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Industry Led Use-Case Development for Human-Swarm Operations

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The UKRI TAS Programme

The TAS Programme includes one hub, 6 nodes, 3 responsibility projects, 12 Pump Priming Projects and more to be announced. The TAS Hub also initiated 8 Agile research projects in 2021.

Total Funding **£33m over 4 years**	**Universities** **20+**	**Industry Partners** **100+**
Funding **Hub: £11.7m** **Nodes : £3m each**	**Researchers** **200+**	**Disciplines** **10+**

One of the world's largest research programme in Trustworthy AI and Autonomous Systems

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TAS Hub Ambition

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“

Deliver **world-leading best practices** for the design, regulation and operation of ***socially beneficial*** autonomous systems, which are both **trustworthy in principle**, and **trusted in practice by individuals, society and government**.

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TAS Research Themes

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AS Research Areas

- TAS TECHNIQUES AND MECHANISMS
- PUBLIC ENGAGEMENT WITH AS
- HUMAN-MACHINE INTERACTION
- RESPONSIBLE INNOVATION PROCESSES
- TAS GOVERNANCE

Example Topics

TAS Techniques and Mechanisms	Public Engagement with AS	Human-Machine Interaction	Responsible Innovation Processes	TAS Governance
▪ Transfer of control ▪ Flexible Autonomy ▪ Failure recovery ▪ Validation & Verification ▪ Resource allocation	▪ Perception of risks & opportunities ▪ Ethical concerns ▪ Explainable AS ▪ Human autonomy ▪ Acceptance, Adoption and participation	▪ Human-machine organisations ▪ Multi-agent Coordination ▪ Teaming & collaboration ▪ Managing conflicts ▪ Task sharing ▪ Social & societal impact	▪ Understanding stakeholder/user needs ▪ Consent and Privacy ▪ Inclusion ▪ Participation / PD ▪ Open science ▪ Skills ▪ Human-centred design ▪ Production / financing	▪ Policy evaluation ▪ Resilience ▪ Regulation ▪ Legal implications ▪ Auditing

Cross-cutting values

Human-centredness; Equality, diversity & inclusion; responsible research and innovation; trust & trustworthiness; fairness, accountability, transparency & ethics (FATE)

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How do we manage a swarm of drones?

What range of failures is possible when machines can make their own decisions (and humans depend on them)?

Watchkeeper accident report: The Captain, during interview, reported feeling under pressure to land to stay within the crew duty period, but was aware that they still had plenty of crew duty time remaining. The Captain also reported considering the fact that it was going to be dark within 90 minutes of the first recovery attempt.

https://dronewars.net/dronecrash2009-2018/

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Trustworthy human-swarm partnerships in extreme environments

The aim of this project is to understand the contextual factors and technical approaches underlying trustworthy human-swarm teams.

Lead contact: Mohammad Divband Soorati, Alan Turing Research Fellow, University of Southampton

PARTNERS

Our Project Partners

[dstl] THALES

Project Leads

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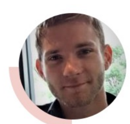

JEDIAH CLARK

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www.tas.ac.uk/research-programmes/agile-programme-2/trustworthy-human-swarm-partnerships-in-extreme-environments/

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Swarm Robotics

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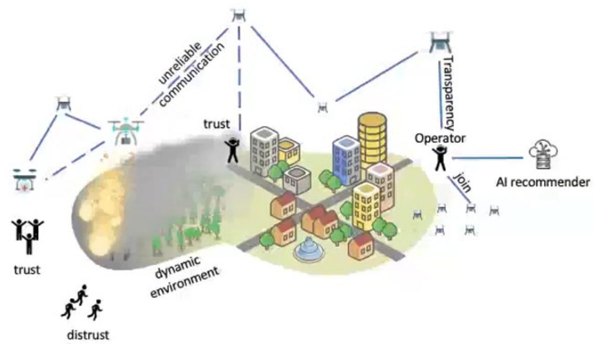
- Definition
  - Collections of autonomous unmanned vehicles distributed to form a common-goal
- Fan-out hypothesis
  - A unique problem due to a difficulty in controlling or supervising agents scales with increasing number of agents (Olsen & Wood, 2004)
- Problem
  - **A requirement for well defined use-cases** for testing and developing Human-Swarm Interaction



Olsen Jr, D. R., & Wood, S. B. (2004). Fan-out: Measuring human control of multiple robots. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, 231-238. New York, NY: ACM.

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Current Study

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- Participants
  - 11 professionals – experts in the research deployment, operation and management of unmanned vehicles systems
  - 2 Hours via MS Teams
  - Three Breakout Groups (each forming a scenario)

Task

Scenario Generation	Operational Boundaries	Trust Implications
Task or problem requiring swarm solution	Physical or cognitive limits (roles, missing information, dropouts, workload)	Main factors affecting trust (e.g., available information, forecast of swarm behaviour)

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Miro Board Overview

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Results - Scenarios

- **Three search and rescue scenarios**
- **Two involve more than one human agent**
  - E.g., Operator, Analyst, Coordinator
- **Mix of treating, assessing and evacuating casualties**

Group	Scenario Description
1	An operator (tasked with controlling the swarm) and an analyst (tasked with analyzing processed data) seek to identify civilians and threats in a reconnaissance mission.
2	Operators and coordinators find suitable landing zones for medical supplies, whilst ensuring that airspace and other parties are managed.
3	Locating and evacuating casualties. Identify, classify, and prioritize casualties based on criticality. Deploy ground vehicles to appropriate locations.

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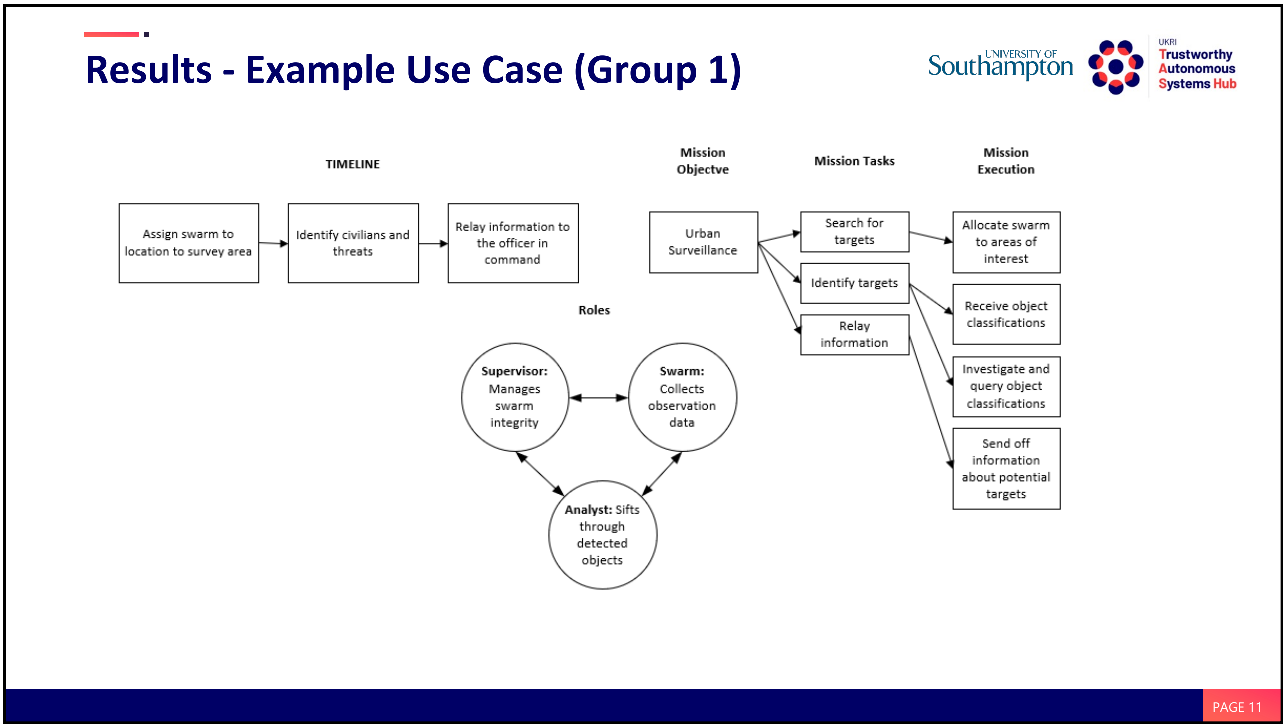

Results - Example Use Case (Group 1)
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TIMELINE
Assign swarm to location to survey area
Identify civilians and threats
Relay information to the officer in command
Roles
Supervisor: Manages swarm integrity
Swarm: Collects observation data
Analyst: Sifts through detected objects
Mission Objectve
Urban Surveillance
Mission Tasks
Search for targets
Identify targets
Relay information
Mission Execution
Allocate swarm to areas of interest
Receive object classifications
Investigate and query object classifications
Send off information about potential targets
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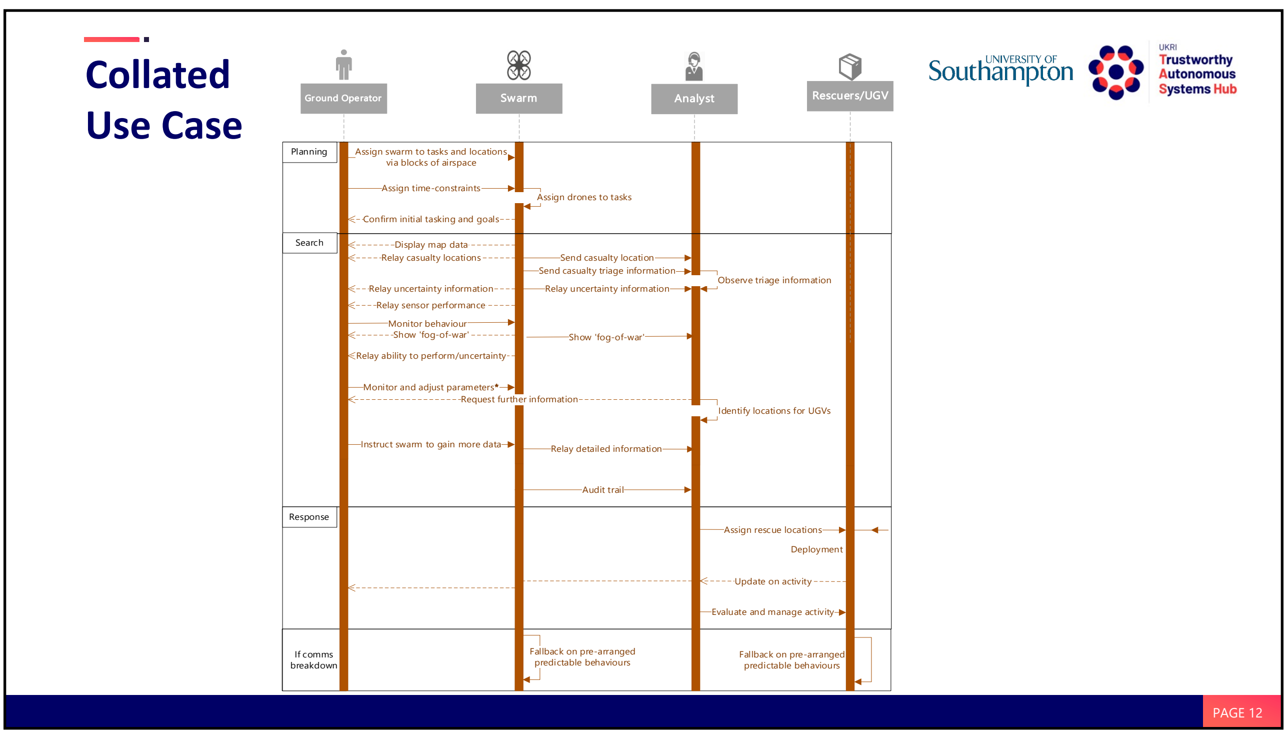

Collated Use Case
Ground Operator
Swarm
Analyst
Rescuers/UGV
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Planning
Assign swarm to tasks and locations via blocks of airspace
Assign time-constraints
Assign drones to tasks
Confirm initial tasking and goals
Search
Display map data
Relay casualty locations
Send casualty location
Send casualty triage information
Observe triage information
Relay uncertainty information
Relay uncertainty information
Relay sensor performance
Monitor behaviour
Show 'fog-of-war'
Show 'fog-of-war'
Relay ability to perform/uncertainty
Monitor and adjust parameters*
Request further information
Identify locations for UGVs
Instruct swarm to gain more data
Relay detailed information
Audit trail
Response
Assign rescue locations
Deployment
Update on activity
Evaluate and manage activity
If comms breakdown
Fallback on pre-arranged predictable behaviours
Fallback on pre-arranged predictable behaviours
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Conclusions

- Sets expectations for multiple human agents
- Robust and detailed use-case for testing
- Can be used for simulations, storyboarding, user evaluation etc.

Limitations

- Participants primarily from defence sector
- Theoretical and relatively new domain of research

Further Research

- Developing a simulation platform
- Testing with human-swarm interaction
- Exploring additional contextual factors

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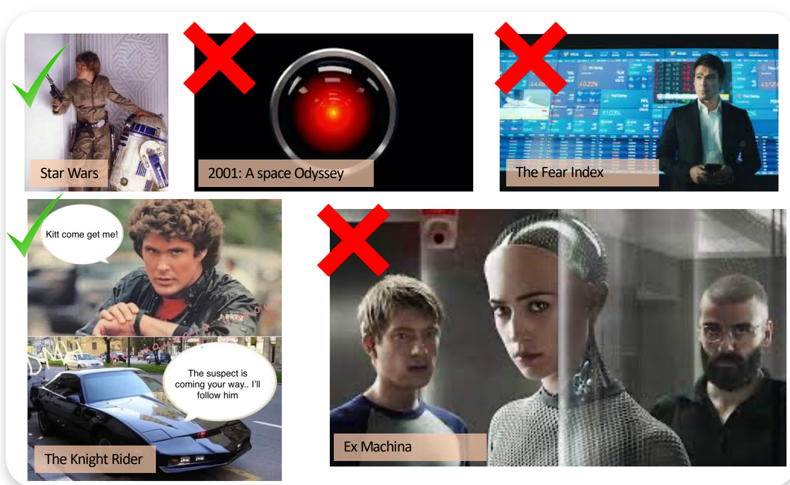
Human-AI Partnerships

Ramchurn, S. D., Stein, S., & Jennings, N. R. (2021). Trustworthy human-AI partnerships. *Iscience*, *24*(8), 102891.

- Socio-technical system composed of humans and Machines
- Both Machines and Humans may be in charge at different points in time
- Humans and Machines **cooperate, coordinate, compete**
- Feedback loops that may reinforce beliefs and influence decision-making
- Ethical and Safe



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Human-AI Partnerships

- Data: learning, tracking, reasoning
- Design: teaming, optimization, explainability
- Incentives: social welfare, fairness, privacy

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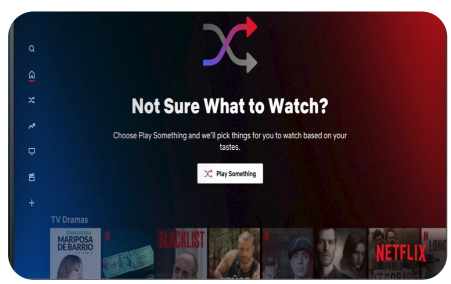
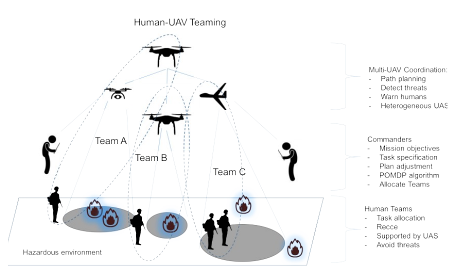
Data: Deciding and Learning

- **Positive Feedback Loops**
  - Continual learning systems that learn from human input and refine their recommendations (e.g., Netflix/google)
  - Risks of oscillations in large systems with many independent actors learning from each others' behaviours
- **Tracking Data and Decisions**
  - Machine-speed decision-making
  - Complex decision-making chains
- **Potential Solutions**: Provenance tracking & Causal reasoning over Provenance traces





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Design: Teaming, Optimising, and Explaining

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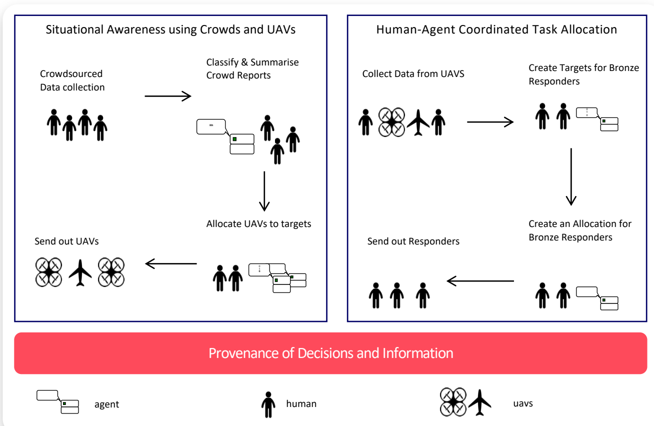
- Operator-to-Machine Ratio: may need to vary over time due to complexity of task
- Complex machine behaviours: interpretability, explainability



Potential approaches:

- Iterative, user-centered design
- Digital twins (Agent-based simulations)
- Multidisciplinary teams
- Participatory design

Ramchurn, Sarvapali D., Huynh, Trung Dong, Wu, Feng, Ikuno, Yuki, Flann, Jack, Moreau, Luc, Fischer, Joel, Jiang, Wenchao, Rodden, Tom, Simpson, Edwin, Reece, Steven, Roberts, Stephen and Jennings, Nicholas R. (2016) A disaster response system based on human-agent collectives. Journal of Artificial Intelligence Research, 57, 661-708.

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Thank you for listening

www.tas.ac.uk/

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