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TCL2 National Campaign Human Factors Brief

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Acronyms and Definitions

ABSAA ....AirBorne Sense And Avoid (radar)
ADS-B ....Automatic Dependent Serveillance-Broadcast
ANSP................................Air Navigation Service Provider
AOL..................................Aerospace Operations Laboratory (at NASA Ames Research Center)
BVLOS.............................beyond visual line-of-sight
CNS ....communication, navigation, and surveillance
GCS ....ground control station
GCSO ....ground control station operator
GPS...................................global positioning system
GUI...................................graphical user interface
iOS....................................internet and operating system
iUTM................................insight UTM
LOS ....line-of-sight
LTE...................................Long Term Evolution (4G cellular network)
mph ....miles per hour
NASA ....National Aeronautics and Space Administration
OC ....observer controller
OPR ....operator
PIC....................................pilot-in-command
RC.....................................radio control
RF ....radio frequency
RPIC.................................remote pilot-in-command
RTB ....return-to-base
SA.....................................situation awareness
STOMP ....Simple Text Orienting Messaging Protocol
sUAS ....small UAS
TCL ....Technology Capability
TCL2nc ....Technology Capability Level-2 National Campaign
UAS ....unmanned aircraft sytems (also ‘drone’ or UAV)
UI......................................user interface
USS...................................UAS Service Supplier
USS Op ....USS Operator
UTM.................................UAS Traffic Management System
VO ....visual observer

TCL2 National Campaign Human Factors Brief

Lynne Martin[1], Cynthia A. Wolter[2],
Ashley N. Gomez[2], and Joey S. Mercer[1]

The Technology Capability Level-2 National Campaign (TCL2nc) was conducted at six different test sites located across the United States during May and June of 2017. The campaign resulted in over 240 data collection flights using 24 different aircraft and involving 23 flight crews. Flights not only varied in duration but also in the environments and terrains over which they flew. The TCL2nc highlighted beyond visual line of sight and altitude-stratified operations and saw five partners bring their own, independently built, UAS Service Supplier (USS) for use during the flight tests. This document presents data collected during the TCL2nc that informs the 'Operator' section of the 'Requirements/Best Practices' from the UTM Technical Capability Matrix and Guidelines to Operate (Rios, version as of March 2017).

A review of the data collected indicated that although teams were well qualified on paper (in terms of both completing training and having experience with flying UAS vehicles), greater consideration should be given to the unique perspectives and backgrounds of future UAS operators. Overall, teams looked at a variety of sources for information, including USS client-displays, and participants became more mindful of the need to be aware of other vehicles, highlighting the value of reporting information. Observations found that flight crews' time to respond to a UTM issue depended heavily on the team structure, communication efficiency, and crew procedures. These points are discussed in more detail in this publicationn.

1.0 Background

As part of NASA's Unmanned Aircraft Systems (UAS) Traffic Management (UTM) effort (Kopardekar et al., 2016), the Technology Capability Level-2 National Campaign (TCL2nc) flight demonstrations took place during four weeks in May–June 2017 and involved six test sites located across the United States. Those four weeks encompassed eleven calendar days on which vehicles flew test flights, sometimes at more than one test site concurrently (see Table 1 and Appendix 1). Over these four weeks and six test sites, there were 23 shakedown (i.e., 'practice') flying days and an additional 17 flying days for data collection. Each test site was utilized and configured to meet the needs of the vehicles and the criteria specified in the test scenarios. Some test sites had as many as five ground control station (GCS) locations from which flight crews conducted their operations while others had two (Figure 1a and Figure 1b). Some test sites moved the locations of their GCSs depending on the scenario(s) they were flying that day while others were fixed bases. Flight crews varied in composition and size. Flight crews from some test sites were composed of individuals from

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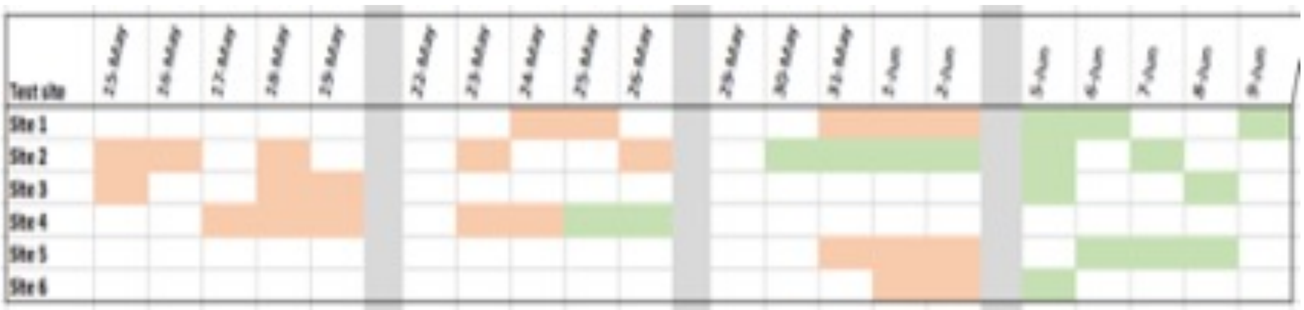
one organization while other test sites sent multiple crews, each from different organizations. Two-thirds of the test sites (Sites 1, 2, 4, and 5) centrally managed their UTM service supplier (USS) onsite, with one USS operator (USS Op) located separately from the flight crews overseeing the USS operations for all of that test site's flight crews. The other test sites integrated a USS Op within each flight crew. Scenarios were developed by each test site to demonstrate the UTM capabilities that they had proposed. Some test sites created one scenario with multiple variations to capture these capabilities while other test sites constructed multiple unique scenarios.

Table 1. Flight Days and Shakedown Days for the TCL2nc



Key: Orange background = a shakedown day; green background = a data-collection day.

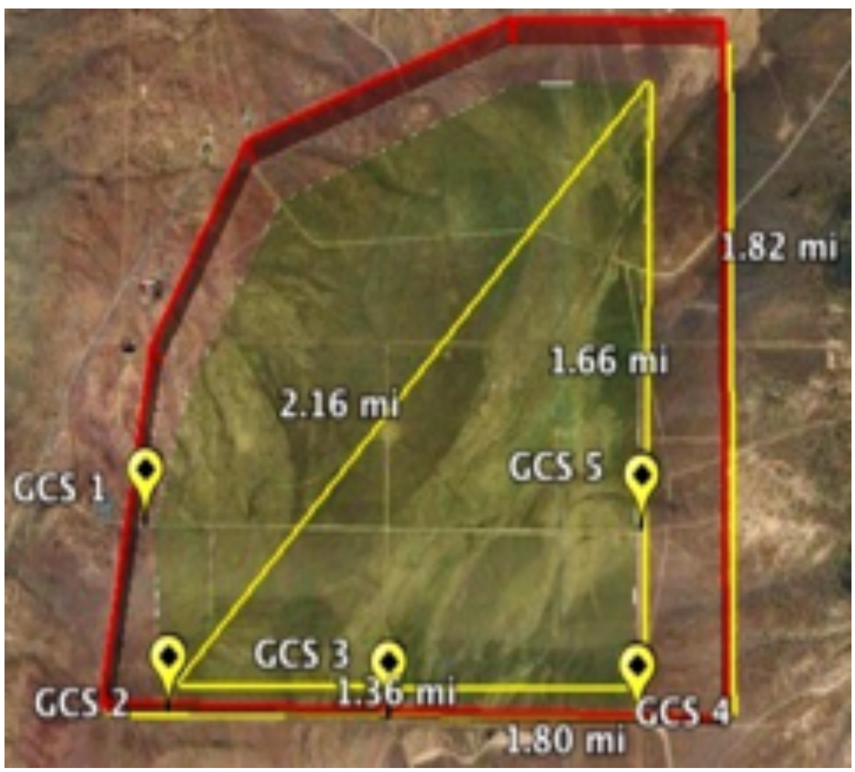


Figure 1a. Example of a UAS test range with five fixed GCS.

Figure 1b. Example of a UAS test range with four variable GCS.

1.1 Participant Roles and Responsibilities

Flight crews varied in number and affiliation: some had just two individuals while others had approximately twelve in their crews (Appendix 2). Primary flight crew positions included those listed in Table 2 and additional positions staffed by some, if not all, of the flight test sites are listed in Table 3.

Table 2: Crew Member Roles and Responsibilities

Crew Member Role	*Crew Member Responsibilities*
Pilot-in-command (PIC)	Serve as the main pilot for the vehicle.
GCS operator (GCSO)	Work the vehicle's flight planning and flight execution software.
USS operator (USS Op)	Monitor and interact with USS displays (and NASA).
Hardware and software flight engineers	Support specific technical aspects of the vehicle.
Visual observers (VOs)	Safety monitors who provide visual contact with the vehicles at all times.

Table 3: Test Site Support Personnel Roles and Responsibilities

Test Site Role	*Responsibilities of This Role*
UTM manager	Ensure the USS software is running and conduct troubleshooting when needed.
Radio control (RC) safety pilots	Serve as alternate pilots if the PIC needs assistance.
Flight test manager	Coordinate the crews and flights to conduct the test scenarios properly.
NASA researchers and observers	Collect observational and survey data; observers were available to support media day and answer flight team questions.

Although each test site created their own configurations of personnel, two types of team organization emerged with respect to UTM. One type of team organization included having the USS Op role as a dedicated member of the flight crew, either completing USS client management tasks alone or by having one crew member splitting the USS Op role with another role (e.g., at test Site 3 the flight crew consisted of two people: a GCSO/PIC/USS Op and a safety pilot/launch engineer). The advantages of having the USS Op role within the flight crew team was that this person was able to focus completely on the crew's mission and communications were reduced. The cost was the number of additional personnel or, if the role was timeshared by one team member, that periods of high workload were compounded if all roles were busy at the same time (e.g., at launch). A second type of team organization was one in which a dedicated USS Op fulfilled that role for a number of crews (e.g., at test Site 1 one USS Op submitted and managed the flight volumes for four flight crews where each flight crew consisted of a PIC, a GCSO, and a launch engineer). Four test sites took this "hubandspoke" approach—test Sites 1, 2, 4, and 5. The advantage of separating out the USS Op role was that this person became a specialist and overall required manpower was reduced. The cost was the increase in communications load as the USS Op had to stay in contact with all the flight crews they were serving and the workload related to managing multiple flights in the case that one flight crew/vehicle was having an off-nominal event.

1.2 Vehicle Characteristics

The vehicles flown during the demonstration were a mix of small fixed-wing, multi-rotor, and hybrid UAS vehicles, each with varying performance characteristics and endurance limits. There were 24 different models of aircraft flown. The multi-rotor vehicles were able to take-off and land vertically in a small area and turn on a point in the air, whereas the fixed-wing vehicles flew similarly to manned light-aircraft: taking off on a climbing trajectory, making banked turns in the air, and either gliding down into a belly landing or descending to a lower altitude before deploying a parachute. All of these methods required larger areas on the ground than the multi-rotor vehicles. Hybrid vehicles performed similarly in-flight to fixed-wing vehicles but with the vertical take-offs and landings of multi-rotor vehicles.

Most vehicles could be controlled either by providing point-to-point direction through a GCS or manually by a PIC, although some were fully-automated only (GCS control only). As an example of the latter, Test Site 3 eventually chose to manage their operations with automated control only, with no manual option (although the vehicles could have been manually controlled) during their flight test. During all flights, whether they were line-of-sight (LOS) or beyond visual line-of-sight (BVLOS), the behavior of the vehicle was monitored by at least one VO at all times[3]. In cases of unexpected vehicle behavior, the VO could contact the flight crew and/or the Flight Test Manager so that the appropriate action could be taken.

1.3 Interfaces and Information Displays

Equipment available at each GCS location varied widely across (and sometimes within) test sites. At most GCSs, several displays were available to the flight crews to give them information about their vehicle's flight and some also included displays to show surrounding operations and/or aspects of the UTM system. For example, Test Site 3 provided four screens for its GCSO/PIC/USS Op. This individual did not have LOS contact with (i.e. could not see) their vehicle. Standard tools shown on their displays were their flight planning/execution software, a USS client, and a fusion of radar, multi-lateration systems, and GCS telemetry. The fourth screen was available for use to show other information of the GCSO/PIC/USS Op's choice, including weather, vehicle and USS data, radio frequency usage, etc. Other test sites which had more mobile/portable GCSs used fewer displays. At Test Site 5, for example, flight crews only had a hand-held controller and one display showing the autopilot software for their vehicle. These flight crews did not have access to a display of UTM information. Instead, UTM information was verbally relayed to them by radio from a centralized location where the USS Op had such a display.

All test sites used at least one surveillance system to provide information about the airspace not provided by vehicles' on-board sensors (GPS, ADS-B), helping to identify other manned and unmanned aircraft flying near the test site. During the national campaign, a NASA-built iOS (internet and operating system) application (insight UTM [iUTM]), provided visualizations of UTM system information and current operations and was made available to the test sites. Test Sites 3 and 5 elected to use iUTM as an additional situation awareness display.

In the same way that there was a mix of team members and vehicle types, the partner-built interfaces to UTM also differed. Across the test sites, five different partner-built USSs and the NASA USS were used during the national campaign. Two test sites used more than one USS (Test Sites 2 and 6), and two test sites used the same USS (Test Sites 1 and 4). The tools and displays available within these USSs varied—primarily because each partner developed their USS independently, with no standard regarding how to display various pieces of information. The USSs were still under development and had a wide variety of available functions and features. To participate in the TCL2nc, all USSs needed to have certain basic capabilities but the manner and extent by which the partners met those requirements differed and are not examined in this paper.

1.4 Partner Focus and Test Scenarios

The test scenarios needed to incorporate some combination of altitude-stratified operations, BVLOS operations, altitude-stratified BVLOS operations, dynamic re-planning, responses to alerts from the UTM System, and the implementation of off-nominal contingency plans. Test sites then used their own test scenarios to investigate one or more of the following areas: USS technologies and procedures; geo-fencing technologies/conformance monitoring; ground-based surveillance/sense and avoid; airborne surveillance/sense and avoid (ABSAA); communication, navigation, and surveillance (CNS); and human factors related to UTM data creation and display. Some test sites

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[3] Multiple VOs were positioned along BVLOS routes to ensure "eyes on" the vehicles at all times.

built only one base scenario and addressed their objectives with several small variations of that scenario (Figure 2). Other test sites built a variety of scenarios with each one addressing specific objectives and varying in length, locations, flight plans/volumes, and number of airborne vehicles (Figure 3). The test sites' local geography and environment also influenced their test scenarios. For example, some GCSs were at airfields while other locations were in agricultural fields and some GCSs had tree cover while others were on marshy ground close to water.

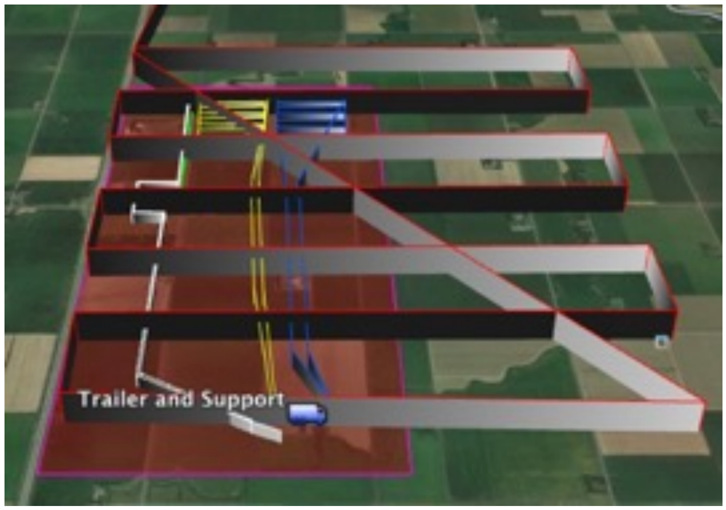

Figure 2. Example base scenario designed to use altitude-stratified operations, BVLOS operations, and altitude-stratified BVLOS operations for investigating data creation and display as well as USS technologies and procedures. Variations of this scenario were also used to investigate CNS, ground-based surveillance/sense and avoid, as well as geo-fencing technologies and conformance monitoring.

Figure 3. Example objective-specific scenario, designed to use altitude-stratified operations, BVLOS operations, and altitude-stratified BVLOS operations to investigate responses to alerts from the UTM system and airborne surveillance/sense and avoid.

1.5 Research Objectives

The research objectives are listed in the Operator section of the Requirements/Best Practices from the UTM Technical Capability Matrix and Guidelines to Operate (Rios, version as of March 2017). The Operator section has four areas: qualification, information requirements, reporting, and response time to Air Navigation Service Provider (ANSP) (as noted briefly in Table 4 and in its entirety in Appendix 10). With the goal of informing what the minimum requirements and/or best practices might be in each of those four areas for TCL2 operations, the driving enquiry was: How do you get the information you need—when you need it—to successfully fly a UAV in UTM airspace? This enquiry touches on the requirement for displays to provide adequate situation awareness (SA), the requirement to share information through a USS, the requirement of operators to have enough knowledge in order to understand what they are seeing, and the requirement to respond quickly enough when an action is needed.

Table 4. Operator Topics from the Requirements/Best Practices Portion of the UTM Technical Capability Matrix and Guidelines to Operate

Topic	*ID*	*Capability*	*Candidate Metrics/Measure*
Operator (OPR)	OPR1	Qualification	Training and operator requirements
	OPR2	Information requirements	Situational awareness displays, notifications connected to USS
	OPR3	Reporting	Ground control station or vehicle connected to USS
	OPR4	Response time to ANSP Directive	Via USS

The definition of operator training requirements included operator experience (with manned aircraft, UAVs, and UTM) as well as team organization (physical and social, including coordination, teamwork, and planning). The focus on information and reporting requirements encompassed the accessibility of UTM information, the information's method of presentation, and the reliability of the information. Of note was information submission and retrieval pertaining to volumes and geo-fences, situation awareness displays, alerting styles, telemetry reporting, and communication links. To investigate response time, general situation awareness, operator workload, subjective decision-making performance, and errors were observed.

2.0 Method

During test days, teams of two researchers collected data from the participants at each test site about their experiences and during shakedowns; usually two researchers were present. To the extent possible, researchers observed all flight crews at some point across the test days. Data were collected in a number of ways:

- observations of the participants during flights
- brief post-flight questionnaires
- end-of-day group interviews

All of these methods solicited feedback on the four areas of operator-specific requirements and best practices (Table 4). In total, 18 end-of-day group interviews were collected across the six test sites, totaling 8.93 hours of recordings. During these end-of-day debriefs, flight crews discussed the operator-specific topics as they related to the UTM operations at their test site (a tabulation of topics covered in the interviews are in Appendix 9). Survey items were generated with the four topics (Table 4) in mind but were presented to the participants in the context of the research objectives of the test site's test scenarios. Approximately 40 questions were generated in the survey but conditions were set so that participants only answered about 15 at any one time. Most questions used a seven-point rating format but some were multiple choice or open-ended. Two sources of operational data were also obtained:

- test sites shared their telemetric flight data, and sometimes other logged data, with NASA
- NASA's internal records of USS data, as captured through a separate, data-aggregation server

2.1 Initial Methodology Adjustments

After experiencing the range of the TCL2nc's shakedown activities, AOL researchers realized that some of the data collection methods that were designed to be universally applicable did not align well with the particular flight crew procedures or conditions at the test sites they were visiting. In many cases flight crews had little spare time between finishing one flight and preparing for the next flight. As a result, the post-flight questionnaires were moved to become end-of-day questionnaires. This caused fewer interruptions to the test site's conduct of their operations but also resulted in less survey data.

3.0 Results

After the flight tests, researchers spent time compiling and organizing the five types of data listed above in the Method section. Initial intentions were to combine data to perform TCL2nc-wide analyses. However, so many differences were present between the test sites that the data has been treated more generally and, to date, only high-level points have been drawn out. These are discussed below.

3.1 Summary of Flights

During the TCL2nc, 611 total flight activities were recorded by UTM. Of these, 503 were live flights and 108 were simulated flights from a GCS communicating with UTM (Table 5). The TCL2nc distinguished between shakedown days and data-collection days. Shakedown days commonly included equipment testing (e.g., testing connectivity with UTM) while data-collection days focused on complete flights meant to satisfy the test scenarios. More detailed numbers regarding how these flight activities were distributed over the six test sites are given in Table 5. For the 244 live data-collection flights, NASA received 128 vehicle-based data recordings from partners, which will be the core data set for future analyses.

Table 5. Overview of all Simulated and Live Flight Activities Recorded by UTM during the TCL2nc

611 total (simulated and live flight activities recorded)				
	503 – Live		*108 - Simulated*	
	274 – flight day	*229 – shakedown*	*53 – flight day*	*55 – shakedown*
Site 1	32	22	15	0
Site 2	32	24	5	1
Site 3	28	39	15	10
Site 4	69	99	16	43
Site 5	28	9	2	1
Site 6	85	36	0	0

3.2 Operator Research Objectives

A subset of the collected data has been reviewed and is described below under the Operator topics from the Requirements/Best Practices table to highlight the key team observations and discussion during the flight tests. Field observers and the surveys focused on the four areas of the project matrix specified above in Table 4:

- operator/training requirements
- information requirements and reporting (information "in" and information "out")
- response time

Reported here are recurring themes noted during field observations that relate to these four areas and were seen in, or reported by, multiple test sites. A summary for each category of observations, the debriefs, and some of the survey questions follows. Although the discussions are split into these four Operator categories, many of the points are not exclusive to the category in which they are mentioned.

3.2.1 Qualifications—Operator and Training Requirements

As part of a shakedown survey ("shakedown 1"), participants were asked five questions about their Remote-pilot (RPIC) and manned flight qualifications and experience. See Appendix 4 for a listing of these questions. Numbers of responses varied from 20 to 29 (out of 29 respondents to the survey) across these five questions.

Participants in the field tests felt well prepared for the task; 23 respondents (out of 29) reported that they held a Part 107 remote pilot's certificate (sUAS). However, note that the respondents varied in their role and not all of these personnel flew the UAS (i.e., were the PIC). Of 29 respondents, 17 were not the PIC (54%) and 29% (9) were neither PIC nor GCSO. Respondents reported having 890 hours (on average) of UAS flying time. There was one outlier respondent who reported three times as many hours as the next highest reporter. (If this outlier is removed m=530 hours.) On average, respondents reported having spent 729 hours-in-the-role they were working for the field test. Again, if the outlier is removed, the average number of hours-in-role reduces to 515. They also reported having spent 123 hours (on average) working with the vehicle they were using in the field test (see Appendix 4, Figure A4.1).

In addition, many of the participants held manned pilot certificates. Only a quarter of the respondents (7) said they they didn't have any piloting certificates. Of those who did, 7 respondents (24%) said they held a private pilot's license or were in the process of attaining one and 13 (44%) reported holding more than one certificate (see Appendix 4, Figure A4.2). On average, manned-vehicle pilots reported having 2,003 manned flight hours (range 41–14,500). Taking just the respondents who said they were PIC in the national campaign flight tests (n=11), the mean number of manned flight hours per PIC increases to 2,944.

Among the test sites, there was a wide range of past experience with UTM and managing airborne operations in a future UTM environment. These varied both within a test site and among all the test sites. The physical and social organization of the teams were also different, whereas some teams operated with a single USS Op/specialist for all operations and others with multiple USS Ops taking the workload for one operation each. Awareness of UTM was generally observed to be higher for the team when USS Ops were co-located with the flight crews. Knowledge of the UTM concept also varied between none and expert level, with USS Ops sometimes having less understanding than predicted. USS Ops sometimes did not know what information was available to them or who in the crew knew—or should know—which pieces of information.

As training was ongoing throughout the flight tests, performance interacting with the USS client was observed to improve as roles were better defined over time. Depending on their background, different operators focused on different tools for situation awareness. Those with traditional aviation experience (or were long-term UAV pilots) were eyes-out (or on the ground station display) while those with a programming background were more likely to interact with UTM and to be informed about states and other information useful for situation awareness of their operation and others'. Procedures were often not firm at the start of the test. This also influenced teamwork/coordination. The flow of the tests was observed to improve as these elements improved.

In debriefs, crews were asked to discuss what experience and qualifications a UAS flight crew should hold. From the debrief transcriptions, there were 50 direct comments that are described under six categories in Appendix 9. For examples of these comments, please see Table A9.1. Debrief participants also talked about operator requirements—the processes and methods they use when flying a UAS mission. From the debrief transcriptions, there were 81 direct operator requirement comments that are described under six categories in Table A9.5 in Appendix 9.

When discussing qualifications to fly UAS, debrief participants underlined that, in their opinion, while the current qualification requirements (Part 107) were adequate for line-of-sight flying, for BVLOS flying an operator needs to have more skill and should be required to have more flight experience and probably a rating to indicate that. Operators discussed that BVLOS training could include time shadowing a more experienced pilot or flying practice sorties into congested airspace and BVLOS under the oversight of a mentor. They discussed that off-flight-line training (ground school) should include many of the aspects of private pilot ground school; for example, modules about the weather, communication, and terrain awareness.

In regard to going out on missions, participants discussed the need to plan sorties beforehand, considering not only the desired flight route but also what contingency actions the crew would take if different problems arise along the way. They emphasized the importance of the entire flight crew team being "on the same page" and therefore how important it is to prepare the whole team (e.g., include in planning and briefings) for flights. Team members, other than the PIC, in addition to their role on the team contribute to the group's situation awareness and PIC gave examples of instances where knowing other flight crew-members had situation awareness or receiving regular communication from a flight team member was invaluable. PIC suggested that that their attention sometimes needs to be focused on the health of their vehicle and at these times they are relying on crewmembers to be aware of other aspects of the event unfolding. They also noted that, because unplanned events can occur at any time, UTM demands and USS interfaces should be designed to minimize PIC distraction.

3.2.2 Information Requirements

In a shakedown questionnaire and during the end of day survey, participants were asked five questions about where they looked during flights to gain information about their vehicle. See Appendix 5 for a listing of these questions. Numbers of responses varied from 24 to 45 (out of 155 respondents to the end-of-day survey) and were 19 for the shakedown survey.

Before taking part in the flight test, respondents estimated that they would look to other personnel (e.g., the GCSO or the USS Op) 75% of the time and look at displays about 25% of the time to gather information about their own vehicle, with talking via radio being the most frequently chosen option (n=14). It should be noted that the question options were uneven, as six personnel roles were listed but only three displays (see Figure A5.1 in Appendix 5). Most respondents reported seeking vehicle information from more than one source of information. After days when they had flown BVLOS missions, participants were asked a similar question. Again, most respondents reported looking at more than one source of information to keep track of their vehicle when it was BVLOS. On average, participants reported looking at three sources of information. About 27% of the time, respondents reported looking at their ground station display and talking to their VO to gather vehicle position information (Figure 4). The USS client display was the third most popular source of information, chosen 23 out of 135 times (17%) (mid-blue [lowest] blocks in every bar on Figure 4).

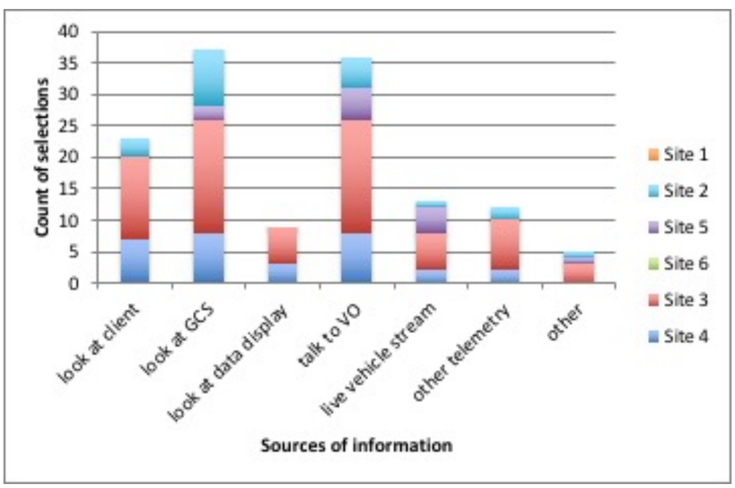

Figure 4. Means by which survey respondents found information about their vehicle when it was flying BVLOS. Note: Due to a number of reasons, including those discussed in the "initial methodology adjustments" section, only participants from four sites answered this question.

Participants were asked the same question again in the context of acquiring information for altitude-stratified flights—although only four sites answered this question. Again, most respondents reported looking at more than one source of information to keep track of relative aircraft positions when their flight was altitude-stratified with another. On average, participants reported looking at two sources of information. About 25% of the time respondents reported looking at their mission planner display (GCS) and/or their USS client display (see Appendix 5, bars 1 and 2 on Figure A5.2). Looking into the airspace was the third most popular source of information, with 10 selections out of 53 being the sky.

When asked questions about the process of finding information rather than the source of data, half of the respondents (16 of 32) reported they were "easily" able to find all the information they needed to support their decisions (Appendix 5, Figure A5.3). Only one respondent said they found it difficult to find information and three more said they had no displays (4 of 32, 12.5%)[4]. Comments supported these option selections but respondents often said that they gathered information from other people rather than displays, e.g., "all information was provided by my eyes, crew, and OC radio calls" (Test Site 2 participant). This also applies to their use of their USS client; a third of the time participants reported looking at the USS displays themselves and the other two thirds of the time they had other people report the USS client information to them. It should be noted that it depended on their role in the flight crew and whether they were reporting or being reported to. Additional verbal communications were required when the UTM Op was remote from the rest of the crew.

In debriefs, operators were asked to discuss information that they would want to gain from their displays/tools and their team about their own flight and others. From the debrief transcriptions, there were 127 direct comments that are described under seven categories in Appendix 9. For examples of these comments, see Table A9.2.

Crews noted in debriefs they wanted to be able to immediately see all aspects of their vehicle health, performance, and location. They also wanted to be able to find out location and health information about other flights in their vicinity. They were interested in receiving alerts about issues with their own vehicles and with others and some suggested that they wanted their USS to suggest courses of action, give an account of why issues arise, or how crews might recover from a situation. However, this is a substantial quantity of information and, along with the list of items they would like to know, crews noted occasions during the flight tests when they experienced both visual and aural clutter from their displays. There were concerns that too much data was available and that crews could not pay attention to all of it without being distracted. Although the amount of information that a crew was able to attend to depended to some extent on the size of the team, the debrief and observation comments suggest that information needs to be carefully prioritized and then layered within the tools available to ensure that the most pertinent information is the most readily available but all information could be obtained if needed.

To facilitate safe and efficient operations, flight crews needed fast access to easily understandable information about the current mission, nearby operations, and the surrounding environment. When available, situation displays were used by crews for awareness and decision-making. Some feedback suggested that crews sometimes struggled to extract the information they needed from the displays they used in the flight tests—sometimes information was buried too deeply in the tool given the time

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[4] Absence of a visual display does not mean that the participant received no information, as many flight crews were designed to receive information via voice.

available and other activities occurring; other times messages were difficult to interpret. Some information participants said they just did not need, although opinion was divided on this. When the information displayed was perceived as unreliable, its usefulness was diminished as operators lost trust and sought out alternate information sources. For example, observers at different sites noted instances of multiple sources for position data showing conflicting information at the same time. Crews considered not just what information they would like to receive but also how it is presented. Many teams liked audio presentation of messages, emphasizing that messages need to be simply worded and that audio presentation should be used selectively. They also noted that the environmental conditions in the field sometimes make visual displays challenging to use.

Hindrances to information being exchanged were observed in two ways. Firstly, network connectivity issues caused problems with information being sent to UTM. Some connection issues identified include: signals from vehicles being interrupted by structures; radio interference; weak LTE cellular connections; slow (ADS-B) data exchange rates; weak wifi signals; unexplained "dead zones"; pauses during in-flight resubmissions; RF interference; and signal scramblers. There were also less clear connectivity issues from the USS to UTM.

Human error when inputting information was also observed at nearly all the test sites. For example, when a flight plan was modified at the last minute, sometimes the corresponding adjustments were not made to the volumes so although the volume submissions were valid they no longer reflected the planned flight—resulting in non-conforming and rogue states. Additionally, operators sometimes neglected to reflect changes in their planned or current flight within UTM. This may be a reflection of an operator's familiarity working within the UTM environment. Calculation errors for appropriate volume altitudes and time-length of segments also caused issues during submission and during flight. The submission process in general was sometimes hindered by environmental conditions such as noise, sun, or glare around the USS operator.

3.2.3 Reporting

In debriefs, operators were asked to discuss information that they would want to send out to other operations and what they thought should be required to be broadcast. From the debrief transcriptions, there were 24 direct comments that were gathered under four categories. For examples of these comments see Table A9.3 in Appendix 9.

Crews were keen to share as much information as possible with support personnel, or "home base," suggesting streaming raw data from their vehicle to these locations. They noted that consistency/ standardization of information and formatting on a USS GUI is needed for these remote personnel (including the USS Operator when s/he is managing a number of flights from a central location) to be able to compare across—and understand—the multiple flights they are likely to be managing. The information that operators felt they should broadcast to others concerned off nominal vehicle states rather than nominal data. This was echoed in the observational data collected. Operators at one site suggested flight crews should have to broadcast low battery states, loss of connectivity, needing to land immediately, and other unplanned vehicle states (Appendix A9.3). Other discussions restated that a USS needs to transmit, or report out, off-nominal events occurring with a user's own operation or a nearby operation, such as non-conforming or rogue states, lost links, return-to-base (RTB), and RTB procedures or intent. However, interviewees emphasized that the community needs to agree on the terminology for each of the states that is broadcast to ensure that everyone broadcasts the same message for the same state. They also noted that the terms should be straight forward, not confusing, and should not conflict with current aviation terminology. Another point crews made about broadcasting off-nominal states is that the crews themselves cannot be required to send these messages since they will be too busy managing the event. This suggests that off-nominal information broadcasts through USS clients will need to be automatically triggered.

Beyond the need to share off-nominal situations, however, the factors that contribute to when, or whether, this information is shared were not widely agreed upon nor was whether to share contact information for those non-conforming operations. Sharing position reporting was also not widely agreed upon, with some operators wanting access to all positions of all nearby vehicles all the time, and other users only wanting access to (or to share their own position) during off-nominal situations that breach a geo-fence (see Table 9.3 in Appendix 9 for more examples). Operators expressed that they may like to know if their own or a nearby vehicle was operating near its endurance limits so they may begin to plan for a contingency. For planning purposes, operators generally thought it would be helpful to see the volumes of existing accepted operations in their vicinity before they submit their own to UTM.

In shakedown questions and during the end-of-day survey, participants were asked four questions about where they looked to acquire information about other vehicles. See Appendix 6 for a listing of these questions. The assumption for these questions is that if flight crews are looking for this information about other vehicles then other vehicles and USS clients should be reporting these data because it is what the community wants to know. Numbers of responses varied from 24 to 47 (out of 155 respondents to the end-of-day survey) and there were 16 respondents for the shakedown survey.

Before taking part in the flight test, respondents estimated that they would look to other personnel (e.g., the GCSO or the UTM Op) for information 63% of the time and look at displays about 19% of the time to gather information about other vehicles in the area, with talking via radio being the most frequently chosen option (n=14)[5] (see Figure A6.1 in Appendix 6). Most respondents reported seeking vehicle information from more than one source. They reported they intended to look for the potential locations of other vehicles during their flight planning whereas, while their vehicle was airborne, they intended to only seek out information about other flights if they could see and/or hear this other vehicle in the vicinity. However, participants reported a slightly different approach in their end-of-day surveys where 30% of the time they looked for other vehicles on their displays "all the time" (see Appendix 6, Figure A6.2). In their general comments, participants from two sites noted that they would have liked to have more information available to them about other vehicles.

3.2.4 Response Time

In debriefs, operators were asked to discuss what they thought would be an appropriate response time to a UTM notification and what factors would influence their answer. From the debrief transcriptions, there were 65 direct comments under six categories (see Table A9.4 in Appendix 9).

Crew comments about response times to non-nominal behavior from their vehicles varied from "seconds" to "a minute or two" until an appropriate action could or should be taken. They further expanded that this variation in response-time estimation depended on several factors, including platform capability, procedures, and the level of automation. For example, although a multirotor UAV could change course and complete an action more quickly than a fixed wing UAV, the potentially faster and less maneuverable fixed wing would be more critical to address quickly.

[5] Note that the question options were uneven, as six personnel roles were listed but only two displays.

Crews working with more capable automation, especially during dense operations or when managing a fleet, could have shorter response times without as much human involvement.

On a similar note, operator decision making and their attention, situation awareness, and workload were frequently cited as factors. Response time is closely connected to experience with UTM, familiarity with sources of information, the usability of those sources, and team organization. Training and familiarity with UTM and the types of information the USS client provided was not equal among operators. Often those flying the vehicles had limited or no direct access to UTM information. If they did, their knowledge was often not enough to diagnose and plan a response without the aid of a USS specialist. Team organization, specifically the location of the team members, was observed to affect response times. If the USS Op was co-located with the flight crews, actions could be taken more quickly than if the USS Op was remote. In hub-and-spoke (or remote) teams, the ratio of USS Ops to GCS/PICs was uneven, with one USS Op managing multiple operations. This meant that the UTM knowledge resource was often pre-occupied when multiple issues with a scenario needed attention. When USS Ops were responsible for overseeing multiple simultaneous flights and had high workload, this lengthened their observed response times to USS messages. The usability of the client interfaces also impacted response time.

If only relevant information was shown, it was easier for operators to diagnose an issue. Conversely, if there was clutter, the operator could be overwhelmed with irrelevant messages while trying to diagnose a particular issue. Consistency with units of measurement was also noted to both create problems with submissions and creating proper solutions. Operators would spend extra time double-checking that they were using the correct measurements. Observers noted that poor USS information usability was associated with frustration and longer times to read, diagnose, and prescribe solutions to incoming USS messages.

Participants were asked three questions about the speed of responses from and to the UTM system. Numbers of responses were lower for questions like these that were placed later in the survey and varied from 6 to 12. Participants from Test Site 4 rated the time to plan a new volume during flight as 4.6 out of 7 ("somewhat acceptable") on average. Participants from Test Site 6 rated the time to plan a new volume during flight as 7 ("very acceptable") on average. Participants from Test Site 4 were more positive about dynamic re-planning, rating the time to submit a new volume during flight as 5 ("quite acceptable") on average. Participants from Test Site 6 rated the time to submit a new volume during flight as 6 ("acceptable") on average. On average, participants at two sites thought the USS alerted them to their potential geo-fence breach in a "quite timely" manner (m=4.72) (see Figure A7.1 in Appendix 7) and respondents from three sites thought this notification "moderately focused (grabbed)" their attention (m=4.41).

3.3 Looking to the Future

The debriefs brought to light interesting discussions on topics outside our main categories. These topics are more forward thinking and address concerns and suggestions by operators for what the UTM architecture might look like in the future (see Appendix 9, Table A9.7).

3.3.1 UTM Feature Suggestion/Implementation

From debrief discussions, it is apparent that operators understand the positive effects that segmented operations have on airspace efficiency; however, the process and complexity of the timing and sequencing of volumes can be a barrier to operation success due to the static nature of these components. It is suggested that time within a segment be more dynamic and possibly integrate a level of intelligence that can allocate segmented space based on a vehicles trajectory (see table A9.6 for more details). This could possibly alleviate crew workload and coordination while increasing flexibility when operations are expected to occupy the same space in a small time window.

3.3.2 Future/Forward Looking (Includes Equipage, USS Features, Fleet Ops)

One of the topics discussed in the debriefs is aimed at future operations and this bred conversation on how operators envision a future with UTM. Feedback ranged from essential vehicle equipage/cooperation to USS features to fleet operations, all of which play a role in the difficulties that could arise from denser operations.

3.3.3 Emergency Ops

Emergency operations and the general need for sharing of airspace and assets raise comments on how UTM could handle these situations in the future. It is clear that there will be a need to quickly allocate airspace for these priority missions and dynamically allow for multiple assets to be integrated on the fly. This includes a portal by which a vehicle's priority can shift as needed as well as a means to communicate with nearby operators should additional support be necessary.

4.0 Discussion

4.1 A Look Back at the TCL2 Demonstration

The field test prior to the TCL2nc was a TCL2 demonstration that was conducted in October 2016 at the Reno-Stead Airport in Reno, Nevada. Afterwards, Johnson, et al. (2017) reported on the activities and findings from this test and identified four key findings. Those key findings are listed here for reference, followed by a reflection of their relevance during the TCL2nc.

Key Finding 1. *"The UTM research platform provided key information needed by operators to successfully conduct missions… ."* Johnson, et al. notes that UASs are currently operating in sparsely used airspace and operators are not always aware of other operations planned in the area without direct coordination.

During the TCL2nc, this Key Finding 1 was observed to be still the case—UAS pilots are not accustomed to other UAS vehicles being in or around the airspace they want to occupy but advances were made in raising awareness during the TCL2nc. Johnson, et al. (2017) made the recommendation that operators should display airspace information and have access to information from other operators. This recommendation was not met by all sites in the National Campaign for two reasons—either philosophical reasons that the team did not want to share their information or practical reasons that the USS client did not have this level of display.

Key Finding 2. *Measurement and reporting of vehicle altitude was not consistent among airspace users*. Johnson, et al. noted that "…differences in measuring altitude can pose hazards to the UAS, airspace, or obstacles... ."

Key Finding 2 was also observed to be still the case during the TCL2nc. In one example, two sensors for measuring altitude on one vehicle showed different heights, reporting the vehicle as simultaneously both rogue and not rogue in UTM terms, depending on which display/reporting tool was read. Johnson, et al. (2017) made the recommendation, which still holds, that altitude reporting should be consistent or translatable across airspace users.

Key Finding 3. *The sources of weather information for the Reno 2016 flight test were inadequate to support BVLOS operations*. The paper notes "…significant variability in observed weather based on location exposed a hazard for BVLOS operations...poor awareness of the localized weather conditions... ."

In the TCL2nc, crews were much more aware of their local weather. This is due both to better knowledge of the microclimates in their own test areas and having access to "home-base" weather sensors and also, for those who participated in TCL2, having more awareness of the potential effects of the environment on their vehicles. The increased awareness of local weather led to fewer flight days being flown than originally planned but most test sites had scheduled extra test days to accommodate this. Although the recommendation from Johnson, et al. (2017) that weather information sources should be augmented with GCS and UAS reports and shared with other airspace users, it wasn't fully implemented during the TCL2nc, the test sites were working towards this. The recommendation from Johnson, et al. (2017) that BVLOS operations should not conduct altitude-stratified operations unless there is accurate relative position information shared between UAS, it was not fully implemented and tested and therefore still applies. Although most test sites were able to share relative position information to the flight crews by way of their USS displays (albeit relayed by voice in some cases), the above discussion regarding disparate altitude measurements suggest more research is still needed.

Key Finding 4. *Operational plans were not always consistent between the UTM system, GCS, and UAS*. Johnson, et al. (2017) noted "of the 35 flights…46% left their flight geography."

This Key Finding was an area of huge improvement for the TCL2nc. Most test sites learned from participating in the TCL2 demonstration in Reno and through having to plan their flights themselves and, as a result, they developed volumes within which their vehicles were able to stay. Take-off volumes were observed to be larger so the 'rogue-on-take-off' issue happened rarely in the TCL2nc. However, volume construction/management was still a learning point. The recommendation from Johnson et al. (2017) that flight trajectories should be contained within geo-fence boundaries was well understood by partners but some found that achieving this is not as straightforward as it sounds. In addition, the recommendation that the aircraft enforce the geo-fence boundary was only partially achieved because some vehicles do not have software that permits boundary configuration beyond setting a radius.

Participants in the TCL2nc made improvements in the areas of all five recommendations from the Johnson, et al. (2017) paper but in order to complete the TCL2nc tests with the resources available some of those recommendations weren't addressed as extensively as were others.

4.2 Observations from Test Site Partners and NASA Researchers

At the end of their TCL2nc final reports, test sites completed a discussion section that included general observations, findings, and a summary of their experiences from the TCL2nc. NASA researchers summarized their notes in a similar way which were compared against the TCL2nc final reports from the test sites. Where more than one test site and/or the NASA researchers made a similar point, those observations are listed and discussed below.

In general, test sites seem to have had experience running their first UTM flight tests and many of their take-aways reflect similar points to those made by Mercer & Homola (2017). For example, the test sites recognized that fixed-wing vehicles have different performance characteristics from multi-rotor vehicles and need larger volumes, especially for take-off. Also, they were keenly aware of how environmental conditions can affect flights. However, these issues should not be dismissed; rather, it indicates some of the findings from Reno in 2016 are still relevant.

Situation Awareness: When pilots or GCSOs lost sight of their vehicle they relied on other sources to maintain their situation awareness. Often this was through a USS Op. If the USS Op was not co-located or busy, relevant UTM information was sometimes slow to filter down to the flight crew. When the pilot or GCSO had access to UTM information, the usability of the information was often poor and frustrating to use for the untrained/unfamiliar operator—to the point of being largely ignored. This meant that operator situation awareness during critical phases of flight (such as flying BVLOS or altitude-stratified) was often limited. Additionally, communication links to the vehicle were also observed to be an issue while BVLOS, either due to physical obstructions or poor LTE/wi-fi connections.

USS Client Messages: Some UTM system messages did not contain enough information for the user to quickly diagnose a problem and make a decision about how to remedy it. These issues occurred rarely because scenarios were scripted (and, in general, nothing was a surprise). While it is not within the project's remit to specify USS client interface features, more research is required to define "usable" information for such displays.

Focus on UTM: The Airspace Operations Lab observers noted that, at times, test sites seemed more focused on flying their vehicles than on testing the UTM concept and on completing a test scenario rather than exercising their USS(s). One reason for this was that some partners had purchased new vehicles for the flight test and were still "getting to know" how they worked. A second and more significant reason was that the flight crews had less direct exposure to UTM, which resulted in a lower commitment to exercise the UTM concept and a lower level of situation awareness in the field. Another reason was a lack of time to train some members of the team on the UTM concept. In more than one location, only a few of the test site personnel were familiar with UTM at the start of the field testing, with the other members of the team focused on flying. This level of understanding affected data collection as many participants were unable to provide comments on their usage of and experience with UTM.

Accurate and Complete Data Reporting: Many test sites weren't able to obtain complete data coverage using the sensors they had planned, had poor cellular coverage, or had telemetry "dead spots" in their test area due to RF interference or unknown causes. Some test sites solved this issue by relaying information using different media. Others noted discrepancies in their telemetry data, as in the example above, wherein two altitude-reporting sensors that fed different tools (GCS vs. USS) disagreed over the altitude of the vehicle. Another test site stated that "These items must be taken into account during planning of UTM missions so that they do not introduce flight safety concerns." A third, related area, was that in teams where the USS Op was situated away from the flight-crews, and USS 'relay displays' were available to them, NASA researchers noted that on occasion the displays were showing different information. This caused issues because the "truth" was different for different flight-crew members. However, not all issues necessarily originated at the test sites. In debriefs, participants commented that Simple Text Orienting Messaging Protocol (STOMP) seemed to work only intermittently during some days (Appendix 9, Table A9.6) and that some rogue notifications seemed spurious.

Standardization: Because of the wide variety of vehicle platforms available today, the effort to connect vehicles to UTM was substantial for some partners and resulted in abandoning some vehicles or dropping them from their test plans part-way through the TCL2nc. Some guidance on vehicles known to have been difficult to integrate may help future partners. A related concern is the time and effort flight crews spent translating units for flight parameters between systems that use different units. The potentially negative consequences of not standardizing units are well documented in the domain of manned aviation.

Setting Expectations: Many of the take-aways outlined in the test sites' summaries concerned their interactions with NASA. Appendix 8 lists some of the points test sites made, so as to help improve future field test activities. Partner expectations of the TCL2nc were slightly different from those of NASA, creating a learning process for both the partners and NASA. In general, partners found that preparing for their field test required more effort (took more man-hours) than they expected and was associated with more interactions with NASA Ames Research Center than they expected. This was also noted internally by NASA and the upcoming TCL3 effort is being planned with a schedule to address these comments, where test sites are able to select their test dates within a six-month period, allowing for—as requested—longer "spool up" and "spool down" times. Furthermore, any additional considerations from NASA to improve the efficiency of the interactions with partners would be well received.

4.3 Recommendations

From the discussions above, some suggestions and recommendations were extracted from the TCL2nc. While the main points of these recommendations apply to all those involved with UTM, the recommendations are written looking ahead to TCL3 and future flight tests in particular. Focusing solely on TCL3, those to whom these points may be applicable are listed in Table 6.

- *Users participating in flights operating in a UTM environment should be familiar with the UTM concept and the kind of information that is exchanged or available.* When operators had a firm understanding of the UTM concept and had general operational experience, there was an observed benefit for performance. Highly functioning crews need good coordination and teamwork, including the definition of roles and responsibilities and advanced planning and checklists. Another recommendation is to conduct training sessions before flight tests to familiarize participants with UTM and the UTM objectives of the flight tests.

- *Further investigate whether training/experience requirements should differ based on the responsibilities associated with an operator's specific tasks.* Operator roles were not all created equally and the associated responsibilities depended largely on the team structure. In some cases, an operator had no interaction at all with UTM, such as a PIC who was not at the same station as the USS Op. If a PIC had no interaction with UTM then the corresponding training or knowledge required to fly might be less than a PIC who also acts as GCSO and USS Op regularly interacting with UTM. However, UTM is currently benefitting from many in the field having knowledge from manned aviation. Some of the training required to obtain a manned aviation certificate (e.g., weather assessment, radio communication protocols, etc.) need to be investigated and potentially added to obtain UAS certification.

- *Team organization should allow easy dissemination of information between operators and ensure there are enough operators filling a role to avoid unmanageably high workload*. In general, there were not enough USS Ops with expertise to handle the amount of operational demand, especially when the line of communication to other operators was cumbersome or disrupted.

- *UTM interfaces should help users of all experience levels perform their tasks with more efficiency and fewer errors through the use of automation and tools*. Frustration with UTM and UTM interfaces—or operators not using their USS client to its full potential—could be attributed to either the UTM/USS system or the operator but is likely the responsibility of both. When solely viewed through the lens of operator requirements, one could incorrectly conclude that the errors seen in the tests could be mitigated for future tests with more rigorous training or more stringent procedures. However, it may be more effective if there is system automation implemented to help operators of all experience levels perform their tasks and procedures are more formalized.

- *Include cross-check procedures (automated or human) for submissions and telemetry calibration as part of the preflight checklist*. Emphasize the importance of equipment calibration for accuracy in telemetry reporting. This may mitigate human error when submitting information into UTM and also help teams focus on contributing to the UTM objectives of their testing.

- *Secure reliable connectivity during shakedowns (or knowing the weak points and avoiding them during testing)*. This may help teams focus on their interactions with UTM by reducing the frequency with which they need to troubleshoot their connections. Research procedures that are robust to potential telemetry 'dead spots' that vehicles may fly through, and research to better understand RF interference, offer possible mitigations.

- *The information shown on situation displays should be from a reliable source*. Without this, the operator can lose trust in the information and its perceived usefulness can be diminished.

- *Standardize units of measurement (e.g., meters vs. feet and knots vs. mph)* both on vehicles and on USS displays. Also standardize USS terminology.

- *Streamline the NASA-partner interaction*. Improve the efficiency of NASA requests to partners during flight-test preparation. This could include clarifying data collection methods and expectations for data collection well in advance, expanding software check-out sessions for each test site to involve UTM concept training, discussing test methods, and simulating partners' suggested scenarios (with full-USS interaction). Establish clear definitions of what accomplishments are expected in a given test scenario and then define a short set of success criteria for each contributing vehicle that could be used to quickly determine whether the key UTM goals have been met. Set communication protocols for what flight-crew members are expected to be reporting on SLACK, so that those communications do not occupy flight crews during a flight.

Table 6. Flight Test Participants and Recommendations

		Partners	Test Participants	NASA Project	Researchers	Others
R1a	Users participating in flights operating in a UTM environment should be familiar with the UTM concept and the kind of information that is exchanged or available.	✔	✔			
R1b	Conduct UTM training sessions.	✔	✔	✔		
R2	Further investigate whether training/experience requirements should differ based on the responsibilities associated with an operator's specific tasks.				✔	
R3	Team organization should allow easy dissemination of information between operators and ensure there are enough operators filling a role to avoid unmanageably high workload.	✔	✔		✔	
R4	UTM interfaces should help users of all experience levels perform their tasks with more efficiency and fewer errors through the use of automation and tools.	✔	✔		✔	Developers?
R5	Include cross-check procedures (automated or human) for submissions and telemetry calibration as part of the pre-flight checklist.	✔	✔	✔	✔	NASA test team
R6	Secure reliable connectivity during shakedowns (or knowing the weak points and avoiding them during testing).	✔	✔	✔		NASA test team
R7	The information shown on situation displays should be from a reliable source.	✔	✔		✔	
R8	Standardize units of measurement and terminology.	✔				Manufacturers, developers
R9	Streamline the NASA-partner interaction.	✔		✔		

5.0 Conclusions

Six test sites participated in the TCL2nc duirng May and June 2017. The data discussed above came from on-site and remote NASA researchers for each test site, end-of-day debriefs, post-flight and end-of-day questionnaires, and data submitted as part of the data management plan. The TCL2nc flight tests were a great success and much was learned about operator, information, and response time requirements in a TCL2 environment. Test sites made improvements in the areas of all five recommendations from the Johnson, et al. (2017) paper but in order to complete the TCL2nc tests with the resources available some of those recommendations were not addressed as extensively as others.

- Data showed that teams were well qualified on paper, in terms of both completed training and having experience with flying UAS vehicles. However, the understanding and experience of UTM was much lower across the flight crews which affected their interactions with UTM and, ultimately, the collected data. Crews indicated that qualifications or experience requirements may have to increase for those who want to fly BVLOS.

- Overall, teams examined a variety of sources for information, including the USS displays. The usability of the displays themselves determined, to an extent, what operators looked at or listened to while quality of information was also variable and influenced crew usage. In addition, there were some issues that either prevented information from getting to flight crews or corrupted the information en route.

- Over the course of the flight tests, participants increasingly understood the need to be aware of other vehicles. With respect to reporting requirements, a problem arose in that some partners preferred not to report-out information that they considered private/proprietary but at the same time they wanted to receive this information from others because they recognized they needed it to form their own situation awareness of the airspace environment. Most partners agreed that providing information to build the situation awareness of the community is valuable.

- Operator response time (i.e., in units of seconds) was not assessed as part of the observations and surveys. Crews noted that response time in terms of vehicle maneuvering depends heavily on the vehicle itself. Participants reported that for some procedures, interacting through their USS took an acceptable amount of time. Observations found that a flight crew's time to respond to a UTM notification depended heavily on the team's structure, communication efficiency, and procedures.

- Individual training, team organization, preparedness, and UTM understanding all influenced the information required and accessed by the operators, as well as their response times. Future tests should continue to investigate these factors as research transitions to the more complex TCL3 and TCL4 environments.

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Appendix 1. Test-site Flying Days for the National Campaign

Table A1.1. Test-site Fying Days for the TCL2nc

Flying weeks	*Site 1*	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*
May 15–19		May 15, 16, 18	May 15, 18, 19	May 17–19		
May 22–26	May 24, 25	May 23, 26		May 23–24 May 25,26		
May 29–June 2	May 31–June 2	May 30–June 2			May 31–June 2	June 1, 2
June 5–9	June 5, 6, 9	June 5, 7	June 5, 8		June 6–8	June 6
Number of shakedown days	5	5	3	5	3	2
Number of data-collection days	3	6	2	2	3	1
Number of planned test days	5	8	3	2	4	2

Key: orange background to text = a shakedown day; green background to text = a data-collection day

Appendix 2. GCS and Flight-crew Information

Table A2.1. GCS and Flight-crew Information

	Site 1	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*
Most common number of GCS	3 (with 4 crews)	5	1-2 (with up to 4 crews)	2 (with 4 crews)	3	3
Number of scenarios	2 (with variations)	4 (with one crew flying only 1 scenario)	6 (with variations)	1 (with variations)	3	1
Number of organizations flying	2 (to make 4 crews)	5	2 (to make 4 crews)	4	2	3
Most common number of personnel in a flight crew	4 (not co-located)	12 (co-located) 4-6 (not co-located)	2 (not co-located)	3	3 (not co-located)	1 or 2 (not co-located with USS Op)
Common crew positions	GCSO, PIC, Launch Eng, USS Op		GCSO/PIC/ USS Op, Launch Eng (UTM manager)	GCSO, PIC, USS Op, Comms	GCSO, PIC, USS Op	GCSO, PIC, or GCSO/PIC
Additional crew positions	VO for every crew +2, Mission Manager, USS Manager, Video Engineer	Mission Manager + helper, VO, Range Safety Officer	Mission Manager, +2 VO (total)		Radar Team, Police Department	

.

Table A2.2. Vehicle and Flight-crew Information

	Site 1	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*
Vehicle-PIC pairing consistent through test	No 3 of 5 were consistent	No	No, mostly but not all	Yes	Yes	No 1 of 3 was consistent vs. Yes
PIC-rest of crew pairing consistent through test	No 2 of 4 GCSO changed, other personnel rotated	Yes	No, mostly but not all	Yes	No	Yes
Same vehicle type used for same mission	Yes	Yes	No, mostly but not all	No	Yes	Yes
Vehicle flew from same location within a scenario	Yes	Yes	No	No	No, changed with scenario	Yes
Number of flights per PIC-vehicle combination	5, 2, 7, 2, 5, 2, 2, 2 (5 cannot account for)	N/A	N/A	2 x (2 to 4) x 3 approximately	9	?
Number of flights per vehicle-GCS combination	4, 2, 1, 5, 2, 2, 2, 5, 2, 1, 2	3 x 2 x 5 approximately	4 x 4 x 2 approximately	2 x 3 x 3 approximately	3	?

Appendix 3. Vehicles Flown in Flight Test

Table A3.1. Flying-vehicle Information for the TCL2nc

	Site 1	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*
Number of UAS models	5	4	4	5	4	5
Type of UAS flown	5 multi-rotor	1 multi-rotor 3 fixed-wing	1 hybrid 3 multi-rotor	1 hybrid 1 multi-rotor 3 fixed-wing	2 multi-rotor 2 fixed-wing	1 hybrid 3 multi-rotor 1 fixed-wing
PIC employers	1	5	1	3	1	3
GCSO employers	1	5	1	3	1	3

Note 1: Partners did not always fly the aircraft that they had planned to fly during the test for a variety of reasons, e.g., due to software mismatches, or mechanical difficulties, or other events.

Note 2: For rows 3 and 4, "employers" indicates the number of separate business entities (companies) that people in these roles were employed with at that site. E.g., at Test-Site 1, one business provided the pilots for all the vehicles, at Test-Site 6, three different companies provided personnel to fly the vehicles they own and brought to the test.

Appendix 4. Qualifications, Survey Questions and Responses

Q4. Do you have a remote pilot certificate with a sUAS rating (small Unmanned Aerial System)?

Q5. How much experience (number of hours) do you have operating in the role you have for this flight test?

Q6. How many flight hours do you have with the vehicle you are operating today?

Q7. Do you have any manned aviation certifications? Please check all that you hold.

Q8. How many hours do you have as PIC of a manned aircraft?

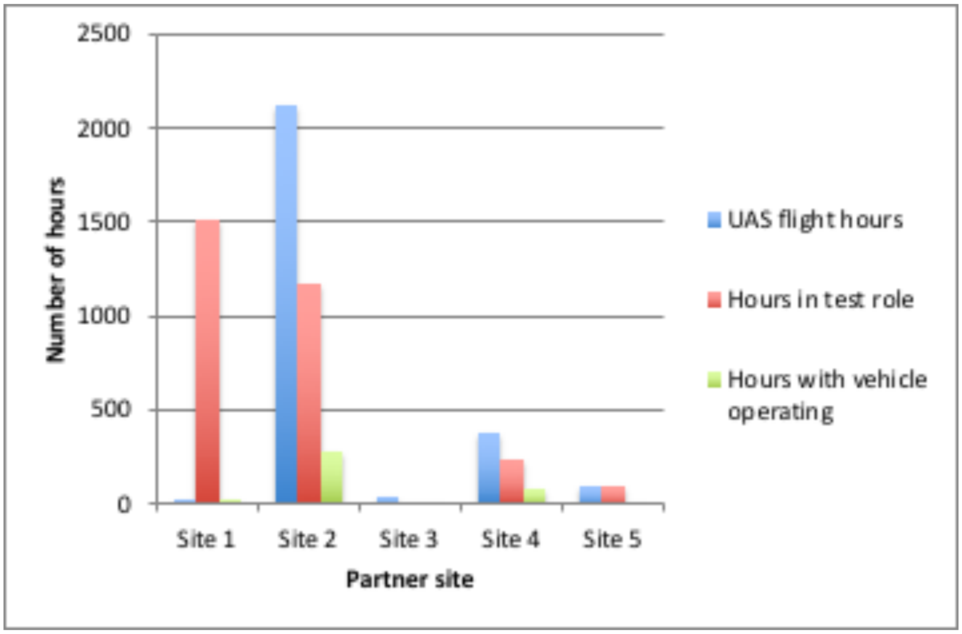

Figure A4.1. Experience with operating UAS in terms of hours flying, hours in role, and working with a specific vehicle (n=22).

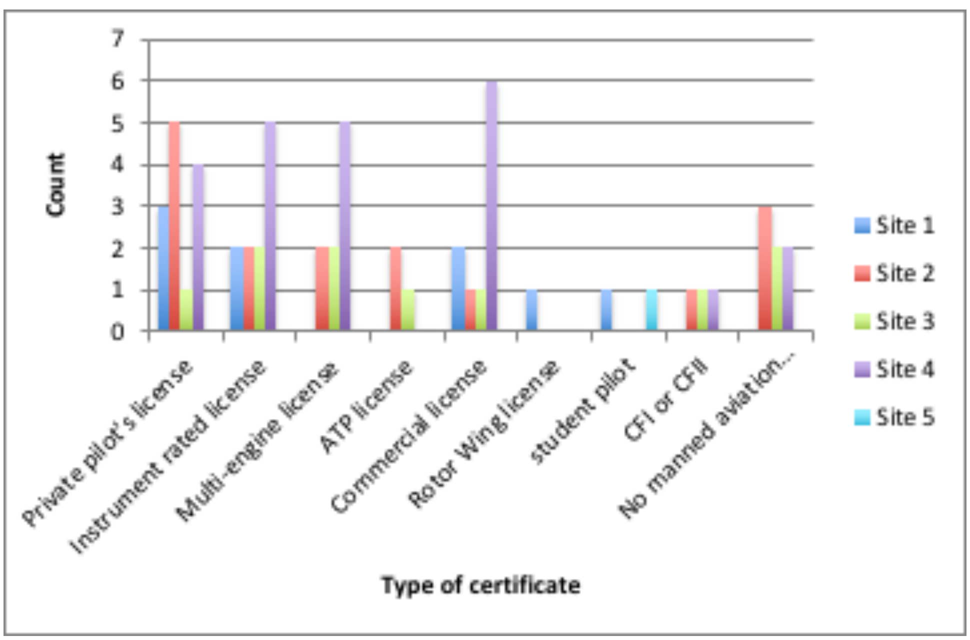

Figure A4.2. Manned flight certificates held by respondents (n=29). Note pilots often only cite their highest certificate.

Appendix 5. Information Requirements, Survey Questions and Responses

S-Q4: Which displays do you look at and/ or people do you talk to, to find out information about your vehicle?

S-Q8: How was UTM information relayed to you?

BVLOS3: How did you acquire position information when your vehicle was flying operations beyond the pilot's line of sight?

AS1: How did you acquire relative position information when your vehicle was flying in stratified operations with another?

R2A5: Were you able to find the information you needed to support your decisions about actions you needed to take as you were flying in the direction of another vehicle? E.g., head on, overtake. Please note which displays you used.

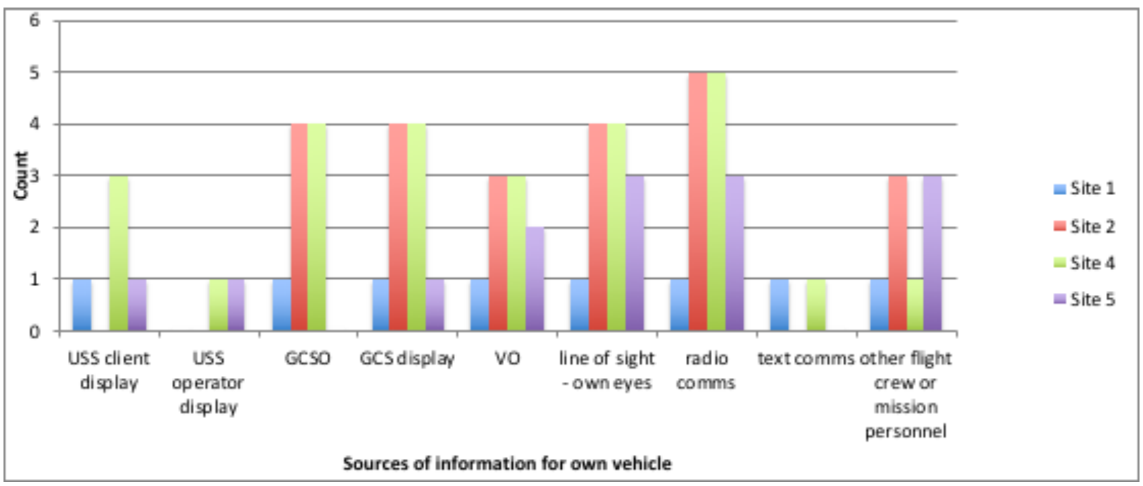

Figure A5.1. Source of own-vehicle information as estimated by participants before their flight tests (n=19).

Comparing the two sets of survey responses (Figure 6 versus Figure A5.1) shows a shift from participants thinking they would talk to others more often to looking at displays more often. It must be noted, though, that the options between the two questions are different and the shakedown survey offered many more roles while the end of day survey offered many more displays/tools.

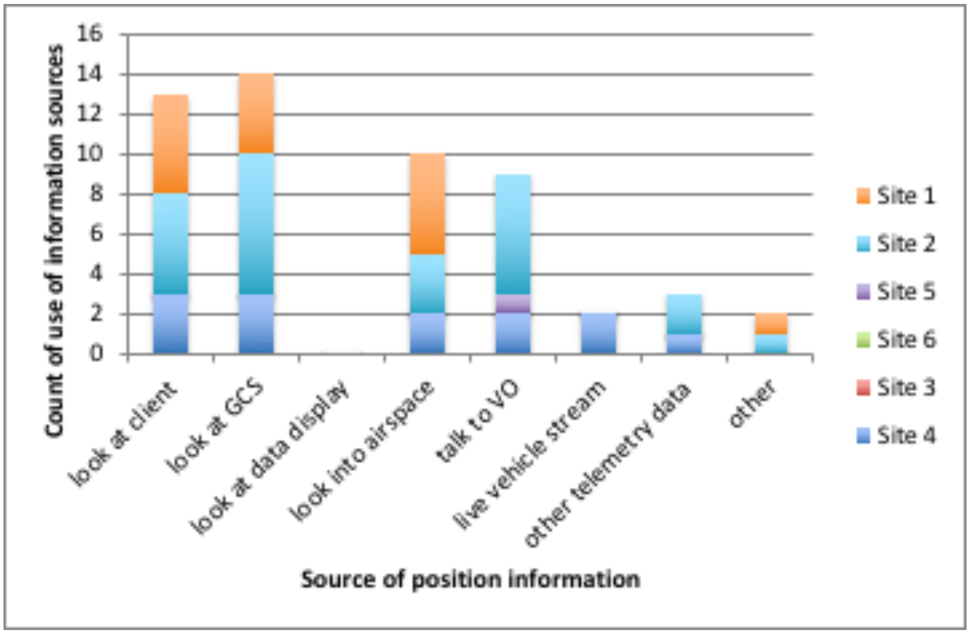

Figure A5.2. Source of position information for altitude stratified flights (n=24).

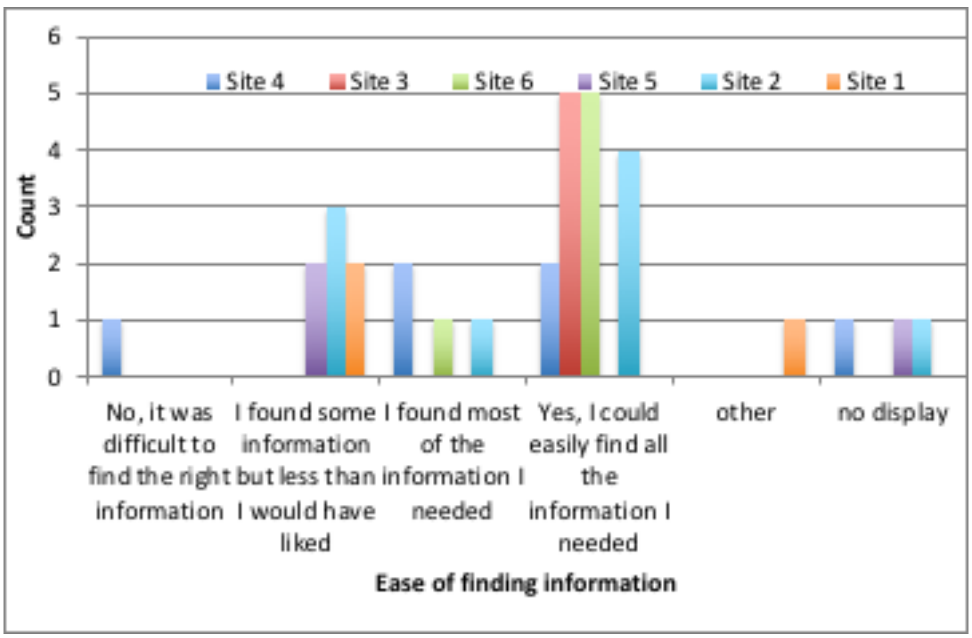

Figure A5.3. Ease of finding information to support action decisions (n=32.)

Appendix 6. Reporting, Survey Questions and Responses

S-Q5: When do you actively seek out information about other flights?

S-Q6: Which displays do you look at and/ or people do you talk to, to find out information about other nearby vehicles?

MV1: How often did you check for other operations as you were flying your mission?

SnA1: Please rate your level of awareness of the other vehicles that were flying close to yours in this mission.

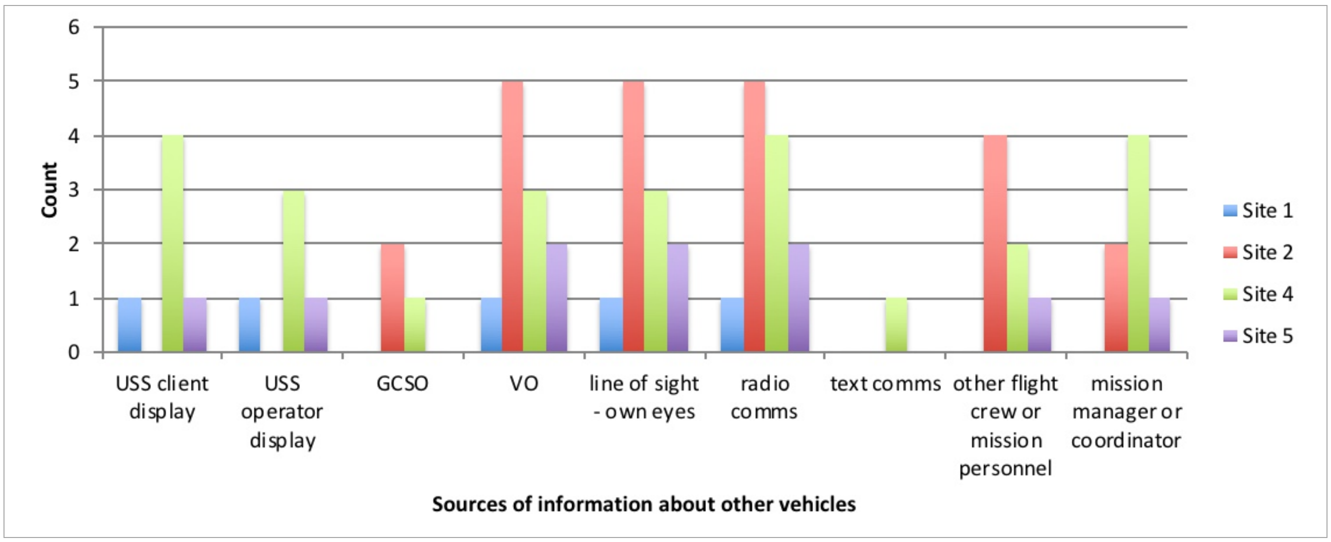

Figure A6.1. Source of other-vehicle information as estimated by participants before their flight tests (n=16).

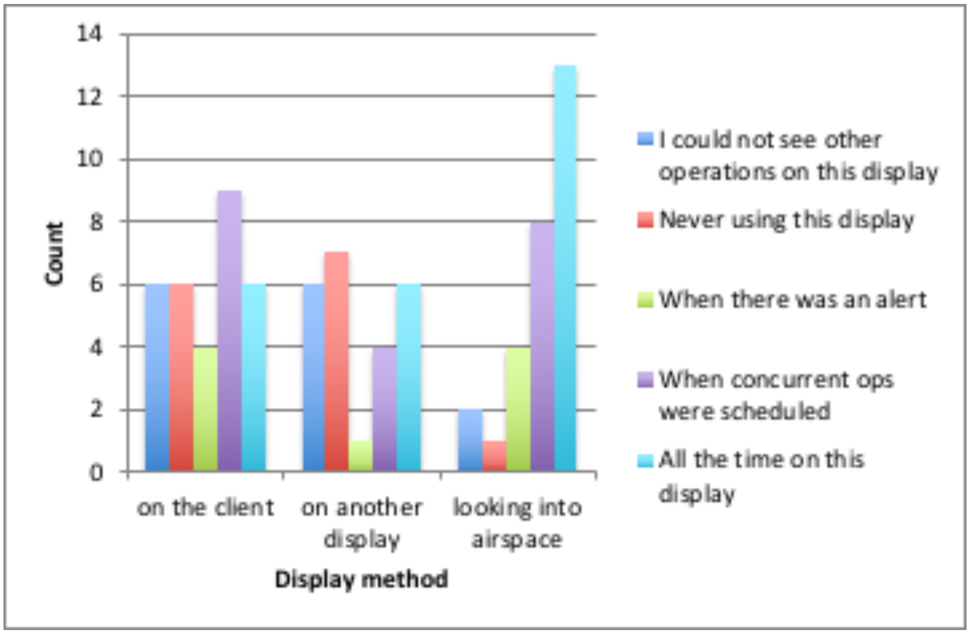

Figure A6.2. *Displays that participants used to check for other vehicles in the vicinity (n=31-24)*.

Appendix 7. Response Time, Survey Questions and Responses

DRP1 & DRP3: How efficient (in terms of time elapsed) was your flight planning and volume submission for your redirected (second) mission area?

GCM1: Did the USS client alert you to a potential geo-fence breach in a timely manner?

FTP12: Did the indication of your vehicle state as “nonconforming” show in time for your team to react and prevent your vehicle from moving into a “rogue” state?

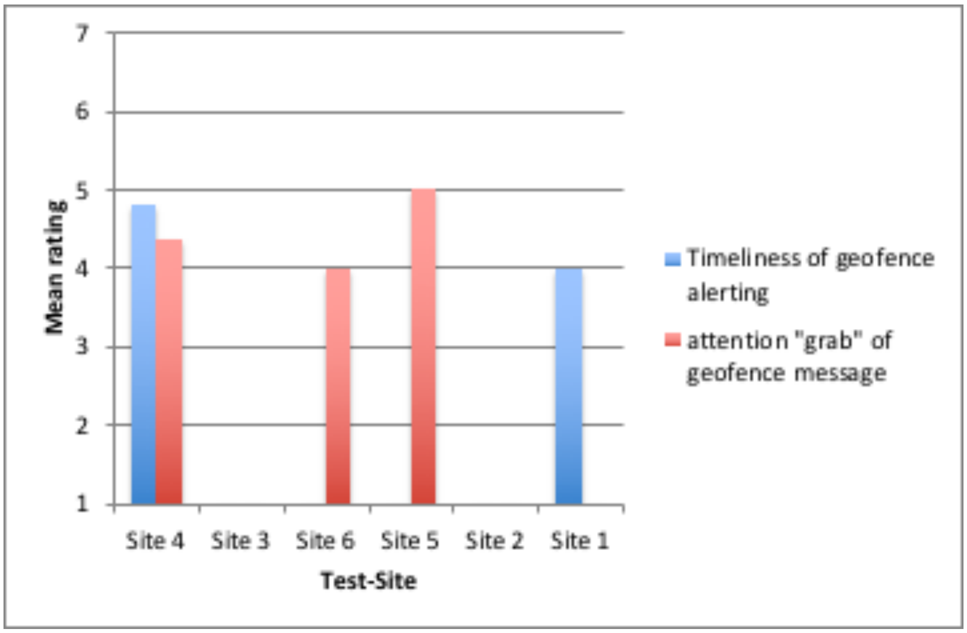

Figure A7.1. Geo-fence management: timeliness of alerting and attention focusing (n=11, 12).

Appendix 8. Partner Feedback on General TCL2nc Conduct

As noted above in the Observations section, partner expectations of the TCL2nc were slightly different from those of NASA. Much of the feedback that the test-sites outlined in their summaries concerned their interactions with NASA, or the "methods" of the field test. Listed below are some of the points test-sites made, so as to help improve future field test activities.

Depth of checkouts: One of the areas of flight-test preparation that many sites noted they did not feel they had time to adequately complete was the USS client system checkout process. For example, Test-Site 2 said "additional time for connectivity checks was required." Test-Site 6 said "There is need for a more well defined and structured USS checkout process since some issues slipped through the last checkout process and didn't come to light till during the National Campaign." Others just noted that they did not have enough preparation time. Additionally, AOL observers noted that while the pre-testing exercised the functionality of the partner USS systems, it did not put the systems under load. This meant that the tests showed only that tools were working and not that they were able to perform for the duration and complexity of the planned flight test(s).

More structure: Partners found some of the flexibility of the national campaign difficult to accommodate, for example some documents (e.g., the FIMS specification documents) continued to evolve and change in the weeks leading up to the start of TCL2nc. Also, conditions and types of operations to be completed were clarified by NASA during the preparation time (and new documents were sent out throughout), but when these did not match with partners' plans, changes to plans then had to be accommodated. Partners recommended that for future flight tests, it would benefit both industry and NASA to have a lock down date for documents, flight test specifications and requirements, and for NASA to provide templates well in advance for documents that the project requires. They felt this would aid in developing and testing all required functionality that NASA and the UAS Test-Site would like to demonstrate.

Definition of criteria: A second source of flexibility that partners and AOL observers found difficult to accommodate was the lack of exit criteria specified for flight tests. More than one site, when flights were completed but did not go entirely to plan, was unsure whether they had met the exit/success criteria for that flight.

Adherence to scenarios: Conversely, some sites used the lack of definition of success or exit criteria to change their flight scenarios or flight plans. This impacted data collection as some of the data collection tools (the survey, in particular) had been tailored to the specific scenarios that were outlined in test plans and a change in scenario meant data could not be collected.

Site set up: Tied in to more than one of the points above is the observation that some sites were still shaking down their flight tests or installing/configuring equipment while they were collecting data. Scheduling: Some sites planned for their shakedown days to be adjacent to flight test days. This saved on expenses of set up and tear down but moving straight from shakedown to test did not leave any time for the team to fix flaws found in equipment, or with test plans, before they needed to move onto data collection.

Appendix 9. Categorization of Debrief Topics and Examples

Key:
Site = number of test-sites who discussed this topic (out of 6)
Com. = number of comments coded under this topic

Table A9.1. Qualifications

Theme	*Site*	*Com.*	*Example Comments*
Experience you need to fly as a crew	3	18	You need to have a certain amount of experience, but I think there needs to be some of that demonstrated BVLOS, in certain situations, maybe adverse conditions...instead of flat out saying you need 100 hours. Not a quote but a list of items mentioned: Hours on platform, real experience (meaningful not the same thing over and over again), demonstrate BVLOS, have a mentor watch for some number of hours, shadow an experienced pilot for some number of hours, experience in congested airspace, simulator hours, hours working with the UAV you plan to fly.
Ratings you need to get to fly more complicated missions as a crew	4	10	BVLOS would require the equivalent of an instrument rating on the manned side, just because you're having to look at effectively instruments. Not a quote but a list: BVLOS, some scaled down portion of the manned pilot IFR rating, manned commercial rating if you want to fly BVLOS.
Things you need to learn about to fly UAV	4	12	Ability to be able to read and interpret instruments, whether that be on a computer screen, and know that that means in terms of your aircraft in 3D space and in time. Not a quote but a list: An analysis of terrain avoidance, understanding what radio waves at different frequencies, ability to read and understand your instruments, prove ability to develop SA when BVLOS, manned a/c ground school.
Basic qualifications to fly UAV	3	7	You have to have the basic civilian ground school for manned aircraft and…add more on.
Poor training/SA	1	1	He didn't know that he had a box that he was supposed to climb in, to his altitude…actually we had same issue during data collection.
Qualifications are unnecessary	1	2	I never really consider their different rating, different qualification, or different certification to be able to do this. It's not that complex. I would consider flying in the clouds under IFR much more challenging than operating an autonomous vehicle… .

Table A9.2. Information Requirements

Category	*Theme*	*Site*	*Com.*	*Example Comments*
Quantity	Concerns about too much information	3	7	If you have comm loss and it's not doing lost link procedure, then you don't have any control over it anyways. I'm just concerned that we flag too much, and we're not paying attention to it.
Quantity	General information about other vehicles	3	6	I was able to know that they were my space, and be able to communicate with them.
Quantity	Process of flying the UAV, building SA	4	11	because he's BVLOS, I have no eyes on the a/c so all I've got is my heads up display. Its synonymous to flying instruments on a manned a/c. when he's flying it's the constant scanning, signal strength, altitude, airspeed, battery voltage, waypoint, is the a/c doing what it's supposed to, how bad is the a/c crabbing.
Quantity	Creative ways to get information	1	2	What we did was we actually take and we run the exact same flight plan in simulation mode. So if we have a lost comm or a comm drop out we'll know approximately where it should be during that lost comm period so we could tell VO stay here to recover it.
Quality	Short time to make decisions	1	2	Moving towards something very simple like that, where he can look at his a/c and he says okay I have traffic on my one o'clock and I have 20 seconds to make a decision.
Quality	Usefulness of tools	2	4	I thought was beneficial was having that iPad. My pilot was able to see a map of earth while he's looking, and I was standing right next to him, and that's how we knew when we were coming up against that imaginary wall.
Quality	Poor information from tool	4	16	P1: So, honestly I couldn't tell who is rogue or doing what. P2:...I had the same…an emergency, which confuses me…just to clarify…an emergency is yourself you said.
Quality	Information that crews would like to see in a tool	4	10	Showing me all the other aircraft, I want to know, your speed, how far away that approaching vehicle is and what its altitude is. Corridor/ route and track of own vehicle, other vehicle bearing, heading, speed altitude, vertical change, type of aircraft in the same airspace, flight patterns for other vehicles, other aircraft, position, heading, speed, type, routing, predicted path, for self know position of vehicle (relative to boundary) [this is a list not just 1 quote[.
Quality	Decision making	4	6	One aircraft flyin around has all the information he needs to make decisions.
Usability	Type of information that is not useful	4	5	Once you start that flight plan, the only warning you should get back from UTM is if somebody else has now encroached in to that area. That would be the only message I would want to hear. Not that "I want a change" message. I'm not gonna change my flight plan.
Usability	Clutter	2	2	So I'm getting a lot of clutter, like me visually there is a lot stuff going on and when the solo's flying, not only am I seeing the solo, seeing its flight path, seeing the UTM volume, seeing all these yellow targets.
Usability	Things that reduced usability	1	1	It was a bit tedious to go in and try to find that message and especially, if I would be an one operator system like that.

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Table A9.2. Information Requirements *continued*

Category	*Theme*	*Site*	*Com.*	*Example Comments*
Usability	Form of words to use in aural announcements	2	4	Starting off with 'Other aircraft, south, 300ft, breaching your airspace'.
Usability	Usefulness of other tools for SA	2	2	From our situation awareness display, when I see other general aviation a/c in the area, I can click on them and find out what's going on with them.
Usability	Functions in a tool	2	3	Always having an acknowledgement actions like request received and that we are processing it. Facing extremely high volume and this is your estimated wait time.
GUI	GUI for information in	3	11	Maybe hearing an audible, because he may not be looking. Audible is key.
Alerts	Type of alerts that would be useful	5	21	Position, where it's coming from, altitude, vehicle coming down due to an emergency, airspeed, heading, last known location, warning sound several seconds before reaching bounds [this is a list not a quote].
Hardware	Concerns about running one computer	3	9	Would you want the surveillance data integrated with your control screens? Texas: my opinion would be a separate screen.
Hardware	Concerns about amount of equipment that UTM takes	1	3	I cannot see people having three or two laptops out and doing this much work.
Comms	Issues with team structure (comms)	1	2	You still have to communicate there is an issue to the PICs… because they need enough time to make a decision.

Table A9.3. Reporting

Theme	*Site*	*Com.*	*Example Comments*
GUI items for outgoing information	2	3	[prompt: asked about flights crews interaction with UTM] my software contains all the telemetry data for the a/c, so my software is read by a translator...puts it all in the same format for all the different a/c, so he [USS Operator] can read it and sent it out however he needs to...so altitude, waypoints and where its supposed to be at, and the track as well, he's able to see that. So I have to have my software running in order for him to get the data.
Distracting actions that you can't handle during an emergency	2	2	(send message) That's not the time to do it. As a flight crew you are concentrating & making decisions about what you're doing on the flight crew. If you have something that starts saying "message" in the middle of a flight, that's not a good idea.
Important information to broadcast	3	16	(not a comment but a list of items from various comments) Battery low, connectivity loss, need space, I need to put down. With [XX autoflight system] you could forward your nav link stream out over (UDP?) and using MAV proxy you could receive that and display it. So, if someone in the commanding positon wanted to see my flight state, but they weren't actually issuing commands on the flight, you could forward it to them and they could see it just like they were flying but I'd be the one controlling it.
Things you might not want to tell other people	2	3	Do you want that vehicle to broadcast it remaining battery percentage to everyone else? Other items, list not quote: surveillance band that you're using

Table A9.4. Response Time

Category	*Theme*	*Site*	*Com.*	*Example Comments*
Time	Time taken to start corrective action	4	20	I: how quickly could they reasonably expect you to correct? ND: I would imagine for most scenarios seconds would be the correct response.
Time	Using automation to reduce response time	1	1	[paraphrased] need to integrate more automation to reduce the time for a plan change, specially when the vehicle is in the air, orbiting, burning batteries, waiting for approval of a plan change. This becomes a larger issue when the vehicle has a primary and secondary mission, and its costing money to wait. Time is money, so the speed of getting things accomplished is the challenge.
Procedures	Reasonable expectations of coordination with neighboring operations	3	7	[prompt, paraphrased: a UAS is flying a neighboring mission and they made a mistake in their plan that puts them outside their volume, and they are coming towards your area of operation, what is reasonable expectation of coordination?] reasonably I would assume that they could modify their mission, if they realized they made an error...even if they did make a modification it would take a minute or two still, so even if you did change it right away it still takes time.
Procedures	Future procedures for off nominal events	1	2	If the UTM system, in the future when you go rogue, it tells you what to do...and for a lot of this to work in dense environment it's going to have to be really fast. It's almost like the UTM system is going to have to be what actually controls the drones.
SA	Attention direction during a scan	1	2	In Reno, I think they timed us and the most I would even look at either UTM or his laptop or the iPad…was 3 seconds.
SA	Source of off nominal information	2	3	It would be nice to have interaction between the two neighboring missions, I mean more than just having notifications popping up, like this is going to go into your boundary, is that okay, like accept or deny kind of…like a request.
SA	Situation awareness of a UAV	2	5	Having that iPad, I had situational awareness of what was happening with that UAV. I didn't utilize it to it's best [coughing], because I didn't realize it at the time, but I could see what was going on.
Decision Making	Awareness of RTB options during flight	2	6	It's considering where I'm at…most of the a/c we're flying with are just a direct flight home, so I want to consider quickly if that direct flight, you know if there are obstacles on the way or if that's the most efficient way to come home or whatever.
Decision Making	Decision making (time) during an off nominal event	2	5	[TX 12] If it had an RF interference located at the site, its highly likely that I would have dropped out again, so I made that split second decision to bring it home, be on the safe side.
Workload	Workload flying UA	3	4	I'm also focused on monitoring the airspace with XX tool, I'm also focused on maintaining separation with the other a/c, even though there are VO's. so there's a lot to do.
Workload	Having to multitask during off nominals	2	2	P4: In terms of typing in while you're flying and monitoring…P3: Yeah, you're not gonna be able to do that. P4: It just takes your attention away from what you are supposed to be doing.
Automation	Using automation to assist	4	8	I think the more we move from the operator to the UTM system for handling the situations will be better. Removing the human as much will be beneficial overall for autonomous system.

Table A9.5. Operator Requirements

Category	*Theme*	*Site*	*Com.*	*Example Comments*
SA	Attention when flying	2	3	Awareness level is much higher when you have more traffic in the area. Where exactly are they even if they are not at the same altitude. Definitely more attentive.
SA	Reduce distractions to pilot	1	2	That's a good point, because PIC is ultimately responsible for safe operations of the aircraft and anything that distracts him from doing that job has to be evaluated or handed off to somebody else.
SA	Attention strategies for flying without a team	1	2	But if the bird is in my area, part 107 rules, you don't have to have a VO when flying by yourself, your face is rarely on the screen, you're just checking vital stats, you're keep your eyes on the bird the whole time.
SA	Skills you need to develop to fly UAS safely	5	6	I check NOTAM for sure, so I would be aware, if there would be something out there. But yeah, most of my attention is devoted outside of my plane, looking down and of course looking up for obstructions and stuff, but I know the terrain and I know the point where I'm gonna turn and stuff.
SA	Access to UTM info	1	2	So [the flight crews] don't currently have a display. We want to do that, but we don't currently have the resources or equipment available to do that. It would be ideal, just so they could see the visuals and know what's happening from a UTM standpoint… .
Procedures	BVLOS ops requirements/ procedures	1	4	[in reference to whether training changes with BVLOS] That should all be sense and avoid. I think [the same knowledge] would still apply, but you would apply it in a different manner. It's the difference between, let's go back to piloting, VFR and IFR. The ultimate result is to provide a safe flight from takeoff to landing and it's just the manner you do it is different... .
Procedures	Procedures/ preparation for off nominal events	2	3	I don't know how you could eliminate the human factor when you're talking about the scenario like that. I just don't see it. It doesn't happen today, I mean airliners, under a TCAS conflict avoidance system. If something happens with the aircraft you talk about it first but then do it, maybe have something like that...but i don't know if you can have something specific like hard-coded procedures every time.
Procedures	Handling intruders in your airspace	1	1	P3: Or you're just gonna reason with them. You'll try to find out who's violating the airspace that you have reserved, & talk with them before you are going to risk losing a vehicle.
Client function	Client functions	6	13	If I were using it and I was a PIC and I had to use it myself rather than rely on somebody to import everything, having that 'pause' capability…that's gold
Workload	Ways to reduce workload/ streamline operations	1	2	[paraphrased] network reliabilty is a huge factor as well. Right now workload is higher than it probably will be in the future because of networking issues.

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Table A9.5. Operator Requirements *continued*

Category	*Theme*	*Site*	*Com.*	*Example Comments*
Planning	Need for preflight planning, especially planning for off nominal events	3	16	Planning from the beginning, anticipating any problems you might encounter, and say, ok, this is something that could go wrong here. We're gonna go and send the airplane away from that if anything goes wrong. If there is lost comm then its gonna go away from that mountain or away from that tower.
Planning	Preparing the crew as part of flight prep	2	4	We do a crew brief and mission brief...so the entire crew for that a/c, including the VO's knows what the a/c is supposed to be doing at any given time, that why they know that if the a/c is supposed to be going north and all of a sudden its spiraling south, something's not right.
Teamwork	Usefulness of team members with respect to SA	4	8	If you are BVLOS and you have a VO who has eyes on, or even if its line of sight and you have a VO that's watching it, it could help so they could keep an eye on the a/c while you build these points or make a decision based on the map
Teamwork	Team organization	3	5	[paraphrased] it depends on what triggers the modification…if it was a simple change like the PIC wanted to leave the area and go somewhere else, that would be initiated by the pilot and coordinated with the manager, but if there was an intruder or a priority mission, then the manager would initiate and help coordinate since he has more awareness of other traffic.
Team work	Crew structure/ flow of UTM information	2	10	he was calling out stuff that I couldn't see because he had eyes on it and I was operating just off listening to him. That's where CRM comes in and good teamwork. We're flying 1000ft mile out, he stayed eyes up, I stay eyes down because you look at that computer screen, even if you've got it dimmed down, you're going to lose your night vision. So he sat in front, I was behind him, so his eyes would acclimate to the dark and stay acclimated. I stayed on the screen and communicated everything.

Table A9.6. Flight Tests

Theme	*Site*	*Com.*	*Example Comments*
Planning/scripting test for safety	1	3	What a holding pattern does…is ditch points and you put those in a spot where if we lost power for rason descend into one of the orbits and orbit down till it lands on the ground. But at least we know where it will be.
Importance of real world testing	2	3	It's important to do real world scenarios when you're doing testing, because testing is a controlled, sanitary environment, but what these guys are striving to do is to take that sanitary environment and put it in a situation where it could be utilized.
Unresolved test issues	3	18	It's like you're requesting to start in the past rather than in the present. Like, I want to start in 10 seconds but 20 seconds goes by and it's still waiting to receive the message and finally it receives the flight plan and 20 seconds has passed and it says "I can't start you"!
Limited understanding of UTM	2	4	And this is three iterations, I have worked on it. So, when those questions are asked, I have a really hard time honestly answering how well it [UTM] worked with my aircraft.
Test coordination	2	2	You should already have it coordinated and its already set to go, and they are getting the feedback they meaning they have the telemetry that they are looking for. They see the aircraft on the ground and once its takes flight, the flight crew doesn't care about that.
Feedback is through the group not a display	1	2	Because of our proximity to one other and chatting beforehand. We had the visuals, we had like parties talking to one another & then everybody was reading body language too.

Table A9.7. Other Comments

Category	*Theme*	*Site*	*Com.*	*Example Comments*
Airspace sharing/ volumes	UTM philosophy	5	15	I don't know how viable this is for you (...) but look at the aircraft's position and segment and dynamically scale the time allowed left based on its position. So it just sits at the beginning of the position don't count down the time left in the segment because it's not flying towards the end, but then if its flies towards the end of the segment and its half way through, then you could say well the first half took 2 minutes, and the second half will take a similar amount…
Airspace sharing/ volumes	UTM feature suggestion and implementation	5	15	[in response to prompt about UTM and going non-conforming/rogue on one mission] On turn and takeoff I was able to have my home position marked, so just for getting the mission done, I flew it manually and I had an idea of the corridor, but I must have breached outside of that. [didn't have UTM screen up that day] And then obviously not having your mission manager, I can't see that.
Future/Forward looking (includes: equipage, USS features, fleet ops)	Crew/team roles	3	7	The future state is automated flight ops with one person managing multiple aircraft.
Future/Forward looking	Vehicle equipage	3	6	[paraphrased] I like the idea of UTM handling weather info, but only if there is a small degree of error. I don't want the system to restrict a mission if things are really fine.
Future/Forward looking	Concept	4	9	You could potentially have a service that broadcasts the current priorities of the a/c and the a/c could query that service and then assign their flight controller procedures based on their queue in that list of priorities.
Future/Forward looking	Priority	2	2	Some type of vehicle priority. So either prioritizing remaining flight time, vehicle size or vehicle importance, because its pretty easy to sense two vehicles and to sense when you're close to another vehicle, but the difficulty is making the decision of who give right of way to whom.
Future/Forward looking	Security	1	2	Seems like aircraft will be categorized based on applications used like delivery, mapping, surveillance, New York police and where we may be. And we can have generalized category for things like XX delivery. Things which were intended to be used for delivery systems (...) You can feel more comfortable with that aircraft in the air because it is more well known commercial product to trust who keep their integrity of what they are trying to achieve.

continued on next page

Table A9.7. Other Comments *continued*				
Category	*Theme*	*Site*	*Com.*	*Example Comments*
Emergency Ops	Working with emergency personnel	2	5	In the real world when agencies and people come together in ___ types scenarios, it could be this big, or this big, and it grows as needed, we share resources.
Emergency Ops	Getting help from others	1	2	You could say "okay, message this guy, and ask him if he can help us out" In UTM, usually most operators have a phone number attached to them as a point of contact.
Risk assessment	Risk assessment	4	4	Really running [into] another UAV isn't our main concern, our big concern is running [in]to manned asset, helicopter or aircraft. If we have another UAV, well big deal, but taking down manned aviation, now you're talking people getting hurt seriously.
Need for standardization and definition	Procedures	2	4	CW: ...set procedures for lost link? P: we could define one, but it depends on the platform.... you need to turn it around, this is what we can do based on platforms we have, based on software we have. So we don't disagree that there should be one, it just has to be implemented always the way someone is defining it. Again, some standardization on how you're going to do this.
Need for standardization and definition	Terminology can create confusion	1	3	I think it's the mere fact that it was returning to launch point, he was calling it RTB. So there wasn't necessarily a delineation between those two, but they're both called the same thing, because the end result is we're returning back to launch.
Need for standardization and definition	Units of measurement	1	5	[manufacturer] Talks in feet, I talk in feet, that's what NASA wants is feet. Certain other people here in the building do things in meters and I resisted that and so we had that conflict just internally which was problematic.
How equipment works	Procedures	4	14	[asked about how certain vehicles have built in buffers] With ours you can actually set a buffer, so it won't actually breach the fence, right now with ours, its set to 2 meters, so if you're flying right at it, it will actually stop 2 meters before you hit the fence. And you could either have it stop, RTL or land.
How equipment works	Tools (on board in environment)	3	11	That spectrum is available and not being used right now, repurposing it shouldn't take that long, but it is the FAA and FCC.
Wider environment	Public trust	1	4	Its interesting for the general public to have some assurance that there is some drone which is flying over their house is not spying on them and doing something appropriate in the airspace system.
Wider environment	Hazards	1	2	Someone can throw up a mesh-network with a 100 foot tower without any question. They don't have to light it, they don't have to do anything.