NASA's UTM research

joey mercer
lead, user interface technologies & operational procedures

what is UTM?

- UTM = UAS traffic management
  - UAS = unmanned aircraft system
- UTM can be considered as:
  - an air traffic management ecosystem for uncontrolled airspace
  - a separate, but complementary system to the air traffic management system
- the objective of UTM is to inform the needs and requirements for enabling low-altitude UAS operations
  - services, roles & responsibilities, information architecture, data exchange protocols, software functions, infrastructure, performance requirements, etc.

what is UTM?

- important principles:
  - safe integration of UAS operations without burdening the current system
  - leverage private industry to supply new services under the FAA's regulatory authority
  - scalable
  - structure where you need it, flexibility where you don't

what is UTM?

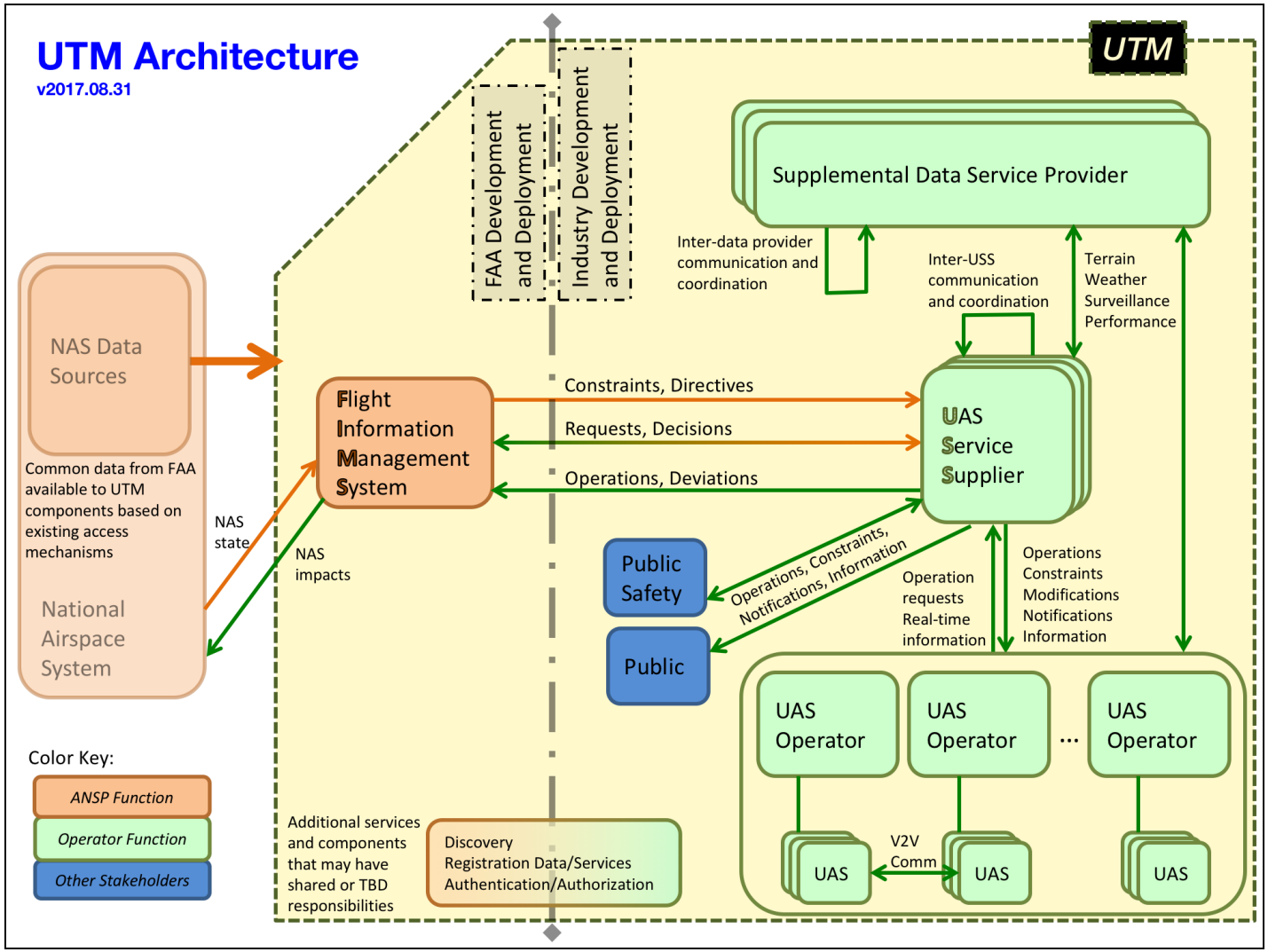
- important rules:
  - UAS vehicles stay clear of each other
  - UAS vehicles stay clear of manned aircraft
  - differentiated access to users of higher priorities
- important terms:
  - line-of-sight
  - beyond-visual line-of-sight (BVLOS)
  - part 101e operations (current-day hobbyists)
  - part 107 operations (current-day commerce)
  - part ??? operations

what is UTM?

- approach:
  - a progression over four distinct technical capabilities, associated with the possible risks of different operating environments
    - TCL = technical capability level
  - TCL1:
    - sparsely populated, rural areas
    - multiple line-of-sight operations
    - constraint checking, information sharing
  - TCL2 adds:
    - BVLOS operations
    - in-flight modifications
    - conformance monitoring
  - TCL3 adds:
    - manned/unmanned interactions
    - moderately populated areas
    - vehicle-to-vehicle communication
  - TCL4 adds:
    - urban environments
    - high-density operations
    - autonomous operations
    - large-scale contingency mitigations

what is UTM?

- system architecture



what is UTM?

- how does it work? (the simple explanation…)
  1. a UAS operator submits their operational plan (kind of like a flight plan), to their USS
  2. the USS checks the intended operation against known constraints
     - ‘static’ constraints (national park boundaries, class-airspace boundaries, airport locations, etc.)
     - ‘dynamic’ constraints (e.g., other operations)
  3. the USS notifies the UAS operator if they are in violation of any constraints
  4. the UAS operator makes any adjustments as they see fit (and may repeat steps 1-3)
  5. the UAS operator begins their flight
  6. the USS monitors the vehicle’s conformance with the submitted plan, and notifies the UAS operator if the maintained ‘state’ of that operation changes significantly
     - accepted, active, non-conforming, rogue, closed
  7. the UAS operator completes their flight

human-factors research in UTM

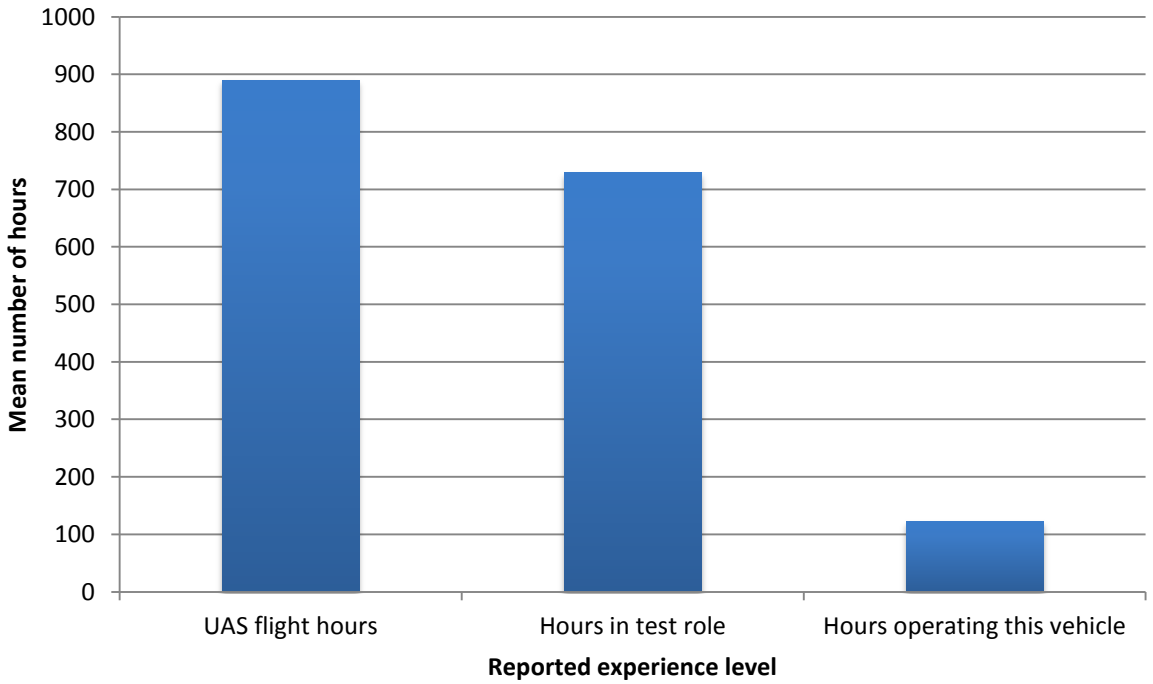
- our focus is on:
  - interface and procedure design
  - identifying minimum requirements and/or best practices that impact an operator's experience
    - operator qualifications and training
    - operator information requirements
    - operator reporting requirements
    - response time [to notifications, ANSP directives, etc.]
- so far, our data has come from:
  - subjective measurements
    - field observations, post-flight questionnaires, end-of-day debrief discussions
  - objective measurements
    - vehicle state data
    - UTM communications/messages logs

human-factors research in UTM

- data presented here comes from our most recent activity, the TCL2 national campaign
- the TCL2nc was a distributed event that took place across six different test-sites
  - 26 shakedown flying days
  - 18 data-collection flying days
  - over 270 data-collection flights
  - 22 different vehicle types
  - 23 flight crews
  - 5 partner-built USSs

operator qualifications and training

- 80% of the respondents reported having an sUAS part 107 certificate
  - not all of these respondents were pilots

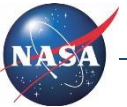


Hours spent on various UAS activities reported by 29 respondents

operator qualifications and training

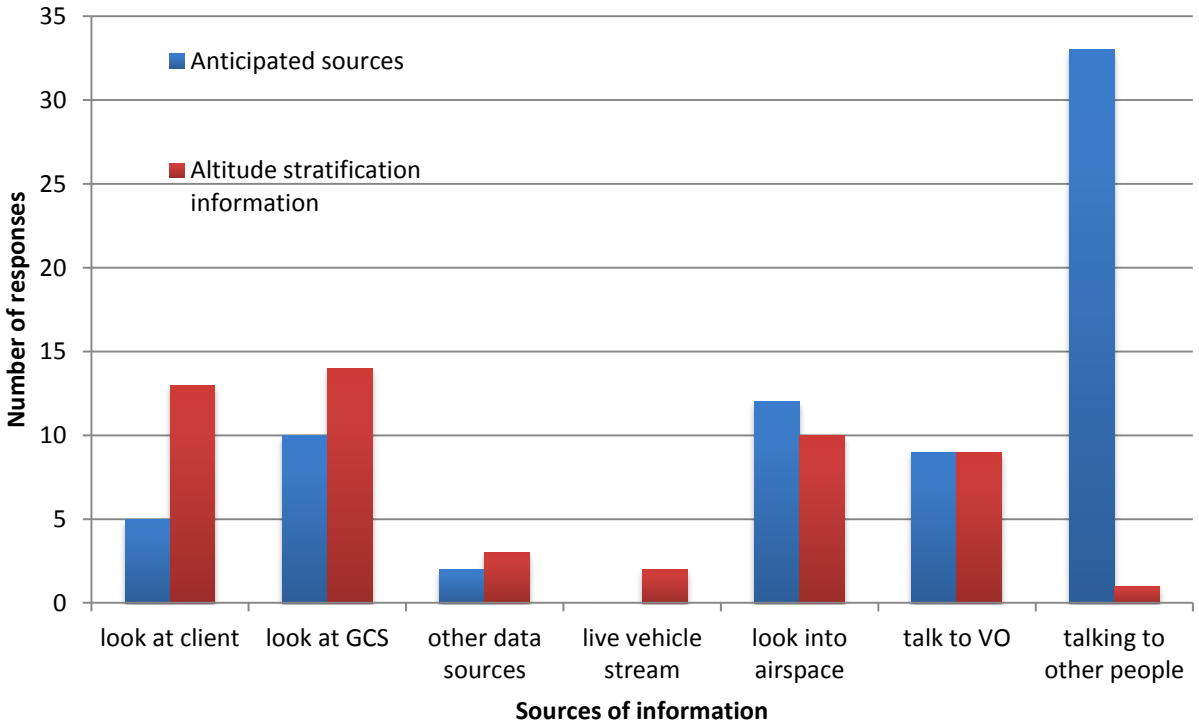
- for some flight-crews, their training and familiarization of the UTM concept and procedures was low, which was detrimental to data collection

topic	comment
training	need for further training for the PIC and actual operation in the [USS] software and [GCS] software - in order to better understand UTM and eventually have the ability to execute the entire sequence of events for flying a mission.
training	for the moment we're not used to using this tool but with few a flights it can become a very helpful tool to make decisions
operator expertise	the USS Operator has to also be very familiar with the performance characteristics of the airframe, similar to the PIC so that they are able to identify when the UAS may or may not become rogue. the USS Operator will [then] be able to better direct the PIC to maneuver accordingly before becoming non-conforming.



operator information requirements

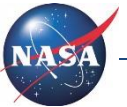
- during shakedowns, 19 participants indicated they anticipated looking to 10 sources for information, 25% being displays and 75% being other people or themselves.
- during data-collection, 19 participants indicated they looked at eight sources for information during altitude-stratified operations, 60% being displays and 40% being other people or themselves.



operator information requirements

- many prototype displays didn't yet have complete functionality and didn't show as much information as needed to be useful

topic	comment
display	would be useful to have a top-level display showing the position and track of other aircraft in real-time so that we can see their altitudes and flight plans in order to deconflict
display	the [interface] does not query and visualize any associated operation volumes, constraints, or other UTM aircraft in the event of alerts or negative UTM responses (e.g. rejected). these kinds of visualizations will become increasingly important to provide as much situational awareness as possible to the user.
information source	all information needed was provided by my eyes, crew, & radio calls. i had no information from [the USS]
GUI	the inclusion of symbology or other standard ways to quickly determine why a UAS entered a rogue state is very important when multiple UAS operations are being managed by one USS Operator
under construction	our aircraft display on [USS] was intermittent



operator information requirements

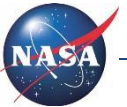
- …were influenced by an individual's training and a team's organization/preparedness

topic	comment
team structure	human-in-the-loop was a critical component of the conformance alerting capability. communication protocols were established and exercised. this combined with the audio alerts and geospatial displays provide an effective alerting mechanism for all levels of operators from the mission director to the pilot.
team structure	although there was significant work that needed to be done within the USS automation, the area of concern was the human-factors elements. timely and effective information had to flow across the operations team, as [did] the operational burden on the mission director/flight director. the USS Operator could not [simultaneously] support nominal and off nominal operations of multiple flights: this was observed when a USS Operator was managing two UAS operations and both aircraft entered a rogue state at approximately the same time. the messages and management of both operations were a bit challenging, as a lot of information was provided to the operator in a very short amount of time.

operator response time

- …will depend heavily on team structure and organization

topic	comment
workload	pilot workload issue: outside of the test environment, during a real lost link / non-conformance event, the pilot workload would be too great such that the pilot may never submit a message to UTM, or the message may be considerably delayed. the expectation that a pilot would message during an emergency procedure is not feasible.
workload	the centralized UTM approach adopted by [test-site A] placed a higher workload on the USS Operator. this was definitely the case for our missions involving simultaneous operations by several (up to 5x) UAS. while this was definitely expected during the training/learning phase for our new [USS Operator], it was also somewhat still the case when our very knowledgeable [USS Operator] was at the helm. while both individuals did show rapid adaption to the environment and tasks, they were still challenged at times with the workload associated with more than a few UAS.
coordination	a centralized implementation of the UTM architecture, where one [USS Operator] manages all airspace reservations and tracks every UAS takeoff/landing, requires close coordination between flight crews and the [USS Operator] both in the preflight phase and during flight operations. however, for the accomplishment of multiple simultaneous UAS operations in close proximity, this approach seems quite reasonable.



summary of main findings

participants were highly qualified…

- had high levels of sUAS training and sUAS flying experience

…but had a low understanding of the UTM concept

- had less, direct exposure to UTM
- flight-crews were neither involved in USS development or test-plan/scenario design
- this affected their interactions with UTM, and ultimately, the collected data

for situation awareness, participants…

- obtained information from a variety of displays, including the USS displays (if available)
- display usability influenced what information operators looked at or listened to

over the course of the flight tests, participants…

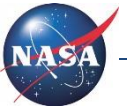
- increasingly understood the need to be aware of other vehicles

operator response time…

- was not specifically assessed (i.e., in units of seconds), during the TCL2nc
- observers noted that the response time to a UTM notification depended heavily on a team's structure, communication efficiency, and procedures

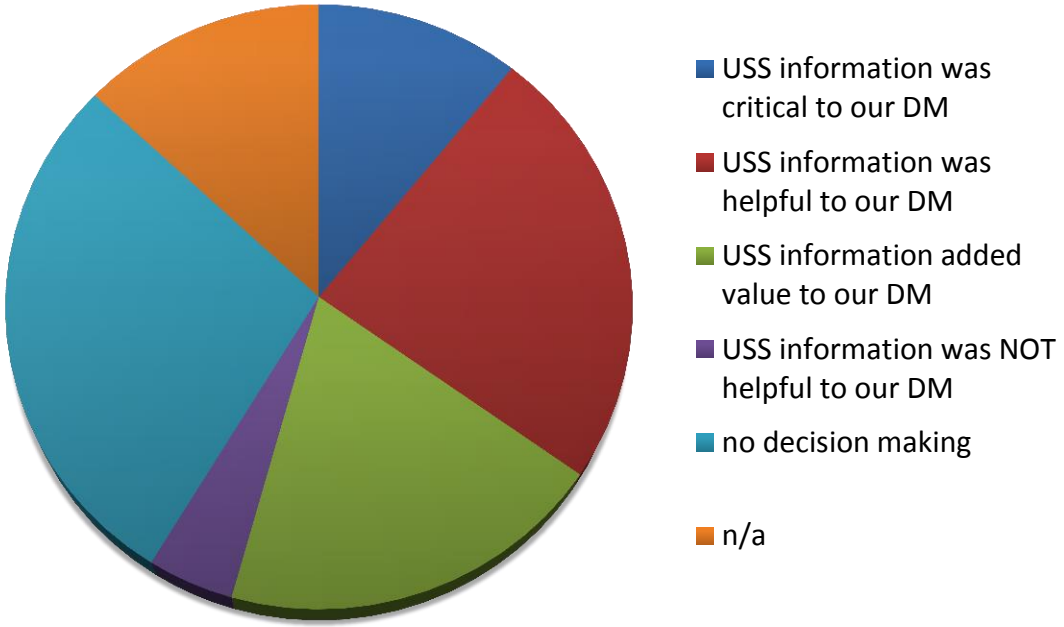
the information requirements (and response times)…

- were influenced by an individual's training, a team's organization/preparedness, and individual/team understanding of the UTM concept
- future tests should continue to investigate these factors within the more complex environments of TCL3 and TCL4



unexpected findings

- the impact of less, direct exposure to UTM
- the impact of safe, scripted flight tests on behavioral research
  - if you had to make a decision while your vehicle was close to another, please indicate how much the information from the USS helped you with your decision



closing remarks

- conclusions
  - we're getting better at extracting informative human-factors data from our field activities
  - some UTM partners/participants are eager to iterate their operations with our findings
  - some UTM partners/participants don't know much about UTM and (this is the issue) don't particularly see the need to know about it
- next steps
  - everyone wants information for situation awareness, but not everyone is always willing to share it
  - the team structure of having the USS Operator remotely located from the flight-crew may lead to SA issues for the flight-crew and workload issues for the USS Operator