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Technical Report: Analysis of Intervention Modes in Human-In-The-Loop (HITL) Teleoperation With Autonomous Unmanned Aerial Systems

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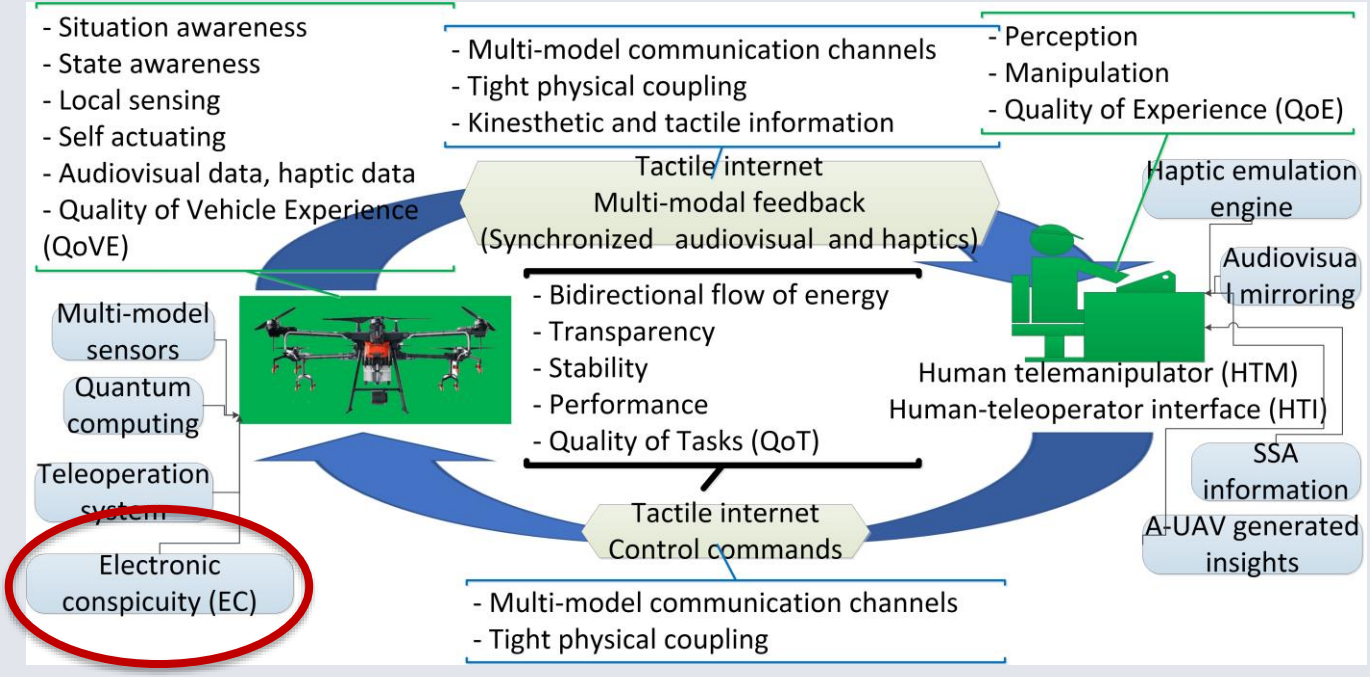
Introduction

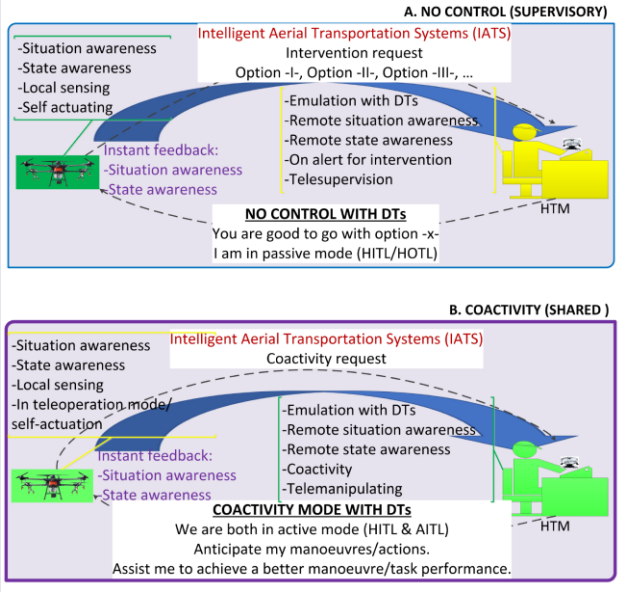
- There are still many limitations with AVs despite several decades of earlier research,
- Many years to come for A-UAVs to become completely self-sufficient,
- HITL telemanipulation to build the required trust in A-UAVs.
- This technical report examines the telemanipulation schemes between two smart agents:
  - human telemanipulators (HTMs) and A-UAVs.

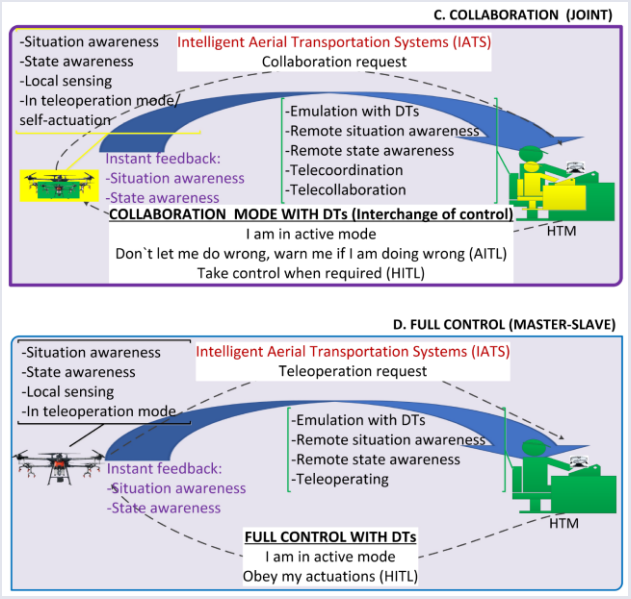
Components of human haptic close-loop telemanipulation of A-UAVs

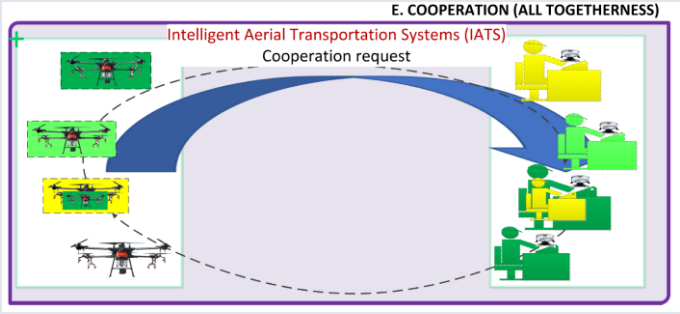


A tight communication channel with high bandwidth capabilities (i.e., ultra-reliable and low-latency communication (URLLC))

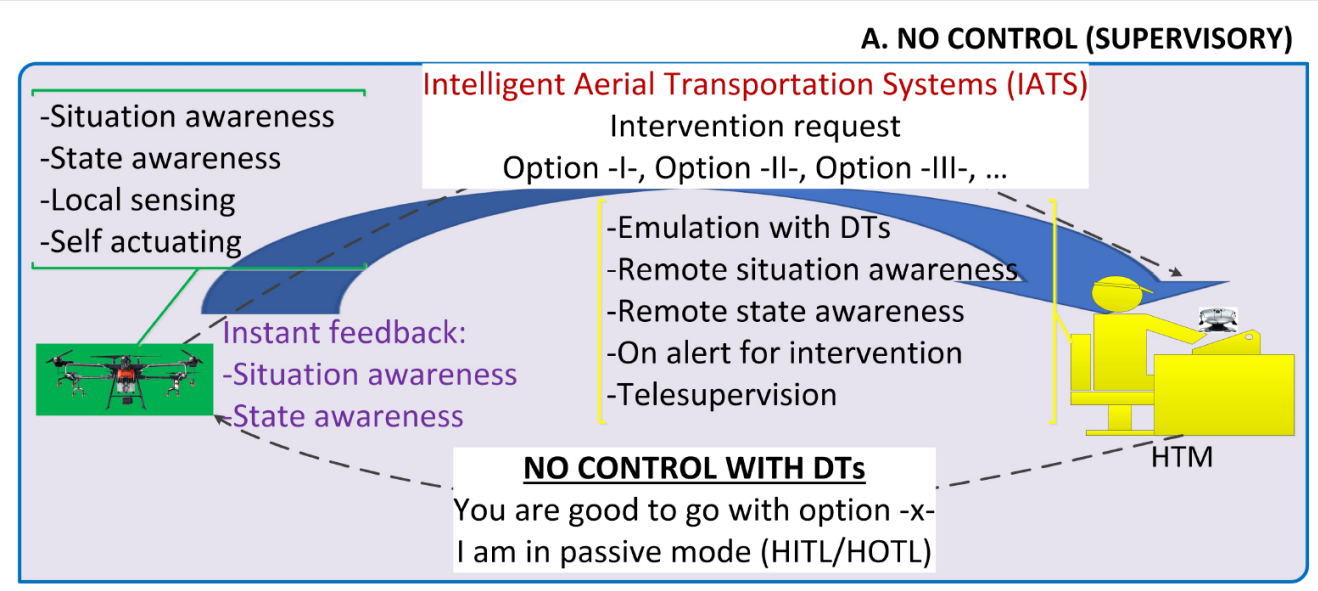
Telemanipulation Schemes with A-UAVs







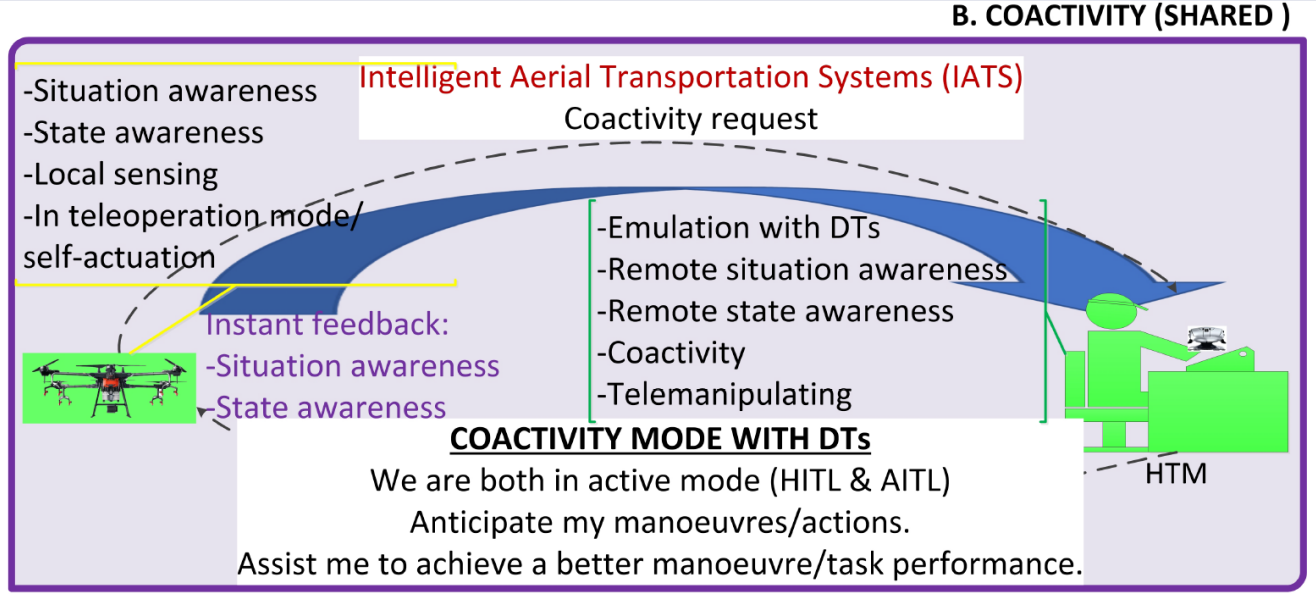
Telemanipulation Schemes with A-UAVs



- The involvement of HTMs minimised.
- A high degree of freedom for A-UAVs.

✓ HTM assists A-UAVs by setting short-range subtasks for the agent to achieve independently.

Telemanipulation Schemes with A-UAVs



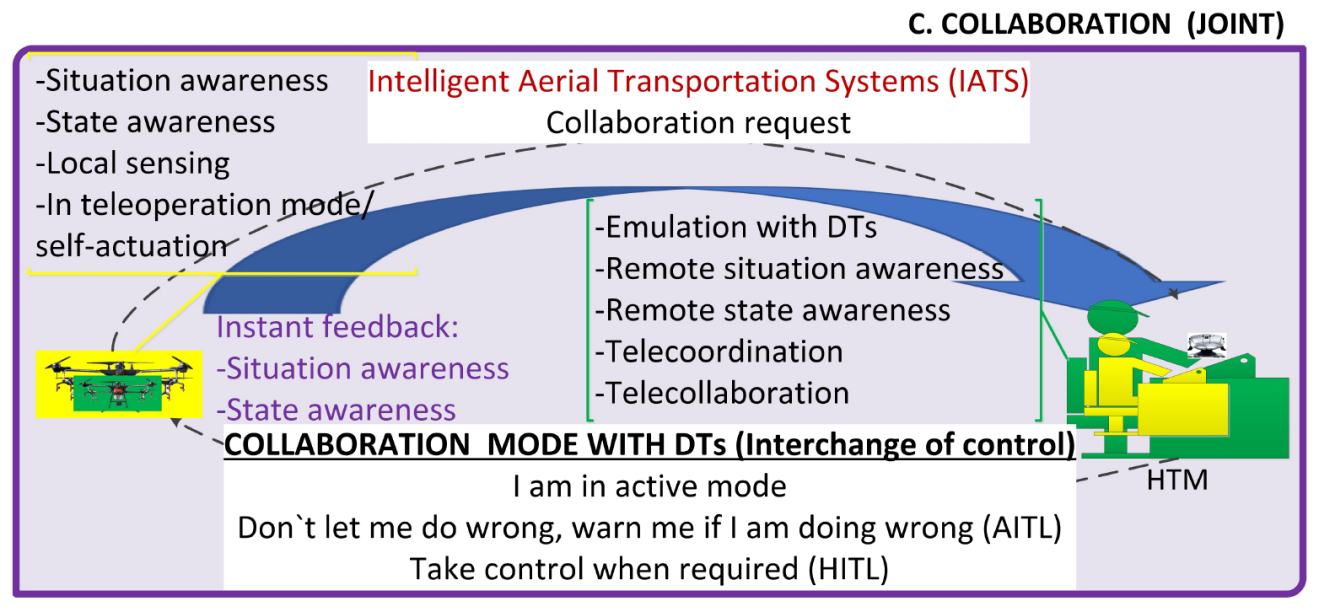
- co-activity
- master-master

(i.e. more equal co-worker)

- combined task performance

- ✓ Roles and responsibilities may not be distinctively assigned.
- ✓ Human and robot skills combined.
- ✓ The combined system can outperform both agents.

Telemanipulation Schemes with A-UAVs

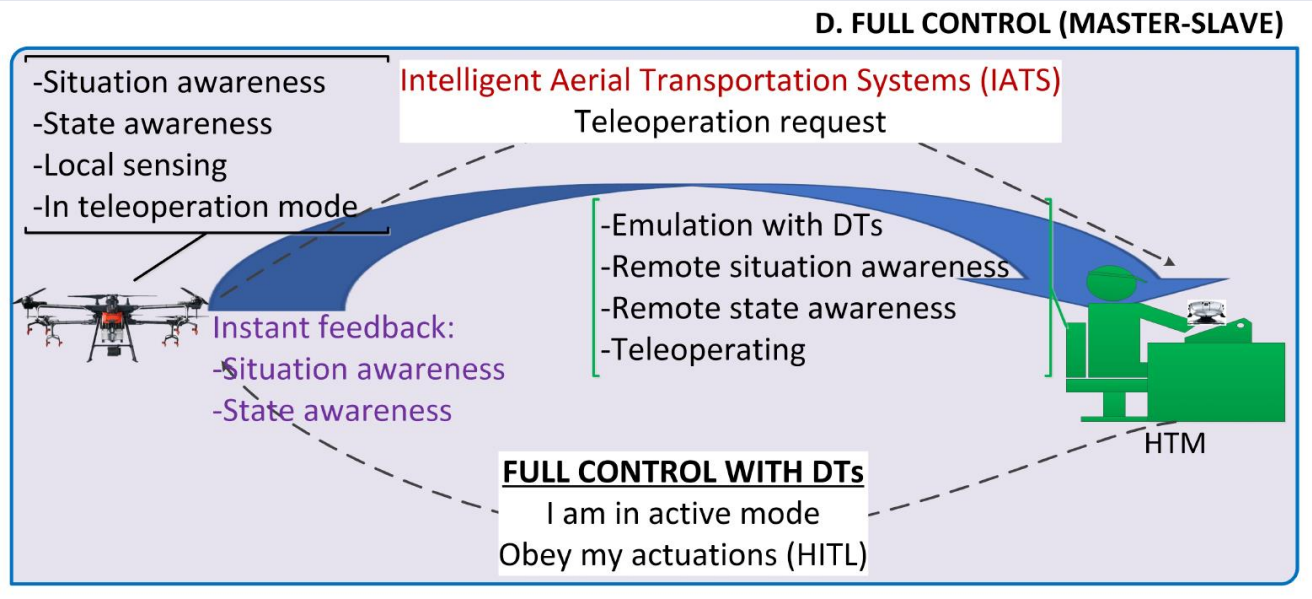


- sub-tasks traded back and forth
- sub-tasks performed individually
- joint task performance

✓ Humans and robots converge to exchange ideas and settle disagreements rather than a superior giving orders to a subordinate.

✓ The robot has more freedom in execution.

Telemanipulation Schemes with A-UAVs

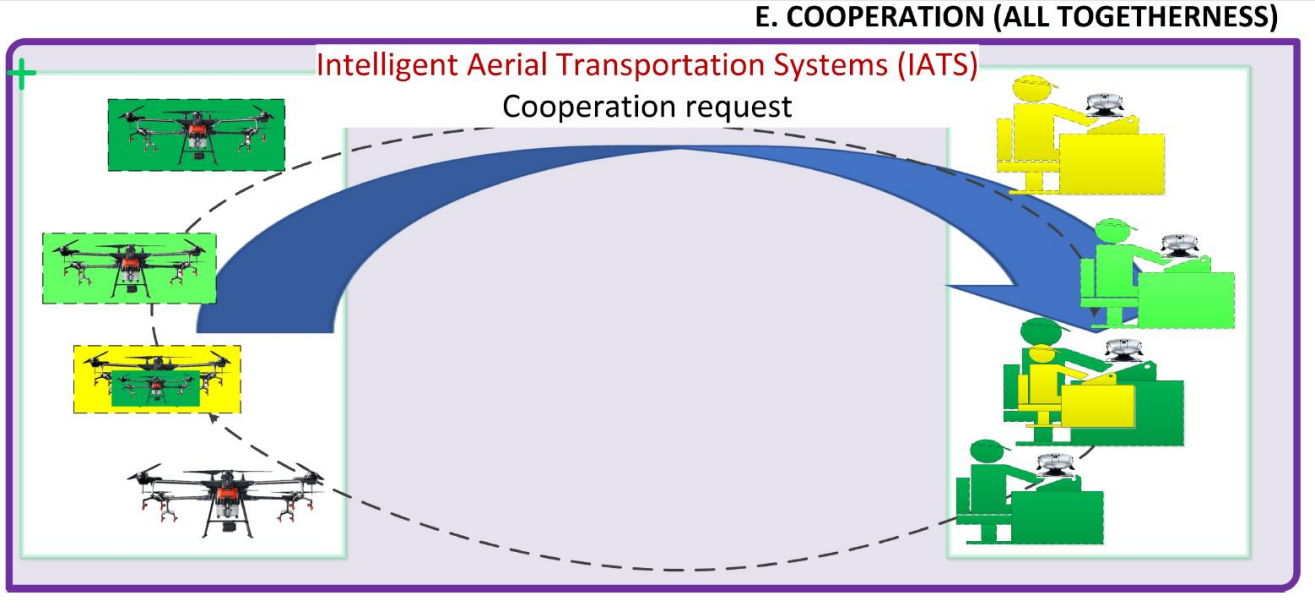


- Onboard sensor failures
- failures of primary actuators

✓ Complete tasks may need to be performed by HTMs alone under extreme conditions in this scheme.

✓ HTMs, as leading agents, take over the control and lead A-UAVs as follower agents.

Telemanipulation Schemes with A-UAVs



- Swarms of A-UAVs
- multiple telemanipulation schemes
- Common goal as a teamwork
- one-to-many or many-to-many human-robot coordination

✓ to accomplish a specific task faster than a single A-UAV or to solve difficult tasks that are beyond a single A-UAV's capability, e.g.

-search and rescue missions,

-transportation of a hefty payload.

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Main properties of the telemanipulation schemes

Schemes	Loop	Decision	Obedience A-UAV	Obedience HTM	Solution for conflicts	Full control	Built-in safety
No-control	HITL	HTM	Yes	No	N/A	Yes (A-UAV)	Operational
Co-activity	HITL & AITL	HTM & A-UAV	No	Yes	HTM & A-UAV	No	Operational
Collaboration	HITL || AITL	HTM || A–UAV	No	No	HTM || A-UAVs	Partial	Operational
Full-control	HITL	HTM	Yes	No	N/A	Yes (HTM)	Inactive
Cooperation	Mix interactions	Mix schemes (above)	Mix schemes (Yes||No)	Mix schemes (Yes||No)	Mix schemes (above)	Mix schemes(above)	Operational

Transitional responsibilities of the HITL and AITL agents during the switching

Switching between schemes	Current control	Next control	Current dominance	Next dominance	Switching control
No >>>>co-activity	A-UAV	A-UAV-HTM	A-UAV	A-UAV&HTM	A-UAV
No >>>>collaboration	A-UAV	A-UAV-HTM	A-UAV	HTM	A-UAV&HTM
No >>>>full	A-UAV	A-UAV-HTM	A-UAV	HTM	A-UAV&HTM
co-activity >>>>collaboration	A-UAV-HTM	A-UAV-HTM	A-UAV&HTM	HTM	HTM
co-activity >>>>full	A-UAV-HTM	A-UAV-HTM	A-UAV&HTM	HTM	HTM
co-activity >>>>no	A-UAV-HTM	A-UAV	A-UAV&HTM	A-UAV	A-UAV
Collaboration >>>>full	A-UAV-HTM	A-UAV-HTM	HTM	HTM	HTM
Collaboration >>>>no	A-UAV-HTM	A-UAV	HTM	A-UAV	HTM&A-UAV
Collaboration >>>>co-activity	A-UAV-HTM	A-UAV-HTM	HTM	A-UAV&HTM	HTM
Full >>>>no	A-UAV-HTM	A-UAV	HTM	A-UAV	HTM&A-UAV
Full >>>>co-activity	A-UAV-HTM	A-UAV-HTM	HTM	A-UAV&HTM	HTM
Full >>>>collaboration	A-UAV-HTM	A-UAV-HTM	HTM	HTM	HTM

Conclusion

HITL telemanipulation modes described in this report can

- play a key role in enabling A-UAVs to instantly handle a multitude of uncertainties and
- expedite the integration of A-UAVs into mixed air traffic.

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