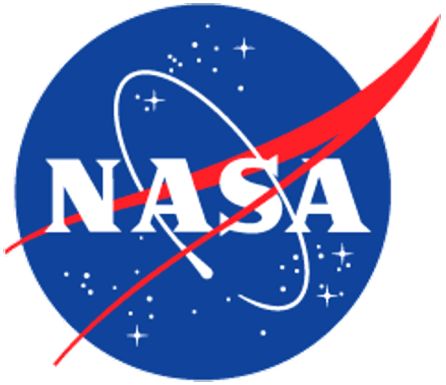
M:N Operations NASA/Uber Collaboration

SARP UAS Information Sharing Workshop

Friday, October 23

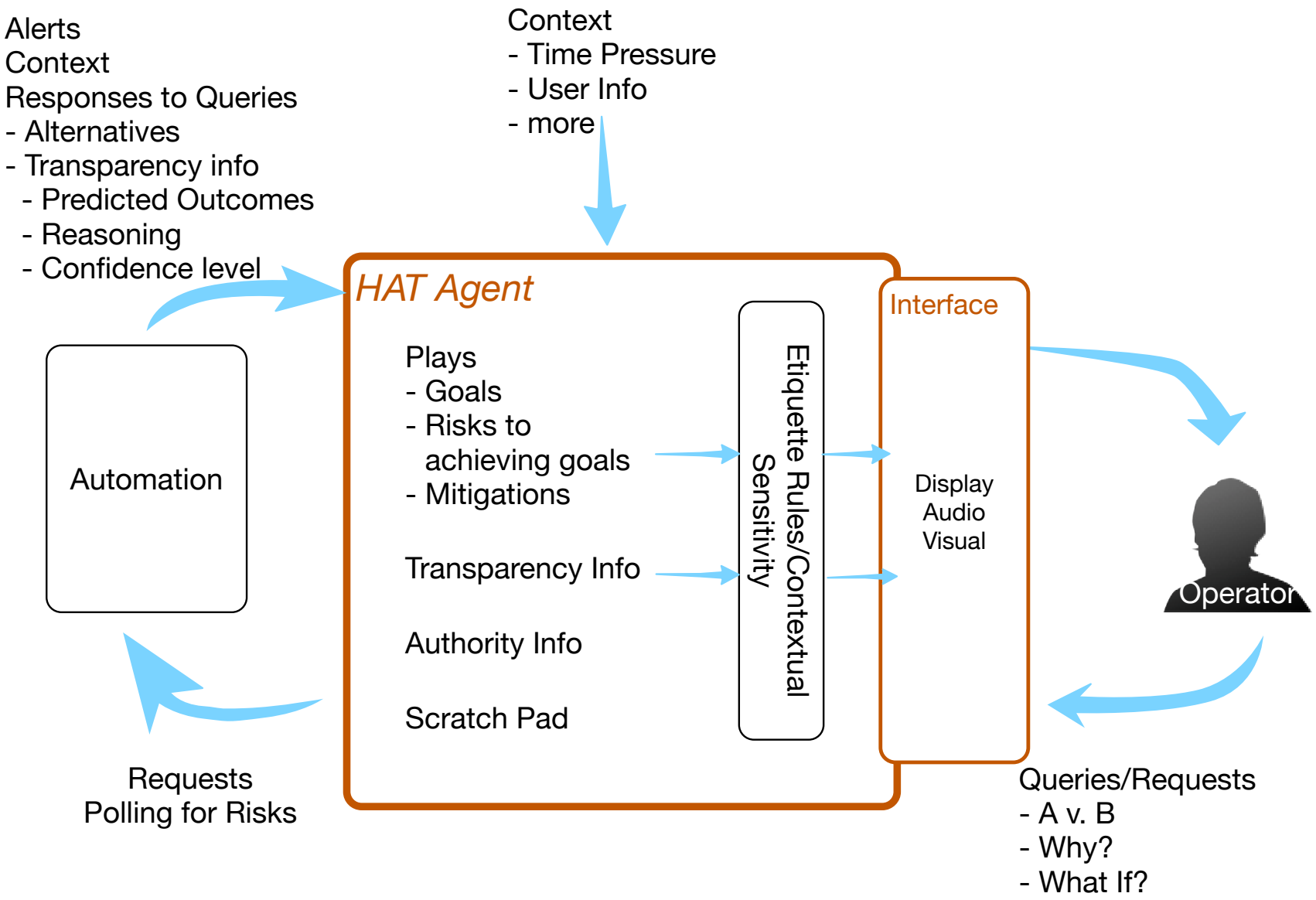
Jay Shively and Garrett Sadler



Background

- Human Autonomy Teaming
- M:N
- Playbook
  - Simulations
  - Flight Tests
- Working agreements
- Cognitive Walkthrough
- Socially distanced Sim
- Meat Servo Sim
- Working Group

Human-Autonomy Teaming (HAT) Agent



M:N – Multiple Operators to Multiple Vehicles

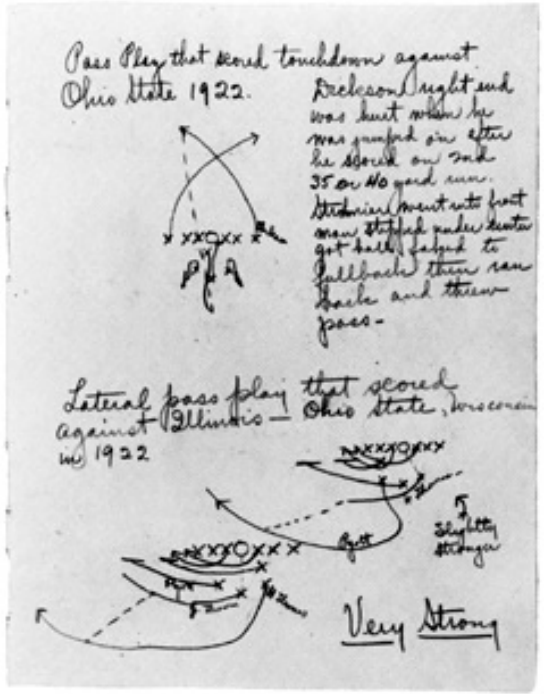
- Enable a single operator (or group of operators (M)) to control multiple vehicles(N) through human autonomy teaming (HAT) principles.

f(Nt, St, dist)

- *Neglect time f(automation, working agreements)*
- *Service time f(contingency management, playbook)*
- *Distro f(predictive timeline displays)*

- Quantify M:N
- Understand parameters
- Tools to support

Delegation Control: Playbook®



A page from Alonzo Stagg's 1927 Playbook
Copyright 1927 University of Chicago

- Delegation: one way humans manage supervisory control with heterogeneous, intelligent assets
- Playbook®: ones means of delegation
  - Playbook® is a registered trademark of Smart Information Flow Technologies
- Plays: analogous to football
  - Quick commands – complex actions
- A Play provides a framework
  - References an acceptable range of plan/behavior alternatives
  - Requires shared knowledge of domain Goals, Tasks and Actions
  - Supervisor can further constrain/stipulate
- Potentially facilitates intuitive cooperative control of Unmanned Systems

Amos Alonzo Stagg, Physical Culture and Athletics. (n.d.). University of Chicago Centennial Catalogues. Retrieved December 8, 2020, from https://www.lib.uchicago.edu/projects/centcat/fac/facch06_01.html


Example: Troops in Contact Tango
Predator Provides Overwatch
and looks for egress routes
TANGO
Shadow provides situation awareness
Firescout
Does Quick Med
Drop
© 2009 Tele Atlas
Map data: Google, DigitalGlobe
Pointer 36°37'12.44" N 121°44'56.80" W elev 287 ft
Streaming 100%
Eye alt 1582 ft

Levels of Automation Simulation

Example: Prosecute Target

Tools:

Arm laser ➔ Lase target ➔ Send coordinates to weaponized UAV ➔ Toggle UAVs ➔ Arm missile ➔ Fire

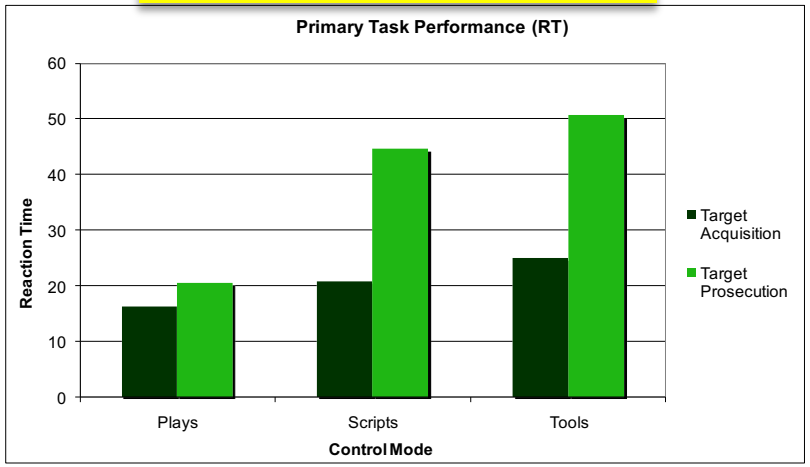
Scripts:

Select ‘Lase’ script ➔Toggle UAVs ➔ Arm weapons ➔ Fire

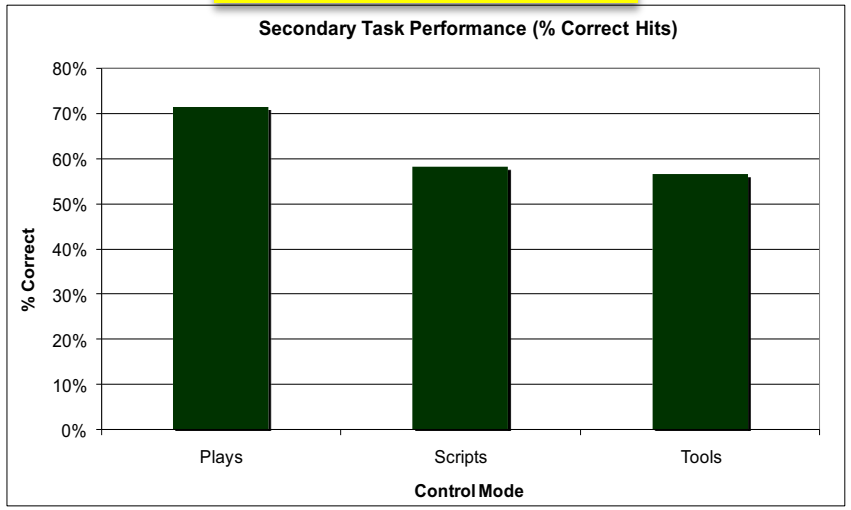
Plays:

Select ‘Prosecute Target’ play ➔ Fire

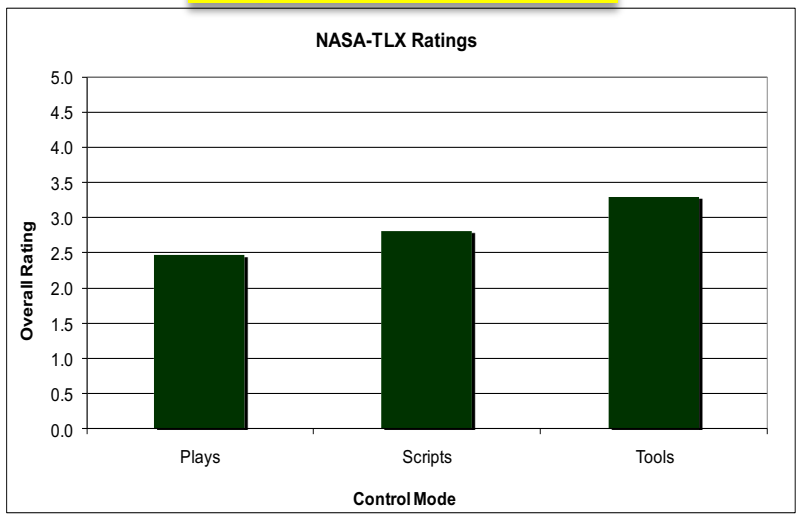
Shorter Reaction Time for Plays



Higher Accuracy for Plays



Plays had lower workload



Flight Demonstration 2009

Ft. Ord CA, 23 APR 2009

Goal:

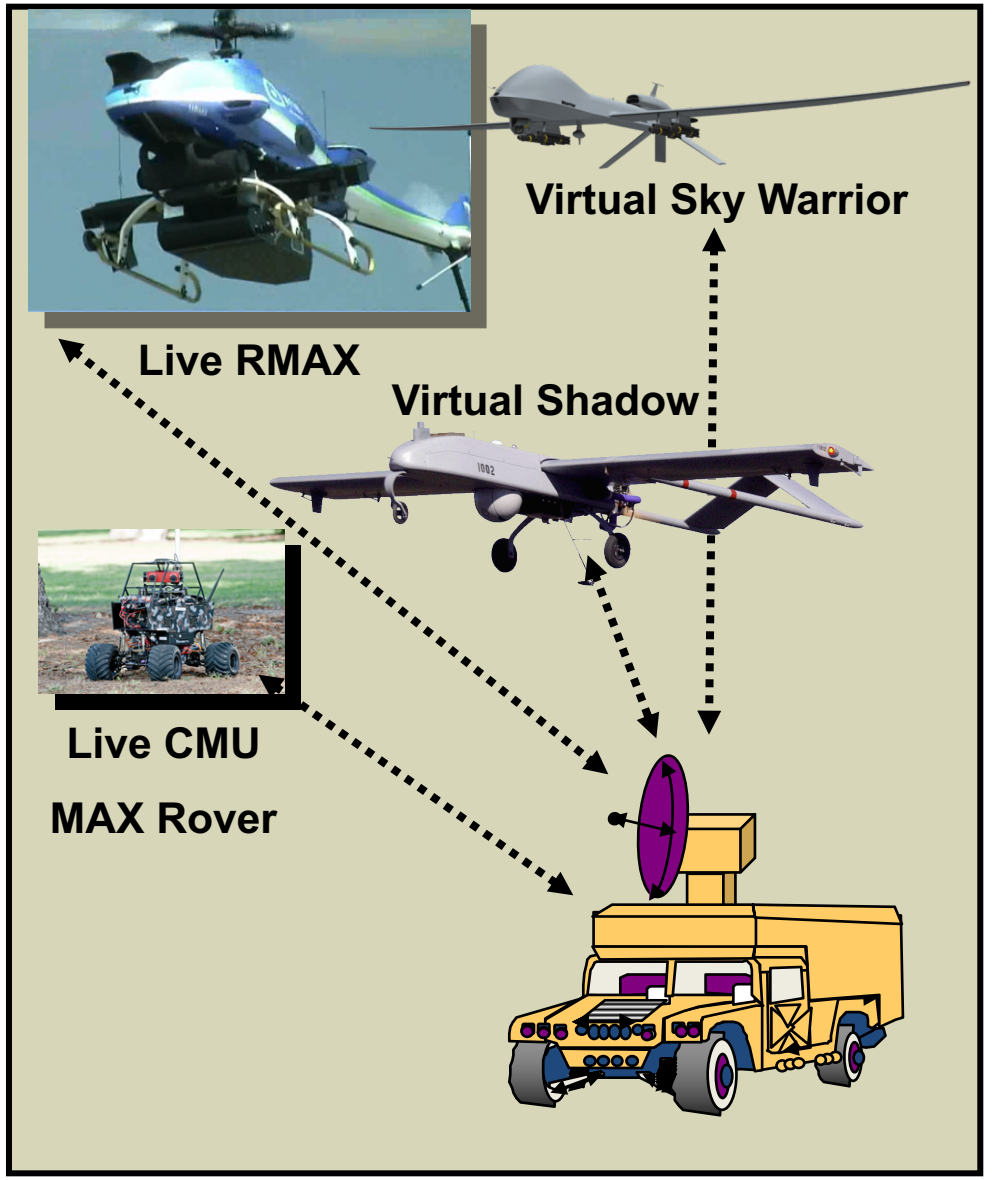
- Demonstrates initial proof of concept of Delegation Control (Playbook) in flight – supervisory control of multiple air/ground assets in MOUT Scenario

Method:

- Live/Virtual Demo – Controlling RMAX, CMU MAX Rover and 2 virtual UAS with Delegation Control
- Voice RGN Control (USAF)

Features:

- Delegation control human-machine interface supports control and monitoring 4 payloads
- Automation Transparency
- Live UGV-UAV coordination for slung load drop
- Reduced operator workload/high situation awareness



Flight Demonstration 2011

Ft. Hunter-Liggett CA, 19 May 2011

Purpose:

- Build on previous simulations and flight test examining single operator control of multiple heterogeneous ground/air unmanned systems through delegation control employment
  - Operator performance data collection/workload assessments
  - Heterogeneous flight assets: Boeing Scan Eagle and Yamaha RMAX; two virtual UAS
  - Testing in operationally relevant mission scenarios
  - Multi-sensor cross-cue in support of both targeting and convoy support
- Army AFDD/Boeing CRADA

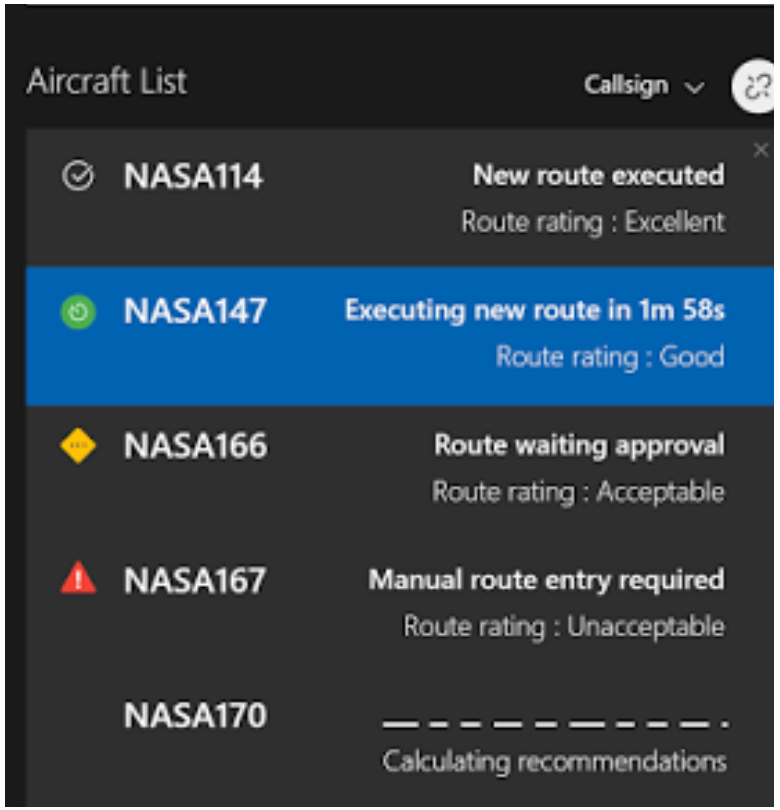
Key Objective:

- Develop and test DelCon Top Priority Plays; route recon, convoy support, troops in contact

ALTA Action Phase

Based on working agreements, the Agent will do one of the following:

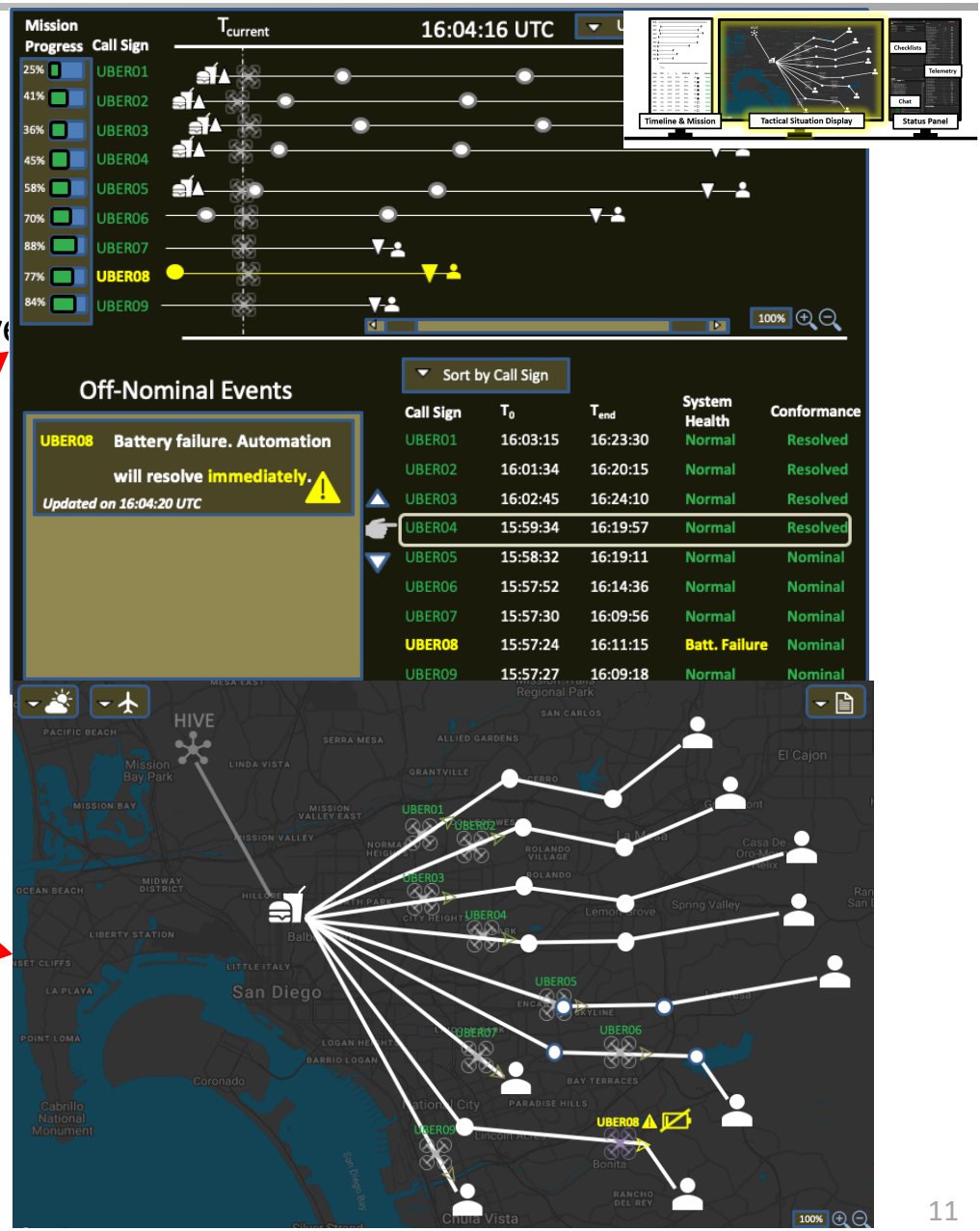
- [Auto] autonomously executes and informs operator
- [Veto] presents a solution which will be autonomously executed unless the operator intervenes
- [Select] presents multiple options for operator selection



M:N Ops Cognitive Walkthrough

- Initial HITL 1 designs adapted for a cognitive walkthrough
  - Feedback to feed into sim/HITL experimental design
    - Displays
    - Use cases
    - Data collection tools/instruments
  - Data on pilot strategy and decision making in resolving contingency ev

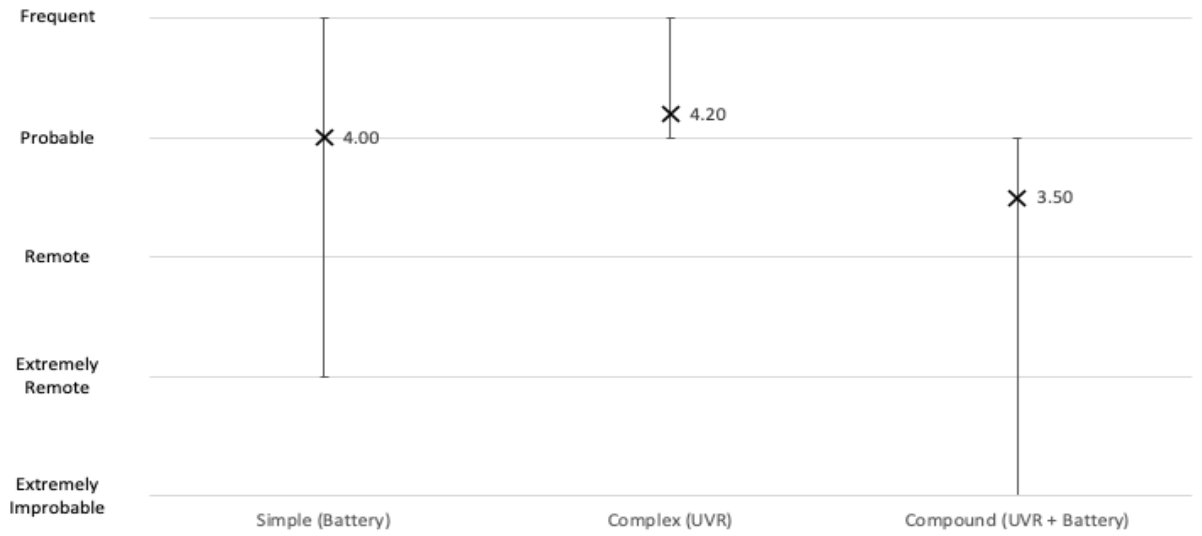
- Overview:
  - "Pre-test:" May 18 – June 3
    - 6 SMEs from Uber
    - Revise and improve displays and use cases
  - Data collection: July 15 – 22
    - 10 subjects (Part 107)
  - Four Use Cases
    - Nominal
    - Simple Contingency (single-vehicle)
    - Complex Contingency (multi-vehicle)
    - Compound Contingency (hetero. multi-contingency)
  - Analysis
    - Quick and dirty
    - Grounded theory



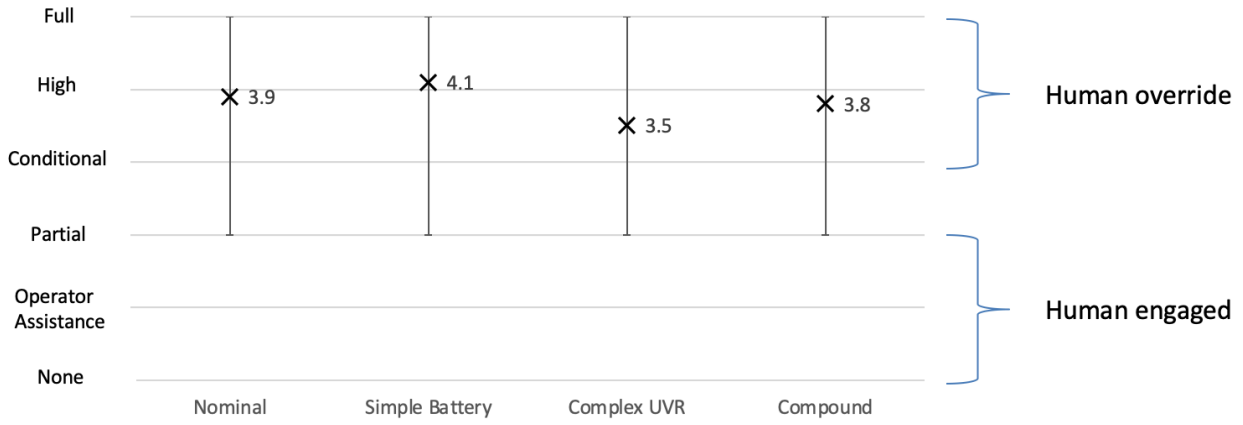
Cognitive Walkthrough – Preliminary Results

- Feedback from pilots indicated that **use case choices were realistic and likely to happen** in M:N operations
  - Likelihood that use case contingency scenarios are mitigated by operator rated as “probable” to “frequent”
  - Time-criticality of operator response in use cases rated as “necessary” to “urgent”
- ***What is the maximum number of aircraft that would normally be manageable?***
  - Average: 12.8 UAs
  - Range: 5-20 UAs
- ***What level of automation should be used/would you be most comfortable with?***
  - Average rating: High automation with option to control vehicle
  - 2 pilots wanted Full automation in all conditions

Scenario Likelihood



Automation Ratings



Cognitive Walkthrough – Meaningful Human Control

Humans have the ability to make informed choices in sufficient time to influence automation-based systems; these can enable a desired effect or to prevent an undesired immediate or future effect on the environment.

Please write an 'X' in the box that best represents your opinion in each of the dimensions below:

Range of Options: *Did you have the range of response options required to respond as needed?*

1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

Temporal Availability: *Did you have the time to assess the situation and respond as required?*

1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

Interface Layout: *Did interface elements support an efficient and effective workflow?*

1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

Information Availability: *Was the information that you needed to respond available?*

1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

Workload (Anticipated): *Was your workload low enough for you to respond appropriately?*

1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

Overall MHC: *Did you feel you were able to exert meaningful human control?*

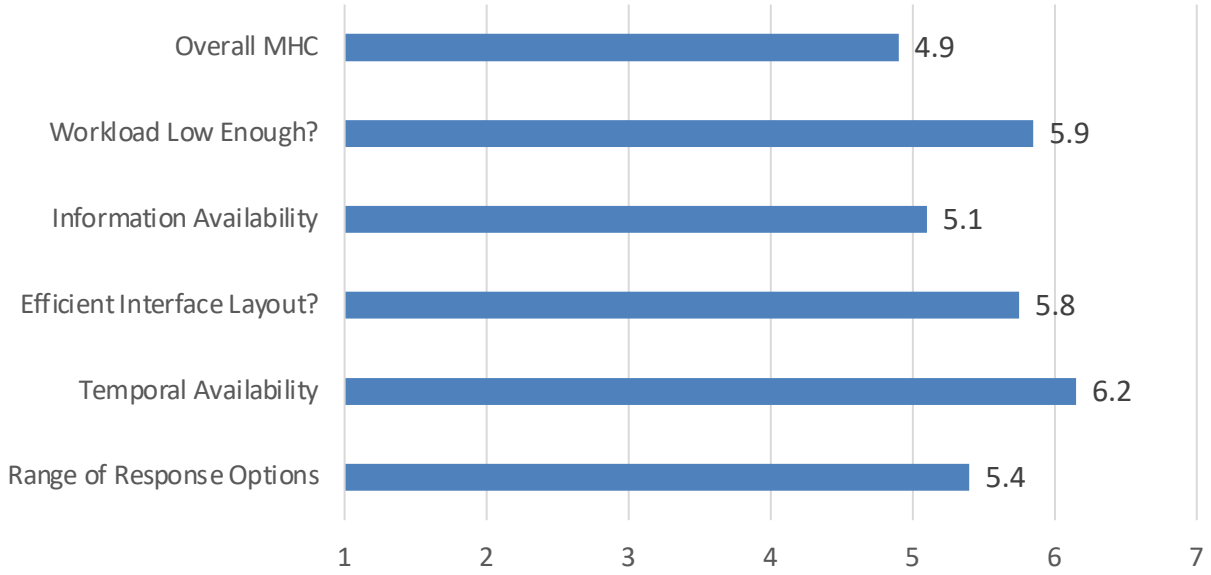
1----------2----------3----------4----------5----------6----------7

Not at all Moderate Absolutely

MHC Concept:

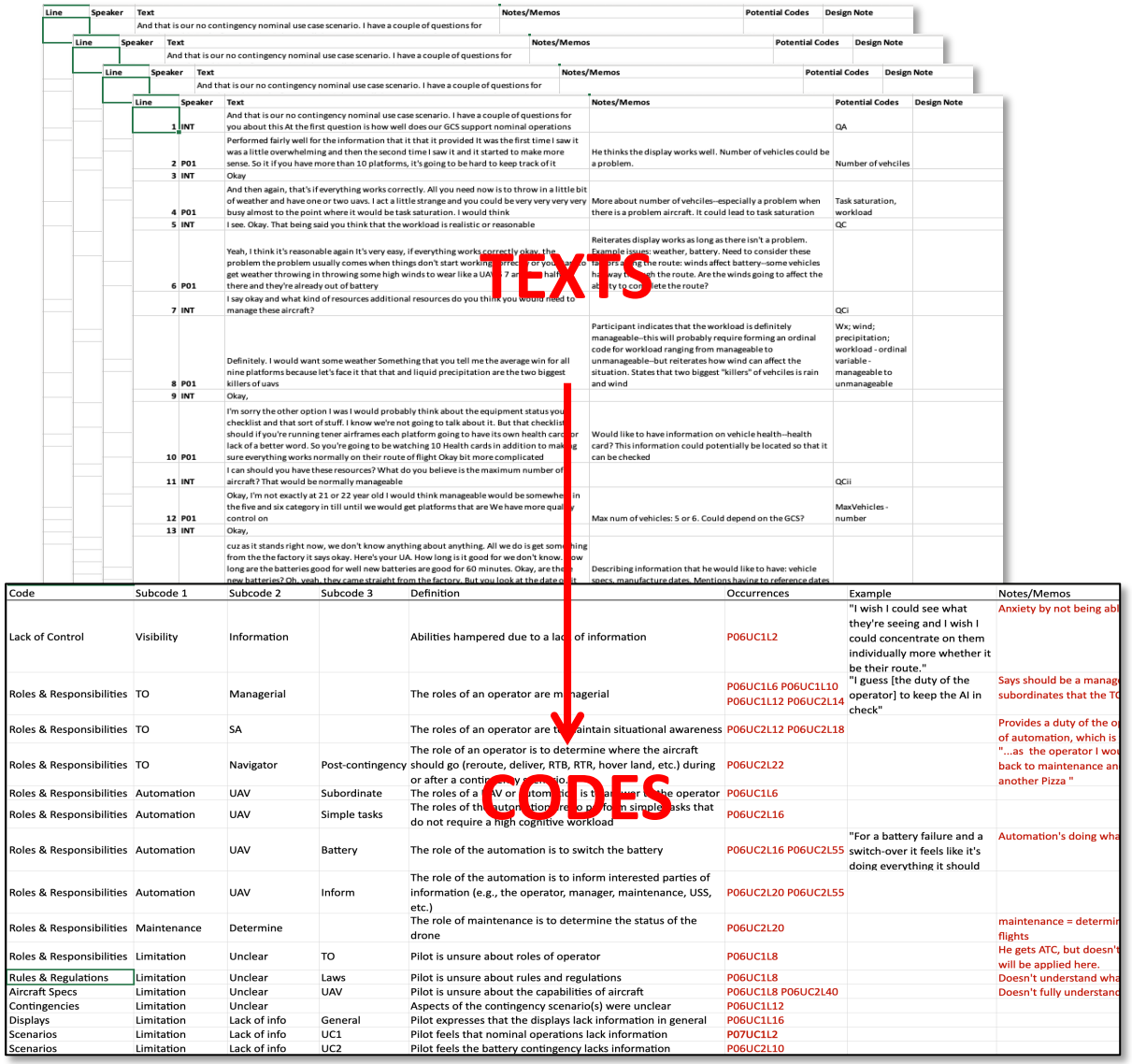
What does Meaningful Human Control mean to you?

Meaningful Human Control Ratings



Cognitive Walkthrough – Grounded Theory Analysis

- Set of techniques used to:
  - Identify categories and concepts that emerge from text
  - Link the concepts into substantive and formal theories/models
- Grounded theory is exploratory
  - It is applied without taking prior assumptions about the text
  - The purpose is for the discovery of hypotheses
- How do you do it?
  - Coding: texts → nominal variables



Line	Speaker	Text	Notes/Memos	Potential Codes	Design Note
1	INT	And that is our no contingency nominal use case scenario. I have a couple of questions for you about this At the first question is how well does our GCS support nominal operations		QA	
2	P01	Performed fairly well for the information that it that it provided It was the first time I saw it was a little overwhelming and then the second time I saw it and it started to make more sense. So it if you have more than 10 platforms, it's going to be hard to keep track of it	He thinks the display works well. Number of vehicles could be a problem.	Number of vehciles	
3	INT	Okay			
4	P01	And then again, that's if everything works correctly. All you need now is to throw in a little bit of weather and have one or two uavs. I act a little strange and you could be very very very very very busy almost to the point where it would be task saturation. I would think	More about number of vehciles--especially a problem when there is a problem aircraft. It could lead to task saturation	Task saturation, workload	
5	INT	I see. Okay. That being said you think that the workload is realistic or reasonable		QC	
6	P01	Yeah, I think it's reasonable again it's very easy, if everything works correctly okay, the problem the problem usually comes when things don't start working correctly for you like you get weather throwing in throwing some high winds to wear like a UAV is half there and they're already out of battery	Reiterates display works as long as there isn't a problem. Example issues: weather, battery. Need to consider these things during the route: winds affect battery--some vehicles have a way to finish the route. Are the winds going to affect the ability to complete the route?		
7	INT	I say okay and what kind of resources additional resources do you think you would need to manage these aircraft?		QCi	
8	P01	Definitely. I would want some weather Something that you tell me the average win for all nine platforms because let's face it that that and liquid precipitation are the two biggest killers of uavs	Participant indicates that the workload is definitely manageable--this will probably require forming an ordinal code for workload ranging from manageable to unmanageable--but reiterates how wind can affect the situation. States that two biggest "killers" of vehciles is rain and wind	Wx; wind; precipitation; workload - ordinal variable - manageable to unmanageable	
9	INT	Okay,			
10	P01	I'm sorry the other option I was I would probably think about the equipment status you checklist and that sort of stuff. I know we're not going to talk about it. But that checklist should if you're running tener airframes each platform going to have its own health card or lack of a better word. So you're going to be watching 10 Health cards in addition to making sure everything works normally on their route of flight Okay bit more complicated	Would like to have information on vehicle health--health card? This information could potentially be located so that it can be checked		
11	INT	I can should you have these resources? What do you believe is the maximum number of aircraft? That would be normally manageable		QCii	
12	P01	Okay, I'm not exactly at 21 or 22 year old I would think manageable would be somewhere in the five and six category in till until we would get platforms that are We have more quality control on	Max num of vehicles: 5 or 6. Could depend on the GCS?	MaxVehicles - number	
13	INT	Okay,			
		cuz as it stands right now, we don't know anything about anything. All we do is get something from the the factory it says okay. Here's your UA. How long is it good for we don't know. How long are the batteries good for well new batteries are good for 60 minutes. Okay, are these new batteries? Oh, yeah, they came straight from the factory. But you look at the date on it	Describing information that he would like to have: vehicle specs, manufacture dates. Mentions having to reference dates		

Code	Subcode 1	Subcode 2	Subcode 3	Definition	Occurrences	Example	Notes/Memos
Lack of Control	Visibility	Information		Abilities hampered due to a lack of information	P06UC1L2	"I wish I could see what they're seeing and I wish I could concentrate on them individually more whether it be their route."	Anxiety by not being abl
Roles & Responsibilities	TO	Managerial		The roles of an operator are managerial	P06UC1L6 P06UC1L10 P06UC1L12 P06UC2L14	"I guess [the duty of the operator] to keep the AI in check"	Says should be a manag subordinates that the TO
Roles & Responsibilities	TO	SA		The roles of an operator are to maintain situational awareness	P06UC2L12 P06UC2L18		Provides a duty of the o of automation, which is
Roles & Responsibilities	TO	Navigator	Post-contingency	The role of an operator is to determine where the aircraft should go (reroute, deliver, RTB, RTR, hover land, etc.) during or after a contingency scenario.	P06UC2L22		"...as the operator I wo back to maintenance an another Pizza "
Roles & Responsibilities	Automation	UAV	Subordinate	The roles of a UAV or automation is to answer to the operator	P06UC1L6		
Roles & Responsibilities	Automation	UAV	Simple tasks	The roles of the automation are to perform simple tasks that do not require a high cognitive workload	P06UC2L16		
Roles & Responsibilities	Automation	UAV	Battery	The role of the automation is to switch the battery	P06UC2L16 P06UC2L55	"For a battery failure and a switch-over it feels like it's doing everything it should	Automation's doing wha
Roles & Responsibilities	Automation	UAV	Inform	The role of the automation is to inform interested parties of information (e.g., the operator, manager, maintenance, USS, etc.)	P06UC2L20 P06UC2L55		
Roles & Responsibilities	Maintenance	Determine		The role of maintenance is to determine the status of the drone	P06UC2L20		maintenance = determir flights
Roles & Responsibilities	Limitation	Unclear	TO	Pilot is unsure about roles of operator	P06UC1L8		He gets ATC, but doesn't will be applied here.
Rules & Regulations	Limitation	Unclear	Laws	Pilot is unsure about rules and regulations	P06UC1L8		Doesn't understand wha
Aircraft Specs	Limitation	Unclear	UAV	Pilot is unsure about the capabilities of aircraft	P06UC1L8 P06UC2L40		Doesn't fully understanc
Contingencies	Limitation	Unclear		Aspects of the contingency scenario(s) were unclear	P06UC1L12		
Displays	Limitation	Lack of info	General	Pilot expresses that the displays lack information in general	P06UC1L16		
Scenarios	Limitation	Lack of info	UC1	Pilot feels that nominal operations lack information	P07UC1L2		
Scenarios	Limitation	Lack of info	UC2	Pilot feels the battery contingency lacks information	P06UC2L10		

Cognitive Walkthrough – Codebook and Themes

Code	Subcode 1	Subcode 2	Subcode 3	Definition	Occurrences	Example	Notes/Memos
Recommendation	Automation	Capabilities - Increase	Needed	Automation needs to be enhanced/improved	P08UC3L28 P09UC1L20		
Recommendation	Displays	Right click		Right clicking something brings up more options	P01UC4L58		
Recommendation	Handoff	Backup/Secondary TO		Pilot recommends a secondary operator for handoff of an aircraft	P06UC1L8 P08UC3L18 P08UC3L20 P08UC3L22 P08UC3L26 P09UC1L20 P09UC3L2 P09UC3L12 P09UC4L4 P09UC4L16		Brings up the idea of handing off to another o workload/problems get to be too much. says aircraft, esp. if something goes wrong, and ha someone else
Recommendation	System	Mitigation	Execute all	Pilot recommends an execute all function for contingencies involving more than one aircraft	P08UC4L12		
Recommendation	Weather info	General		Pilot recommends/stresses the importance of weather information in general	P06UC1L14 P09UC1L22 P09UC2L12 P09UC3L6 P09UC4L10		
Recommendation	Displays	Weather info	Winds	Pilot recommends/stresses the importance of wind information	P01UC1L8 P06UC1L14 P09UC4L10 P09UC4L12 P09UC5L12	"Wind now, I know you have a weather thing up in top left. But what I wish I had the similar to what I have in my G1000 is the little the crosswind component....I'd rather just have the wind components right there for me"	Really wants the wind information. Gives exar he uses regularly. Wants to know how the wir mission
Recommendation	Displays	Airspace		Pilot recommends adding more information about the airspace	P09UC1L20 P09UC1L22 P09UC2L12		
Recommendation	Customize	Screen clutter		Pilot expresses the idea of the operator having control over screen information/clutter	P01UC1L38 P06UC1L16 P07UC1L24	"I like more information now....once you start putting that on there I may wish I can declutter...maybe you're able to do for these operators is give them that option"	Wants more information but recognizes that i Endorses the option of different clutter optio integrated)
Recommendation	Automation	Conditional		Pilot recommends conditional automation	P06UC1L22		Understands the desire for full automation, b control aircraft if needed.
Recommendation	Alerts	Residual alerting	Remove/Reduce	Pilot recommends removing/reducing alerting after contingency is over	P06UC2L2	"I don't want that route highlighted yellow anymore because it almost makes me it almost makes me feel like I need to fix a problem"	Finds residual alerting unnecessary after a pro the yellow highlighting). Instead wants it repl grabbing (i.e., asterisk).

Upcoming Sim: ConOps and R&R Study

Goal: approximate a HAT Lab HITL under restrictions due to COVID-19

- Demonstrate remote simulation capability
- Allow pilots to interact with our current displays (to the extent possible) to better inform our display requirements
  - Current plan is to use researcher as intermediary to interact with displays according to participant's verbal input
- Test and evaluate feasibility of CONOPS, roles and responsibilities of the Tactical Operator
- Gather feedback on how best to manage:
  - Hand-offs between tactical operators and/or the fleet manager (e.g., excessive workload, phase of flight)
  - Potential human-autonomy teaming tools (i.e., 'plays') that could alleviate workload strains while still keeping pilot informed

ConOps and R&R Study: IVs and DVs

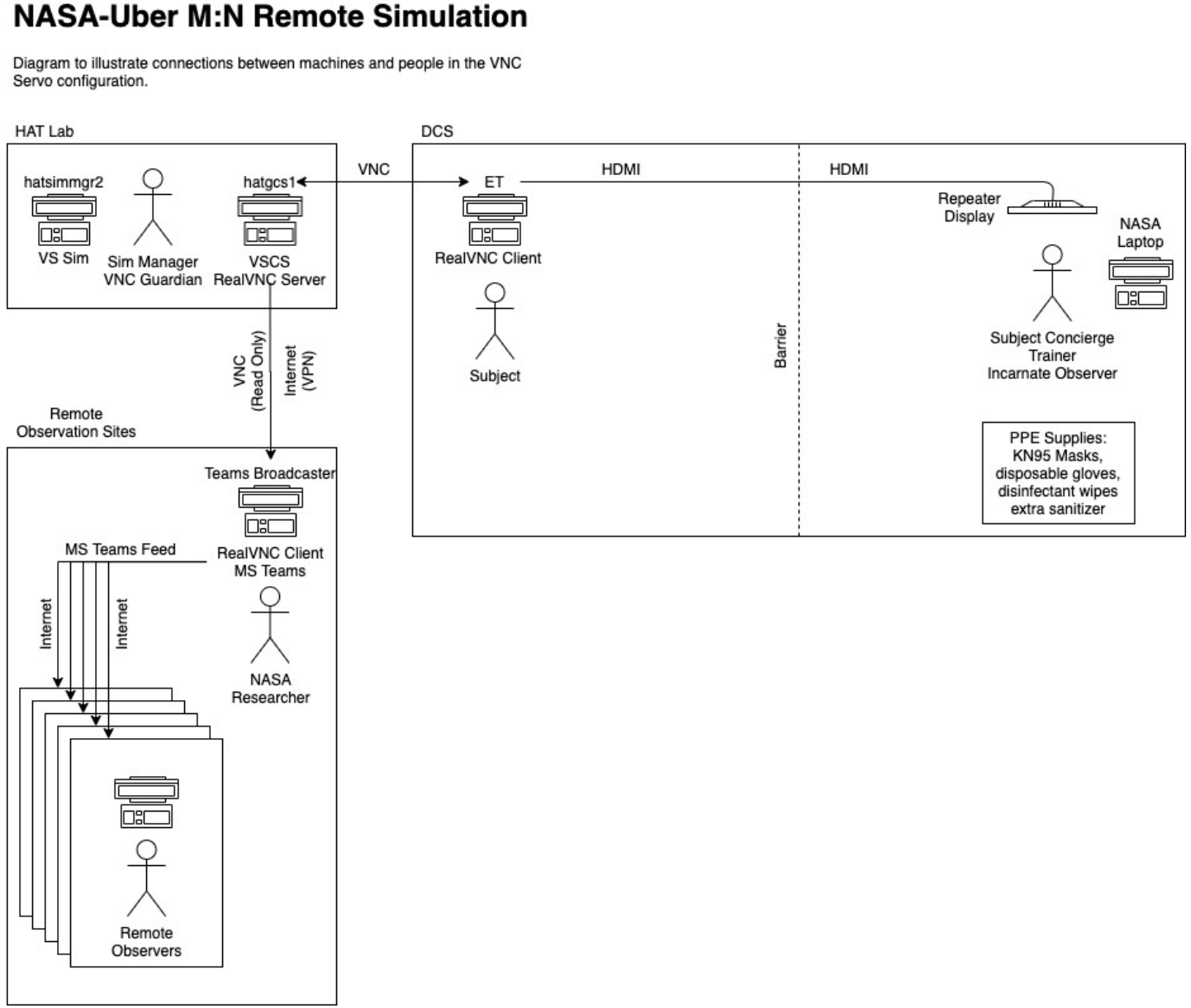
- Independent Variables
  - Workload (within-subjects, 2 levels)
    - High
    - Low
  - Automation (within-subjects, 2 levels)
    - Manual
    - Recommender System

- Embeded Variables
  - Nominal TO tasks
    - Respond to status queries from FAM
    - Monitor health and status of vehicles and routes
    - Monitor conformity
    - Respond to 'minor' events/issues (e.g., batt issue, link hit)
  - Main event: UVR
    - Manipulate occurrence (counterbalanced):
      - 8-min mark, 10-min mark, 12-min mark, 14-min mark
      - Instantly appears vs. small heads up

- Dependent Variables
  - "Think aloud" protocol
    - Strategic and decision-making level data
      - Feedback on CONOPS and procedures
    - (Surrogate) Usability
      - Feedback on displays and interfaces, HMI (maybe… to some extent?)
  - Correctness of responses?
    - Efficiency of the manual response
    - Automation doesn't always give optimal response
      - Perhaps due to circumstances the operator knows and the system doesn't
  - Trust
    - To appropriate assess trust, do we need the system/automation to fail or provide sub-optimal recs?
    - Which scale to use?
  - Workload
    - We can measure these, though I think workload will be very high simply due to needing to pass instructions through an intermediary.
      - Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, Frustration?
  - Meaningful Human Control
  - Debrief responses
    - Where would HAT have helped?
    - Where would another/other operator(s) help?
    - Meta questions:
      - Reflexive queries on how well the sim was facilitated
      - How can the TLX be improved? How would they go about querying this?

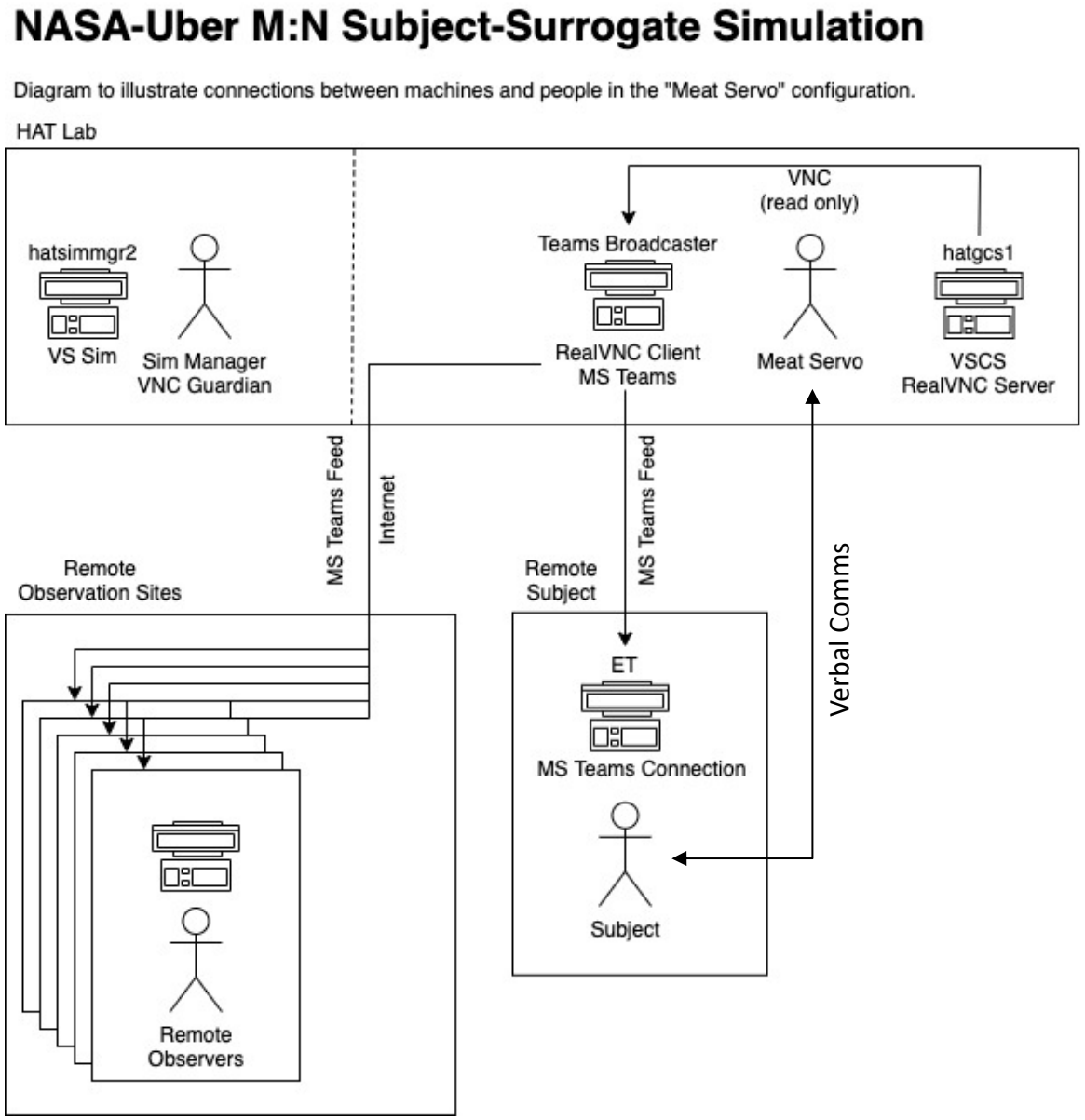
ConOps and R&R Study: Socially Distanced Configuration

- Two HAT researchers @ Ames
  - One @ DCS [outside in tent(s)]
  - One @ HAT Lab
- Subject @ DCS
  - Separated from research staff
  - Strict PPE & COVID-19 protocols
- *N* Researcher Observers
  - Connected remotely



ConOps and R&R Study: Subject-Surrogate Configuration

- Two Researchers @ HAT Lab
  - Sim Mgr in N-262 Rm 243
  - Meat Servo in N-262 Rm 243A
- Remote Subject
  - MS Teams Connection
  - Comms link to Meat Servo for commands
- *N* Researcher Observers
  - Connected remotely



M:N Working Group

Goal:

Bring together government and industry in different domains to pool resources and identify common issues.

Domains:

High altitude, UAS cargo, UAM, small drone delivery, infrastructure inspection.

Products:

Conops, use cases, barriers, current efforts and gaps.

Organizations (for example):

NASA, FAA, DoD, Academia, Loon, HAPS, Traditional OEMs, UAS OEMs, small drone deliver (Uber), RTCA, ASTM, ANSI, SAE

Format:

Monthly telecons, focused workshop(s).