to be taken off the aircraft or shifted to provide proper balance).

5.1.2 Taxi Out

The pilots each receive a PDC. A crew boss has responsibility for the overall operation of the landing strip at CTH, including dissemination of any important information about the status of the airport (such as poor braking conditions) and coordinates surface movement as necessary.

Each pilot asks a tug operator to push the plane back from the loading area to the spot to enter the active movement area. The engines are started and control is transferred to each pilot.

Each pilot contacts Flight Data at Lansing Approach and requests a release time at or after his estimate of his earliest possible OFF time. Flight Data checks with the controller responsible for the relevant departure sector and receives a time window for departure by each flight. Flight Data radios these release time windows to each of the pilots. Each clearance instructs the pilot a time window to hit for departure and to climb to 3000 ft and contact Approach Control on a particular frequency.

The pilot for the flight to KILN taxis to the front of the departure queue to depart within the specified time window.

All communications in preparation for departure are conducted using the Unicom as there could be other VFR flights in the vicinity, so that there is broader situation awareness for all of the relevant pilots and VOs. The pilot and ATC do have a backup landline communication system set up, however.

Note: If the pilot needs to change route while taxiing out, the aircraft needs to be stopped so that he can devote his attention to the route change. This could require moving to the side of the taxiway and further coordination with ATC (and his dispatcher if applicable).

5.1.3 Departure

The pilot departs as cleared with the automation controlling takeoff, including the ability to abort the takeoff in case of some detected malfunction. The pilot has an override capability to abort the takeoff as well. The automation proceeds to fly the standard UAS departure procedure for the cleared route.

As the flight is climbing to 3000 ft, the pilot contacts Approach Control on the specified frequency.

If there is a need to return to CTH or divert to some other landing site due to a mechanical or some other emergency, the pilot communicates to ATC (declaring an emergency if necessary).

> **Implications for Contingency Planning.** All of the off-nominal and emergency procedures applicable to an equivalent manned aircraft need to be reviewed in order to develop the necessary capabilities to provide the equivalent level of safety for the UAS. These UAS aircraft procedures are available to the pilot to apply as needed if such an event arises while airborne.
>
> **One of the proposed next steps will be to review such procedures to evaluate their implications for function allocation, communication requirements, decision support, automation, procedures and training.**

5.1.4 Enroute

As an extra safety net since there is only one pilot, a dispatcher/flight follower working for the contracted flight planning service has shared responsibility for monitoring the aircraft while it is enroute, and is in contact with the pilot.

> **Implications for Contingency Planning and Resilience:** Both the pilot and dispatcher/flight follower have responsibility to monitor weather, ATCSCC advisories and NOTAMs relevant to this flight and to develop a viable alternate route or destination airport if there is a concern regarding the viability of the filed/amended route or destination airport. This shared responsibility provides a safety net in terms of workload, focus of attention and distributed expertise.
>
> **Implications for Pilot Ground Control Workstation Design:** The pilot and dispatcher/flight follower need displays and alerts that make very salient any concerns that arise regarding weather, ATCSCC advisories and NOTAMs relevant to a flight.

ATC communicates with the pilot just he would for a manned flight. The data tag does indicate, however, when an aircraft is a UAS. This includes clearance from the enroute controller to fly the STAR assigned to this flight as the aircraft approaches to Approach airspace.

TFM similarly has an indicator on the TSD marking flights that are UASs.

The automation flies the aircraft under the supervision of the pilot. Either ATC or the pilot can request vectoring, speed changes, altitude changes or reroutes, with the pilot initiating the actual changes through the automation. The other party needs to concur before some change in trajectory is initiated unless it is an emergency maneuver. Such a vector may involve assigning a heading, turning left or right a certain number of degrees, or flying to a new VOR, lat/long, intersection or arrival route.

> **Implications for Ground Control Workstation:** There must be a backup communication channel between the pilot and ATC in case of lost communication through the primary channel.

Implications for Contingency Planning. In the case of a loss of control of the UAS by the pilot (but where the automation continues to fly the planned trajectory), assuming the aircraft is aware that it can no longer receive instruction from the pilot, the contingency plan is for the aircraft to fly the planned trajectory, holding at a prespecified loiter point for a designated amount of time, and then proceed to land as filed, stopping at the prespecified spot for handover of control to the flight operator.

If the UAS is unaware of the loss of control, it will simply fly the planned 4D trajectory.

In both cases, ATC will clear the airspace around the expected trajectory for the aircraft to ensure separation, as well as the airport surface.

Note: A relatively low probability event would be one where there is a loss of control and some barrier to safe flight arises. This could be a pop-up thunderstorm in the path of the flight while enroute, in arrival airspace or at the airport. It could also be a runway closure at the destination airport. For the weather scenario, it might be possible to develop automation to vector around an enroute storm cell or initiate a diversion to the planned alternate airport. Our two ATC/TFM experts advised against putting such “intelligence” into the aircraft, citing concerns that this could lead to uncertainty about how the aircraft might behave (for example turning 180 degrees into traffic in order to avoid a storm). Their view was that this is a very low probability event where the added automation might be unacceptably problematic. (This merits further consideration.)

Finally, in such a case, a determination needs to be made as to whether the flight represents a security risk (e.g., a cybersecurity failure), in which case a military response may be necessary.

Implications for Contingency Planning. In the case where a flight goes NORDO, the backup landline between ATC and the pilot can be used as a backup, resolving the problem quickly if it is a problem with the selected frequency, or relying on the landline itself if there is some other type of problem.

Implications for Novel Adaptive Planning. In the event of a fly away, again, a determination needs to be made as to whether the flight represents a security risk in which case a military response might be necessary. If not, then an assessment still needs to be made regarding whether the flight can be allowed to crash land or whether a military response is necessary.

All aircraft in the airspace along the route for this UAS (at FL230) are under positive control by ATC.

If the aircraft encounters some airborne hazard (flock of birds, another UAS, a sky diver, a balloon, a manned aircraft that is ADSB equipped or has a transponder, a manned aircraft that has no radio, ADSB or transponder) and needs to maneuver quickly to avoid a collision:

5.1.4.1 Variation 1

Automation Initiated Hazard Avoidance (Sense and Avoid). The automation detects this hazard and unilaterally initiates a maneuver because a fast response is required, informing the pilot as it does so (with the pilot then informing ATC).

5.1.4.2 Variation 2

Automation Detected Hazard with Pilot Initiated Avoidance. The automation detects a hazard that does not require an immediate maneuver, informs the pilot and recommends a resolution. The pilot then requests clearance from ATC for the maneuver. The pilot may concur with the automation regarding the avoidance maneuver or may identify some different solution. Once cleared, the pilot instructs the automation to fly the maneuver.

5.1.4.3 Variation 3

Pilot or ATC Detected Hazard Avoidance. The pilot or ATC detects this hazard. The pilot (or ATC) specifies the solution (or the pilot requests the automation to generate a solution). The pilot instructs the automation to fly the maneuver (with clearance from ATC if time permits). If collision isn't imminent, the pilot requests clearance from ATC before initiating the maneuver. If ATC detects the hazard, similar coordination occurs to deal with the hazard.

> **Implications for Contingency Planning.** Any automation and manual procedures or rules of the road that apply to such a sense and avoid scenario represent important contingency plans.

If the controller requests the pilot to use a different approach procedure while the flight is still enroute, he is required to review the details associated with this procedure as well as enter it into the ground control workstation.

The pilot is also supported by the automation if the aircraft needs to be put into no notice holding.

If the pilot needs even a short break, procedures for handoff to another pilot have been defined and are followed.

5.1.5 Approach, Landing, and Taxi-in

Approach, landing, and taxi-in occur at KILN, an airport with ATC tower and two well-separated parallel runways.

All aircraft entering the approach airspace from FL230 are under positive control by ATC.

Some SMEs have suggested that, for busy terminal airspace, a co-pilot should be required during approach. (ATC SME: On manned flights, the time when they get behind the power curve is almost always on arrival.")

If, upon landing, a UAS misses its off ramp, the pilot has the ability to quickly instruct the automation to exit at another.

> **Implications for Contingency Planning.** A standard procedure needs to be defined, including coordination with ATC in case there is a trailing aircraft that needs to go around.

> **Implications for Airport/Airspace Design**. A review should be conducted to determine whether Towered Airports and associated procedures should be reviewed and certified for UAS operations.

The pilot controls the aircraft during taxi in, following the instructions of the ground controller until the aircraft reaches the spot. Once the flight reaches the spot and is no longer under positive control by ATC, the pilot is in communication with a VO who ensures that there are no obstacles along the path of the aircraft as it taxis to the loading area. (At a larger airport, this VO might be in a ramp tower and could be directing all of the traffic in a designated portion of the ramp.) (See Appendix A for an example of the training requirements for VOs involved in search and rescue operations using drones in Washington State.) Both the pilot and VO operate under sterile cockpit rules during taxi in. (Global Hawk Pilot: “You don’t want him talking to his wife on his cell phone while he is taxiing the plane out.”) The automation provides an additional safety net. It has a sensor that provides data that allows it to automatically stop the plane if it detects another obstacle that is close in front of it. (The pilot also has the ability to override this automation, however.)

Pre-designated holding areas on the airport surface have been identified and structured/marked (in terms of traffic patterns). Upon request from ATC, the pilot can route a UAS to a particular position in one of these holding areas.

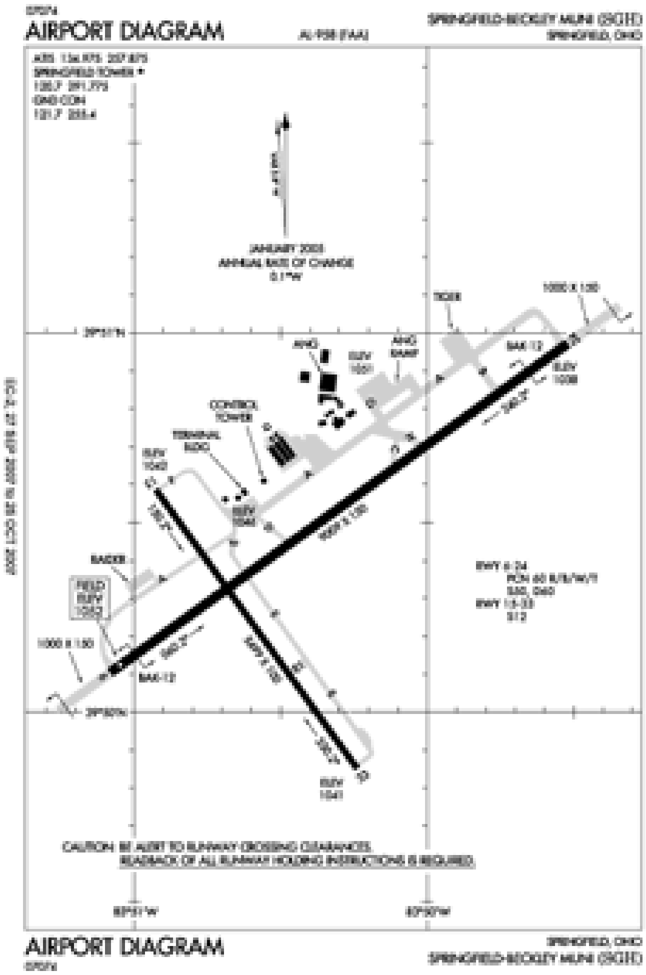
> **Implications for Contingency Planning.** Such surface holding areas need to be identified and marked in order to accommodate UASs.

5.2 SCENARIO 2—LOW VOLUME UAS TRAFFIC FROM KSGH AND BACK TO KSGH USING FIXED WING UAS

We have also considered another type of scenario involving the use of the non-towered airport at Springfield OH (KSGH) which serves a limited number of manned general aviation flights using fixed wing aircraft, as well as UASs. In this scenario we consider a UAS that departs from KSGH to conduct an aerial survey and then returns back to KSGH.

KSGH has two crossing runways, and does not have an active ATCT. Only one runway is active at any given time. (Runway 24 is preferred if the winds are 20 kts or less.)

The figure below shows the airport layout.



For this scenario, we only highlight important differences from Scenario 1.

Difference 1. This pilot might or might not use a flight planning service to develop the flight plan.

Difference 2. A NOTAM is submitted prior to departure to alert other aircraft about the presence of this UAS. The NOTAM indicates that this UAS will be in a given vicinity for a particular time range at a specific altitude.

Difference 3. Unlike landings and departures at KILN (but similar to CTH) there is no ATC tower, so departures and landings are not under the control of ATC. However, the flight is IFR and pre-coordinates with ATC. A flight plan is submitted telling ATC that the aircraft will fly to a VOR or lat/long in the vicinity of the planned aerial survey work (flying a grid at a specific altitude once there), the requested start and end time for the survey work, and requesting clearance to return to KSGH once it is done with the aerial survey. At Cincinnati Approach Control, the responsible controller is given a chart showing the plan for this flight.

Difference 4. If the pilot isn't on site at KSGH, a certified VO is required for departing and landing.

Difference 5. There could be aircraft flying in this vicinity that do not have transponders or radios. The pilots of those aircraft *should* be aware of the UAS based on the NOTAM, and have the responsibility to avoid this UAS.

Difference 6. The UAS does have onboard radar and a forward pointed camera that can be used to detect the presence of aircraft without transponders or ADSB-OUT. The pilot and the automation for sense and avoid will use these data to avoid loss of separation, responding based on the rules of the road.

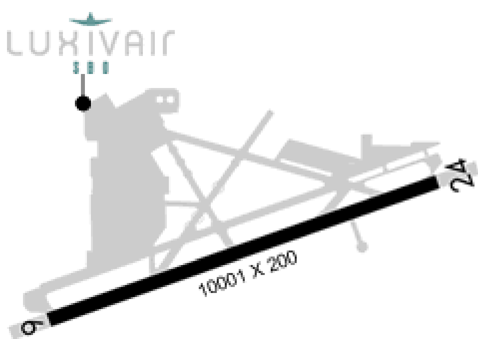
Difference 7. If the UAS has to divert to landing strip where no certified VO is present, aircraft and weather conditions permitting, the pilot needs to take all possible precautions to ensure that there are no obstacles on the runway when he lands.

> **Implications for Novel Adaptive Planning.** While the pilot may have considered a general plan to deal with such an unexpected diversion, he needs to have the resources to quickly develop and implement a feasible plan. This includes procedures for coordinating with ATC and with any authorities who may be available to act as VO, as well as the dispatcher/flight follower where applicable.

5.3 SCENARIO 3—HIGH VOLUME UAS AND MANNED VEHICLE TRAFFIC DEPARTING KSBD TO KILN USING FIXED WING UAS

Departure Airport: The towered airport at San Bernadino CA (KSBD) serving scheduled manned commercial passenger, business aviation and general aviation flights, as well as manned and unmanned cargo flights using fixed wing aircraft operated by a number of different flight operators.

Arrival Airport: KILN (as described in Scenario 1).



KSBD

For this scenario, we only highlight important differences from Scenarios 1 and 2, and assume a Cessna Caravan size UAS. A sample flight plan provided by ARINC indicated that a typical release for such an aircraft would put it at FL230 in cruise, and would require a refueling stop. It is an open question as to whether such an aircraft designed as a UAS would have similar constraints.

Difference 1. Like KILN, this is a towered airport, but it has more complex traffic patterns in the ramp area. Some combination of the use of tugs, VOs and/or a shared ramp controller will be necessary to ensure orderly traffic and to avoid collisions. (Tower/TRACON ATC: "The surface management may be the most complicated part of all this. How do I safely put him into the departure queue where I want him?")

Difference 2. This airport feeds a busier and more complex airspace with many aircraft flying to airports and through airspace that have MIT and other restrictions. This may require more careful airport surface queue management, which in turn will require more effective communication and coordination.

Difference 3. The range of aircraft in terms of performance characteristics need to be carefully considered in terms of ATC and TFM implications. One consideration is whether the true spacing as practiced by ATC will be the same for flows with UASs mixed into the traffic. During the initial introduction of UASs into an airport, it is highly likely that, in order to feel comfortable, ATC will increase the spacing (as have been observed with the introduction of RNAV arrivals into airports). Depending on the performance characteristics of the UASs, this might disappear with experience. If not, this could have implications for defining procedures and airport configurations.

- Sterilized airspace for firefighting or security missions
- UAS (rotorcraft) instead of helicopter for flights from EWR to New York City landing pad
- Complexity of different airports and airspace (including metroplex)
- Use of different classes of airspace
- Implications for TFM
- Performance characteristics of aircraft
- Complexity of pilot ground control procedures in different off nominal scenarios with a single pilot
- Impact of setting (sitting in an office vs. the cockpit) on the extent to which the pilot is "on top of things early enough".
- Loss of visual references for communication ("There's the red barn. I'm over the river.")

The goal of these scenarios is to help organize and situate consideration of the following questions:

- What are alternative strategies for function allocation (including planning and replanning) across different people and technologies?
- What are the human factors issues associated with such decisions regarding function allocation?

Given such human factors considerations, what requirements (assignment of roles and responsibilities; procedures; training; design of technologies; design of the broader work environment) are necessary to ensure safety while enabling cost-effective and efficient operations? (with a special focus on design of the pilot ground control workstation)

6. CONCLUSION

The goal of this report is to focus attention on important issues concerned with planning and adaptive replanning in the operation of UASs. To accomplish this, the discussion above was organized into three sections:

- Planning within a distributed work system.
- Contingency planning and resilience.
- Scenario-based implications for planning in UAS operations.

The first section emphasized the fact that, for UASs as for manned aircraft, planning and adaptive replanning needs to be viewed as a distributed work system, providing a safety net by distributing roles and responsibilities for a number of reasons, including the need to reduce the cognitive complexity and mental workload for any one individual, to provide access to a range of different areas of expertise and to provide a degree of redundancy because several different people are at some level attending to each flight. All of this contributes to increased safety and efficiency in the system. It should be noted that this planning is distributed across not only real time operational staff (pilots, dispatchers and flight followers, ramp controllers, ATC and air traffic managers), it is also distributed across technology and procedure developers.

The section on contingency planning and resilience further emphasizes the important role of technology and procedures developers, as they play a key role in developing explicit contingency plans based on predicted situations and, in the case of technology design, the incorporation of automation that may apply such contingency plans autonomously or under the supervision of a pilot. This discussion also notes that designing and planning to support the roles of humans and technology in monitoring for unplanned events is an important part of the contingency planning process.

In addition, the section on contingency planning explicitly identifies important differences between manned and expected unmanned operations and highlights the need to complete careful analyses that account for how these differences will be accommodated through the incorporation of new technological capabilities, procedures, and strategies for distributing work in order to ensure equivalent or increased safety in unmanned operations relative to manned operations. It is suggested that an explicit evaluation of such issues using current contingency plans (procedures) for manned operations may provide one useful approach for considering these issues in an organized manner.

This second section also makes an important distinction between contingency planning for predicted situations and designing for resilience to deal with unpredicted events. The discussion focuses on implications for supporting distributed work during such events and for designing technology to provide the flexibility for situation assessment, plan generation and plan execution. It also emphasizes ways in which preplanning can increase the resilience of an operation.

Finally, the third section presents three concrete scenarios (emphasizing that this is not meant to cover all of the relevant use cases that ultimately need to be considered). Within the context of these scenarios we begin to point out some of the implications for planning, as well as some limited points concerning function allocation and pilot ground control station design. This is another area where this report provides a foundation for additional upcoming work: A more thorough identification of the implications of specific scenario contexts to help focus the development of recommendations for human factors guidelines for UASs.

7. REFERENCES

Berman, B. & Dismukes, K. (2010). Designing a Better Error Trap: Crew observations show that checklists and monitoring are not as effective as generally assumed. Flight Safety Foundation. http://flightsafety.org/aerosafety-world-magazine/july-2010/error-trap

Boring, L. (2008). Human Reliability Analysis in Cognitive Engineering and System Design,

National Academy of Engineering 2008 Symposium Reports on Leading Edge Engineering, 103-111.

Borgman, A., Smith, P.J., Beatty, R., Billings, C., Evans, M. and Durham, K. (2010). Integrating airspace and surface constraints in pre-departure traffic planning and management. Proceedings of the 2010 International Conference on Human-Computer Interaction in Aerospace, Orlando, 135-147.

Degani, A. & Wiener, E. (1990a). Human Factors of Flight-Deck Checklists. NASA Contractor Report 177549. https://ti.arc.nasa.gov/m/profile/adegani/Flight-Deck_Checklists.pdf

Degani, A. & Wiener, E. (1990b). COCKPIT CHECKLISTS: CONCEPTS, DESIGN, AND USE. Human Factors 35(2), 28-43. https://ti.arc.nasa.gov/m/profile/adegani/Cockpit%20Checklists.pdf

Dixon, S. R., & Wickens, C. D. (2004). *Reliability in automated aids for unmanned*

aerial vehicle flight control: Evaluating a model of automation dependence in high workload (Technical report AHFD-04-05/MAAD-04-1). Savoy, IL: University of Illinois, Institute of Aviation, Aviation Human Factors Division.

Eurocontrol (2009). EUROCONTROL Guidelines for Contingency Planning for Air Navigation Services (including Service Continuity. http://www.eurocontrol.int/articles/guidelines-contingency-planning-air-navigation-services

FAA (2013). JO 1900.47D - Air Traffic Control Operational Contingency Plan. https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentID/1020800

Fernandes, A. & Smith, P.J. (2011). Tools to Support Distributed Adaptive Planning: Airport Surface Displays for Collaborative Departure Management. International Journal of Cognitive Technology, 16(2), 53-62.

Gary A. Klein, (1998) "Sources of Power: How People Make Decisions", MIT Press, Cambridge, Mass, pp. 1-30.

Gawron, V.J. (1998). Human factors issues in the development, evaluation, and operation of uninhabited aerial vehicles. *AUVSI '98: Proceedings of the Association for Unmanned Vehicle Systems International*, 431-438.

Hollnagel, E., Woods, D. & Leveson, N. (eds.) (2006). Resilience engineering: Concepts and precepts. Aldershot, UK: Ashgate.

Hollnagel, E., Paries, J., Woods, D. & Wreathhall, J. (2011). Resilience Engineering in Practice. . Aldershot UK: Ashgate.Jüttner, U., Peck, H. & Christopher, M. (2003). Supply chain risk management. International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management, 6 (4).

Knight, U. (2001). Power Systems in Emergencies: From Contingency Planning to Crisis Management. https://www.rothstein.com/data/dr584.htm

Kontogiannis, T. (1999). User strategies in recovering from errors in man-machine systems. *Safety Science.* 32, 49-68.

Lentzos, F. &Rose, N. (2009). Governing insecurity: contingency planning, protection, resilience. *Economy and Society*, 39 (2), 230-254.

McCarley J. & Christopher D. Wickens. C.D. (2000). Human factors in UAV flight. Proceedings of the IEA 2000/HFES 2000 Congress.

Malakis, S., Kontogiannis, T. & Kirwan, B. (2010). Managing emergencies and abnormal situations in air traffic control (part I): Taskwork strategies. *Applied Ergonomics*, 41, 620-627.

Obradovich J, and Smith P.J. (2003). Design concepts for distributed work systems: An empirical investigation into distributed teams in complex domains. Proceedings of the 2003 Annual Meeting of the Human Factors and Ergonomics Society. Denver, CO.

Orasanu, J. & Strauch, B. (1994). TEMPORAL FACTORS IN AVIATION DECISION MAKING. *PROCEEDINGS of the HUMAN FACTORS AND ERGONOMICS SOCIETY 38th ANNUAL MEETING.*

Prats, X., Pastor, E., Royo, P. & Lopez, J. (2000). Flight Dispatching for Unmanned Aerial Vehicles. Proceedings of the IEA2000/ HFES 2000 Congress.

Pastor, E., Royo, P. Santamaria, E. & Prats, X. (2009). In-Flight Contingency Management for Unmanned Aerial Vehicles. AIAA Unmanned Conference, 6 - 9 April 2009, Seattle, Washington.

Smith, P.J., Beatty, R., Hayes, C., Larson, A., Geddes, N. and Dorneich, M. (2012). Human-centered design of decisions-support systems. In J. Jacko (ed.), The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications, 3rd Edition, 589-621.

Smith, P.J., Beatty, R., Spencer, A. and Billings, C. (2003). Dealing with the challenges of distributed planning in a stochastic environment: Coordinated contingency planning. Proceedings of the 2003 Annual Conference on Digital Avionics Systems, Chicago, IL.

Smith, P.J., Bennett, K. and Stone, B. (2006). Representation aiding to support performance on problem solving tasks. In Williges, R. (ed.), Reviews of Human Factors and Ergonomics, Volume 2. Santa Monica CA: Human Factors and Ergonomics Society.

Smith, P.J. and Billings, C. (2009). Layered resilience. Resilience Engineering Perspectives-Volume Two. Hampshire England: Ashgate, 413-430.

Smith, P.J., Billings, C., Chapman, R.J., Obradovich, J. Heintz, McCoy, E., and Orasanu, (2000). Alternative architectures for distributed cooperative problem solving in the national airspace system. Proceedings of the 5th International Conference on Human Interaction with Complex Systems, Urbana, IL, 203-207.

Smith, P.J., McCoy, E. and Layton, C. (1997). Brittleness in the design of cooperative problem-solving systems: The effects on user performance. IEEE Transactions on Systems, Man and Cybernetics, 27, 360-371.

Smith, P.J., McCoy, E. and Orasanu, J. (2000). Distributed cooperative problem-solving in the air traffic management system. In Klein, G. and Salas, E. Naturalistic Decision Making. Mahwah, NJ: Erlbaum, 369-384.

Smith, P.J., McCoy, E. and Orasanu, J. (2000). Distributed cooperative problem-solving in the air traffic management system. In Klein, G. and Salas, E. (eds.), Naturalistic Decision Making. Mahwah, NJ: Erlbaum, 369-384.

Smith, P.J., McCoy, C.E., Orasanu, J., Billings, C., Denning, R. and Van Horn, A. (1997). Cooperative problem-solving in the national aviation system. In Boyarski, D., Butter, R., Krippendorff, K., Solomon, R., Tomlinson, J. and Wiebe, W. Design in the Age of Information, Raleigh, North Carolina, 97-99.

Smith, P.J., Spencer, A. and Billings, C. (2007). Alternative design to distribute work across multiple organizations: Control at different levels of abstraction. Proceedings of the International Conference on Naturalistic Decision Making, Monterey CA.

Smith, P.J., Spencer, A. and Billings, C. (2008). Traffic Management Tools for Dealing with Weather and Traffic Constraints in the National Airspace System, Proceedings of the 8th Conference on Human-Interaction with Complex Systems, Norfolk VA.

Smith. P.J., Spencer, A. and Billings, C. (2010). The design of a distributed work system to support adaptive decision making across multiple organizations. In Kathleen L. Mosier and Ute M. Fischer, (eds.), Informed by Knowledge: Expert Performance in Complex Situations. New York: Taylor and Francis, 142-161.

Stanard, T., Bearden, G. & Rothwell, C. (2013). A Cognitive Task Analysis to Elicit Preliminary Requirements for an Automated UAV Verification & Planning System, PROCEEDINGS of the HUMAN FACTORS and ERGONOMICS SOCIETY 57th ANNUAL MEETING.

Transportation Research Board (2012). ACRP Report 65: Guidebook for Airport Irregular Operations (IROPS) Contingency Planning. http://www.trb.org/Aviation1/Blurbs/166569.aspx

Tvaryanas, A. (2006). Human Factors Considerations in Migration of Unmanned Aircraft System (UAS) Operator Control. http://www.wpafb.af.mil/shared/media/document/AFD-090121-046.pdf

US Army (2012). The Operations Process. http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/adp5_0.pdf

Vigeant-Langlois, L. & Hansman, Jr., R.J. (2003). Implications of Contingency Planning Support for Weather and Icing Information. SAE 2003-01-2089.

Valavanis, K.P. &, Vachtsevanos, G.J. (eds.) (2015). *Handbook of Unmanned Aerial Vehicles*, Springer.

Wickens, C., Mavor, A. & McGee, J. (eds). (1997) Flight to the Future: Human Factors in Air Traffic Control, Chapter: 7 TEAMWORK AND COMMUNICATIONS. National Academy Press.

Williams, K.W. (2004). A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications. DOT/FAA/AM-04/24, Office of Aerospace Medicine.

Williams, K.W. (2006). Human Factors Implications of Unmanned Aircraft Accidents: Flight-Control Problems. Civil Aerospace Medical Institute, Final Report.

World Healthcare Organization (2011). Healthcare emergency checklist. http://www.euro.who.int/__data/assets/pdf_file/0020/148214/e95978.pdf