U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMY RESEARCH LABORATORY

Human-Guided System Adaptation (HSA) Science Challenge and Hackathon Week

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HACKATHON BACKGROUND

Human-Guided System Adaptation (HSA) Science Challenge and Hackathon Week at Columbia University in New York

https://liinc.bme.columbia.edu/human-guided-system-adaptation-hsa-science-challenge-and-hackathon-week

Includes: Sign up link, link to this presentation, link to pertinent papers, link to github for Hybrid Team Mega Tetris.

HACKATHON IMPORTANT DATES

August 8th at 12pm Paradigm Challenge Videos Submitted

August 9th 1pm to 5pm Experimental Challenge in person science fair style demonstrations.

August 10th. 11am Hackathon begins in person at Columbia University using Hackathon version of Tetris.

August 12th 12pm to 5pm Hackathon Competition in person at Columbia University takes place.

THE FUTURE BATTLESPACE

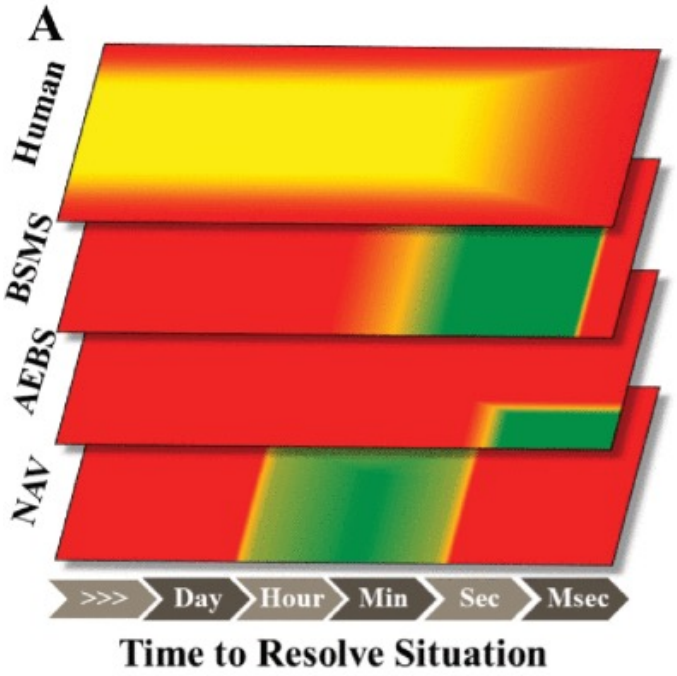
The world is in a phase of great power competition the major technological component of which is an intelligence race to dominate opponents with better/faster technological innovation and battlefield decision making.

FRAMEWORK FOR CURRENT AND FUTURE HUMAN-AGENT PARTNERSHIPS

Can the capabilities of human and machine intelligence be characterized in a generalizable manner? Can such a generalization drive expected relationships in realistic real-world environments and conditions?

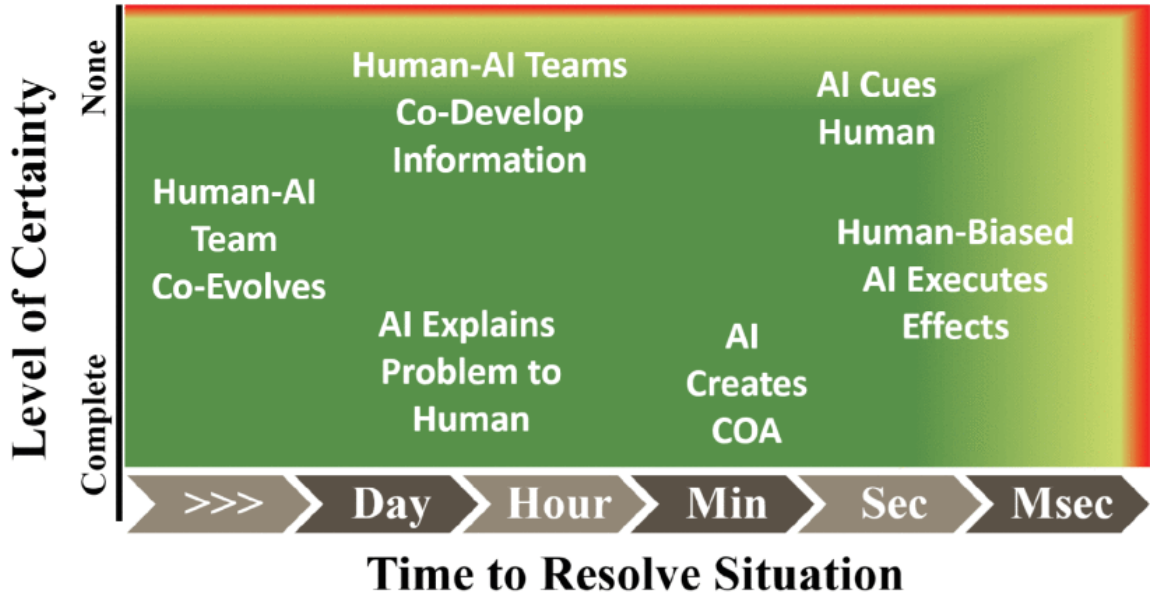
Metcalfe et al, (2021) “Systemic Oversimplification Limits the Potential for Human-AI Partnerships” IEEE Access

Characterizing Human and Machine Intelligence Capabilities for a Complex Realistic Mission



Performance of Humans or Intelligent Technology alone in *Complex* Tasks

Expected Human Agent Teaming Relationships as a Function of Critically of **Time in Mission, Mission Complexity and Information Uncertainty**



Performance of Humans and Intelligent Technology Together in *Complex* Tasks

PARADIGM SHIFT

Systemic Oversimplification Fails in Complex Man-Machine Sociotechnical Systems*

- AI will make humans obsolete
- Human intelligence is unique and irreplaceable by AI

Human Intelligence Effectively Partnered with Machine Intelligence Will Win the Intelligence Race

- Create effective, adaptive, moral human-technology unions that outpace and outlast other forms of technology.

** Metcalfe et al (in press), "Systemic Oversimplification Limits the Potential for Human-AI Partnerships" IEEE Access.*

DEVELOP A NEW PARADIGM FOR HUMAN MACHINE TEAMING

Bridge the gap between Human Sciences and AI development to Focus on Team capabilities

Metcalfe et al, "Systemic Oversimplification Limits the Potential for Human-AI Partnerships" IEEE Access

HACKATHON STRUCTURE

Human-System Adaptation Challenges

Developing Paradigms for future HMT

Paradigm Challenge:

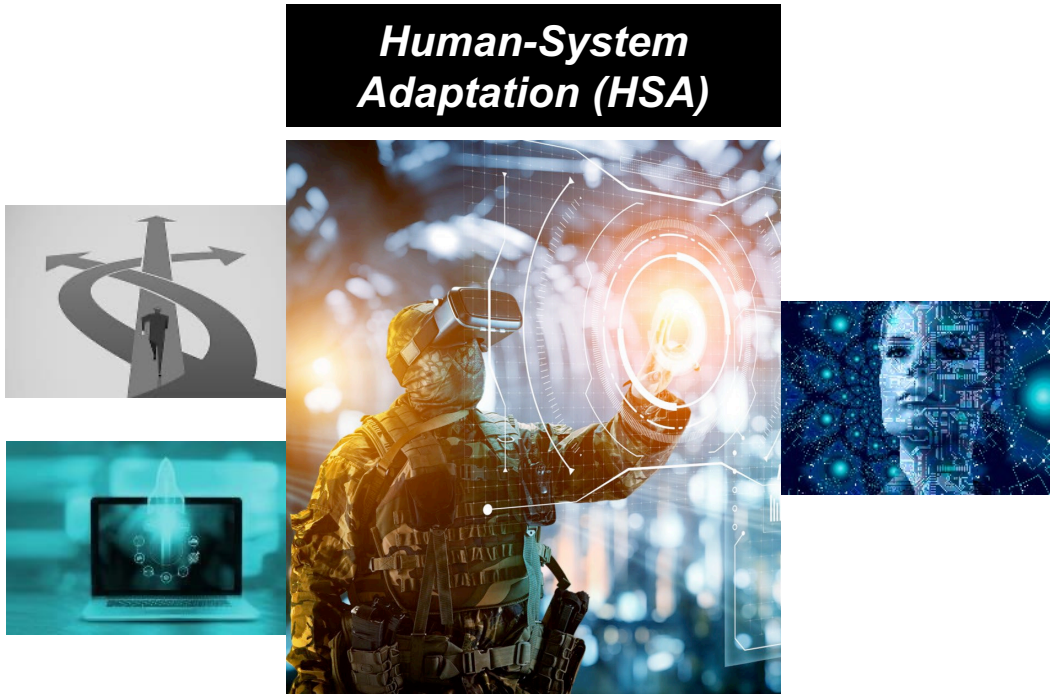
Sociotechnical Challenges of the Future

Experimental Challenge:

Human-System Adaptation Research Thrusts

Hackathon:

Hybrid Team Mega-Tetris



SOCIOTECHNICAL CHALLENGES OF THE FUTURE

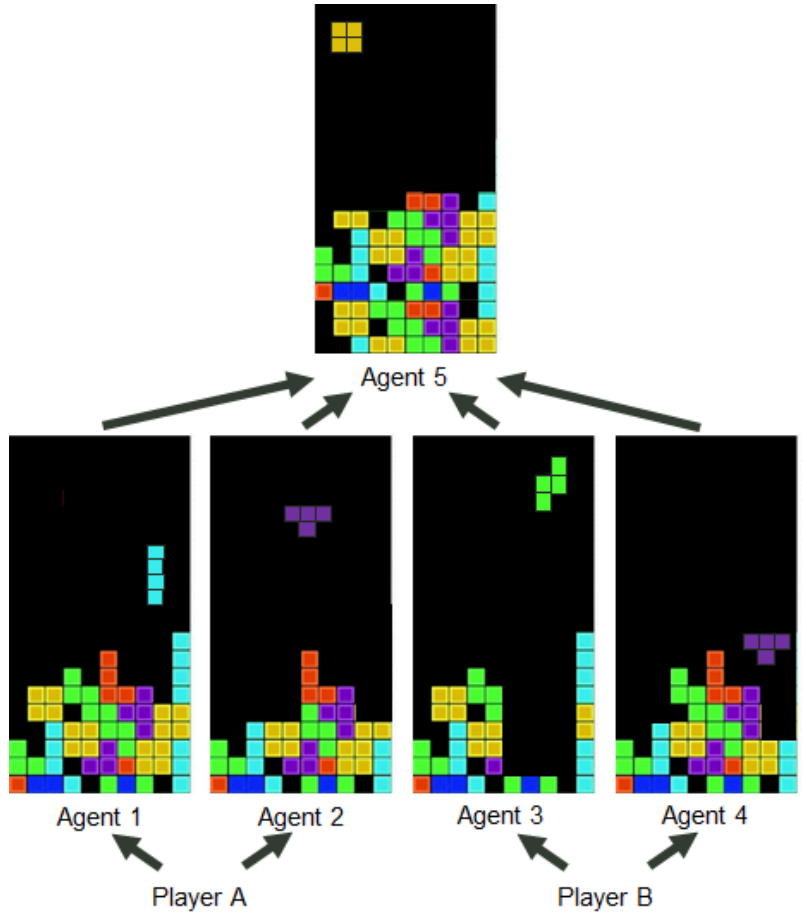
Advanced Intelligence

"Superhuman" Decisions & Actions

Constant Technological Change

Disseminate Versions of Tetris that exhibit 3 challenges with Deep Tamer HGML algorithm to spawn ideation for Hackathon

https://github.com/DCSHGAI/HGAITetris



TETRIS AS AN EXPERIMENTAL PLATFORM

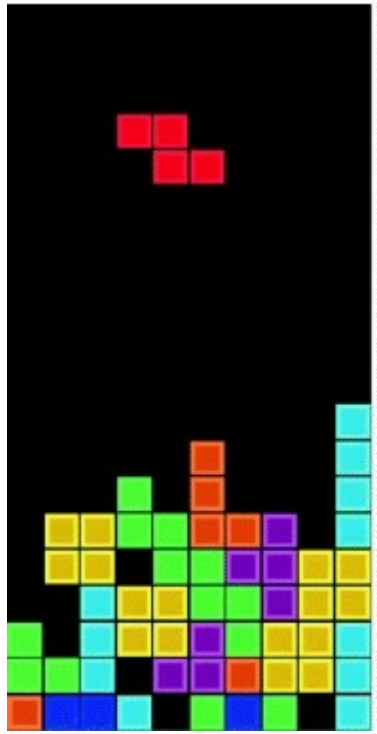
Designed by Soviet mathematician Alexey Pazhitnov in the 1984
One of Best Selling Games of All Time (> 100M copies)

Human-Centric Experimental Use

- Visio-spatial task
  (Haier, Siegel et al, 1992; Sims, Mayer 2002; neural basis - Agren, Hoppe et al 2021)
- Platform to study health, expertise, training
  (PTSD mitigation -Holmes, James et al 2009; Skorka-Brown, Andrade et al 2015; Expertise acquisition - Gray & Banerjee 2021; Cognitive skills training or not – Pilegard & Mayer 2018)
- Published in Science and Nature
  (memory/visual recall - Sickgold, Malia et al 2000; visuomotor control - Green & Bavelier 2003)

AI-Centric Experimental Use

- Challenge for computer algorithms for > 2 decades
  (Burgiel 1997; Demaine, Hohenberger, & Liben-Nowell 2003; Driessens 2001)
- Current Tetris AI Records ~= 100*Human Records
  (StackRabbit – Greg Cannon 2021)



Human-Guided Machine Learning

- TAMER
  (Knox, Stone 2008)
- Multiple forms of Interactive RL
  (Keyboard, facial recognition, gesture RL - Lin, Zhang at al 2020)

Experimental Flexibility

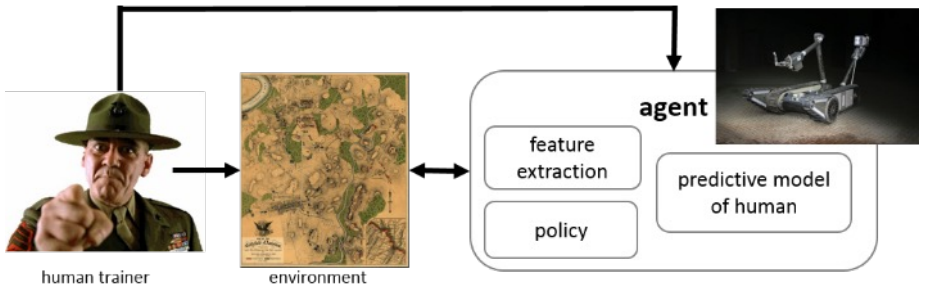
- Configured into an experimental platform for cognitive skills research – Meta-T: Tetris
  (Lindstedt & Gray, 2015)
- Adapted to adjust difficulty
  (Soiel, Bertel & Kayali 2017; 3rd Int. Reinforcement Learning Competition 2009)
- Adaptable to human behavior
  (BCI - Pires, Torres et al 2011; Eye-tracking - Jermann, Nussli & Li 2010)
- Mobile platform (see Facebook applications)
  (Li, Hung, Whiteson, Knox, 2014) (Ki, Whiteson, Knox, Hung, 2017)

DEEP TAMER: INTERACTIVE AGENT SHAPING IN HIGH-DIMENSIONAL STATE SPACES

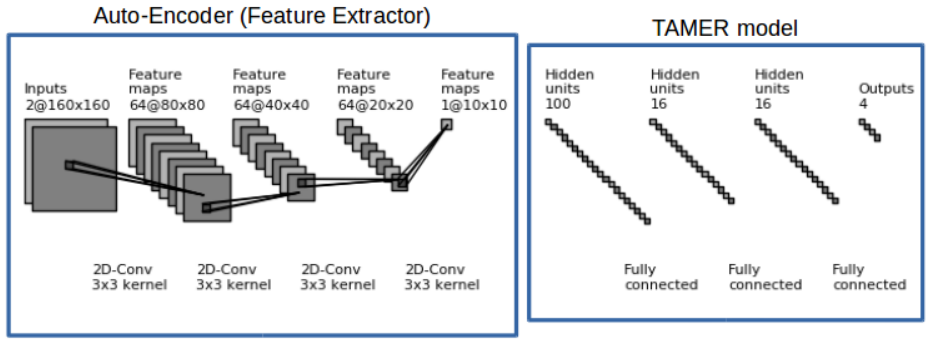
Can we develop human-in-the-loop machine learning (ML) technique that uses binary evaluative feedback to quickly train and adapt ML systems to perform complex tasks in high-dimensional state-spaces?

G. Warnell, ARL; N. Waytowich, ARL; V. Lawhern, ARL; P Stone, UT Austin

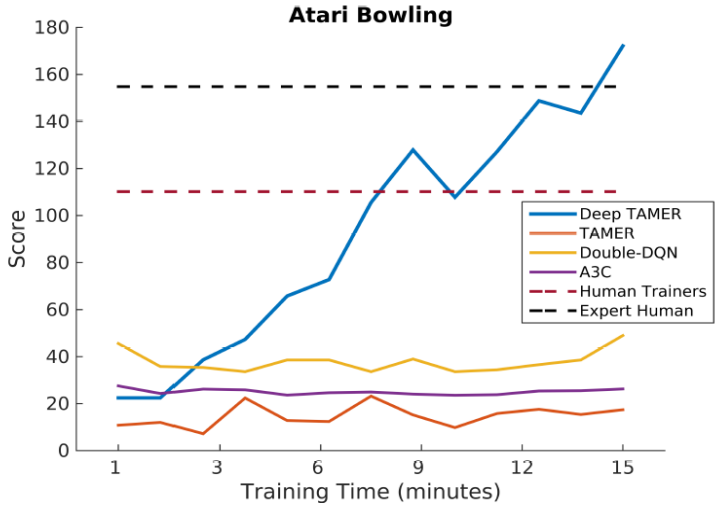
Human-in-the-loop Learning from binary feedback



Deep Learning from High-dimensional state-spaces



Deep Teaching Agents Manually through Evaluative Reinforcement (TAMER) uses human feedback to train models and significantly outperform state-of-the-art



Traditional RL requires Millions of samples

Learning from a human requires significantly less data

Impact: Novel capabilities to dramatically reduce amount of data to train deep-learning based ML systems while also significantly improving model performance. This capability utilizes very simple human interaction to ensure Soldiers in the field can easily train and adapt intelligent systems to meet mission demands

ADVANCED INTELLIGENCE

Advanced Intelligence: Machine intelligence technologies that sense, perceive, reason, and/or learn are expected to continue to become increasingly capable, more pervasive in society, and potentially more “alien” to humans. These technologies will adapt to and learn from a variety of sources including humans, other technologies, as well as the environment. While not as dramatic, human intelligence and its application is also expected to become refined with the continued development of cognitive enhancement technologies, training approaches, and continued exposure to advanced sociotechnical ecosystems.

Sample Challenge: Create future human-technology interactions for human and machine intelligence that does not yet exist.

Related Research Thrusts: Rapid Small Team Adaptation, and Thinking

Ideation/Creativity

Decision Making

Rapid Adaptation

ADVANCED INTELLIGENCE

Advanced Intelligence

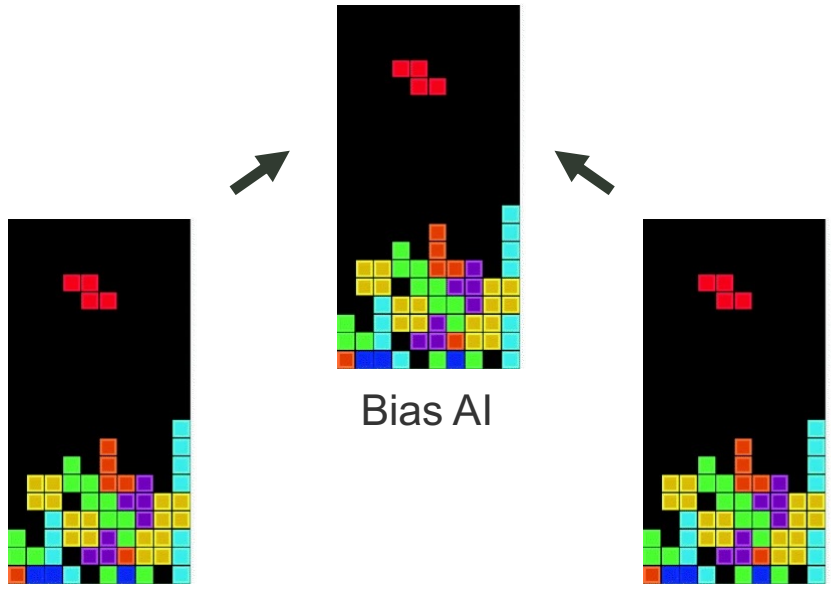
Current Tetris AI Records ~= 100*Human Records --- (StackRabbit – Greg Cannon 2021)

Critical challenge is to find a meaningful interaction between Humans and AI

Tetris Changes:

- "Hidden Rules" that are only initially presented to a single or a sub-set players or agents.
- if the "Hidden Rule" is that anytime a row is cleared with >3 yellow squares, a "favorable" tetrimino is presented as the next piece (see Spiel et al 2017)
- Alternatively, whenever the row with >3 yellow squares is cleared, a "10*bonus score" awarded.

Reconceive Tetris as parallel games with different human and AI control mechanisms



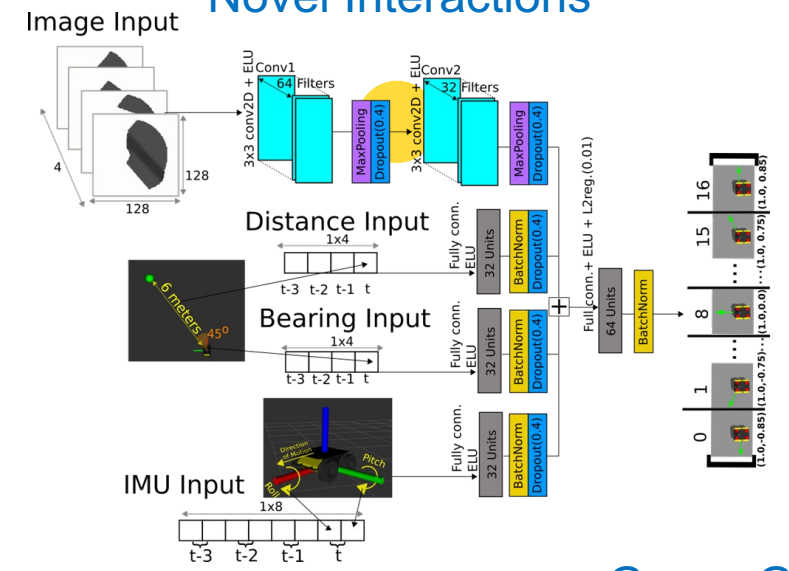
“SUPERHUMAN” CAPABILITIES

“Superhuman” Capabilities: The continued evolution and growth of interconnected sociotechnical ecosystems combined with more capable data processing and interpretation capabilities will continue to create conditions where decisions are made faster and/or on more data than humans can effectively process through traditional means.

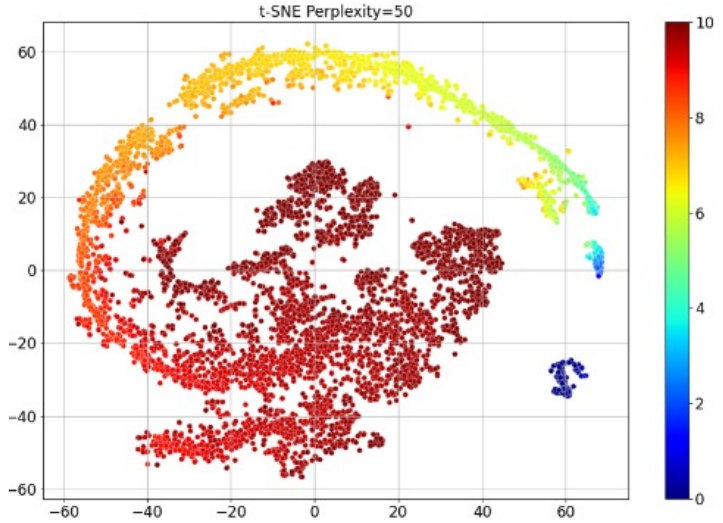
Sample Challenge: Create future human-technology interactions that allow for humans to influence “superhuman” decisions and actions without limiting overall performance.

Related Research Thrusts: Human Guided Machine Adaptation and Distributed Teams

Novel Interactions



Group-Guided Learning



"SUPERHUMAN" DECISIONS & ACTIONS

Tetris difficulty based on outpacing Human Capabilities

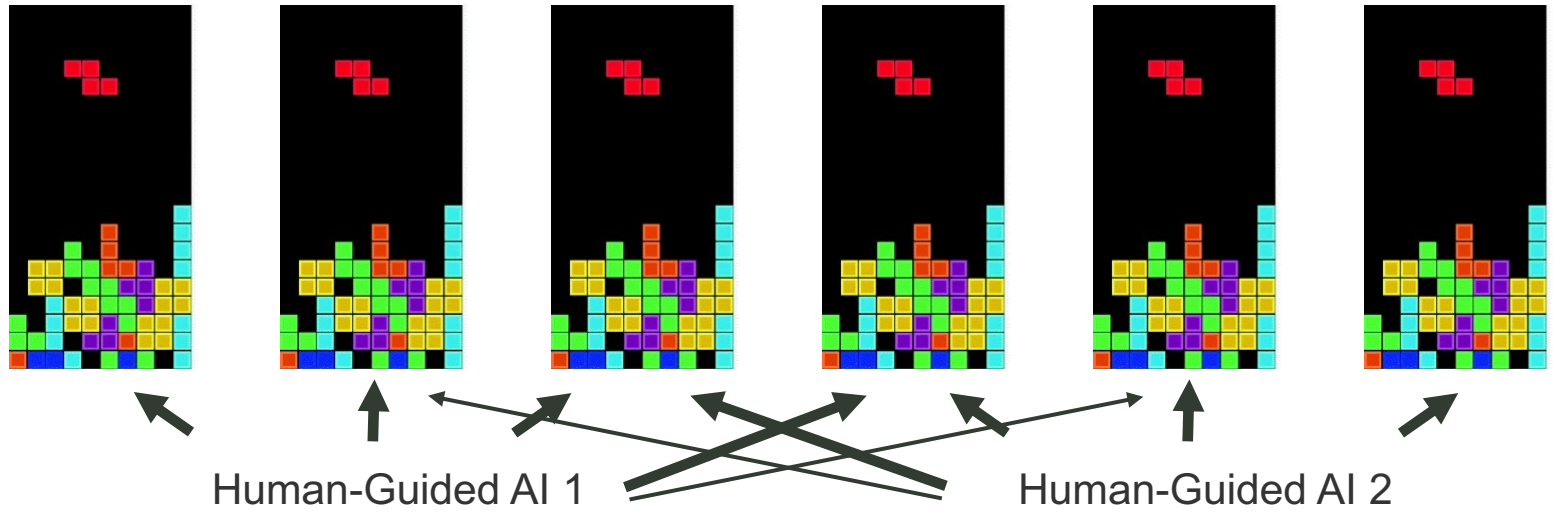
Critical challenge is to create novel interactions and capabilities to allow Humans to influence superhuman game play

"Superhuman" Decisions & Actions

Sample Changes:

- Human-guided AI plays multiple instances of game with increasing speed.
- Enable Crowdsourcing-like Human-Guided AI gameplay (e.g., allow humans to make decisions based on discrete moments in time rather than continuously – while the game(s) play continuously)

Teams of Humans Play Numerous Games Simultaneously



RAPID TECHNOLOGICAL CHANGE

Rapid Technological Change:
Continued decreases in the time from ideation to fielding of new technologies combined with the fact that these technologies have become increasingly pervasive in society has created an environment of constant and rapid technological change.

Sample Challenge: Enable humans and machines to have effective and stable in-field adaptations to predicted and unforeseen changes in the sociotechnical environment.

Related Research Thrusts: TSAVVY, (all to some extent)

Soldier-AI teams ***must*** provide the capability to perform ***any*** mission and adapt to ***any*** situation

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RAPID TECHNOLOGICAL CHANGE

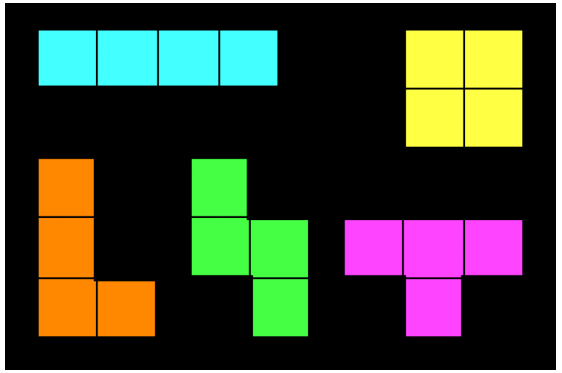
Constant Technological Change

Adversarial Tetris adjusts Tetrominoes dropped based on board configuration
3rd International Reinforcement Learning Competition 2009

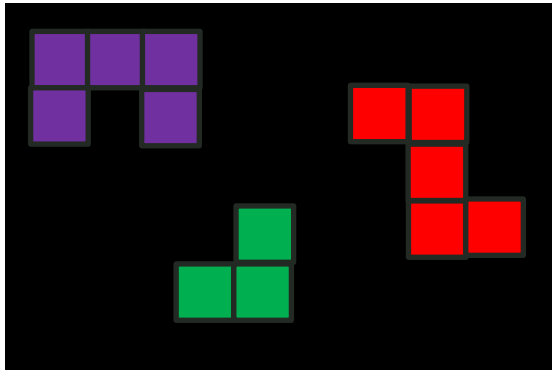
Critical challenge is to introduce changes that substantively change strategy while maintaining effective gameplay

- Introduction of novel Tetrimino pieces at random times, potentially at specific times
- alters the rules awarding points as game time elapses requires adaptation.

Reconceive Tetris Pieces



Original Tetrominoes



Novel Tetrominoes

HSA PARADIGM CHALLENGE

Thurs June 30	Kick-Off that 1) proposes the future problem space, 2) explains the 5 lines of research, 3) shares Hybrid Team Mega-Tetris openly as an initial baseline paradigm, and 4) details the challenge rules
Mon Aug 8	Video Submissions and Closed-Door Judging
Tues Aug 9	Hybrid Video Sharing and Awards Announced

Paradigm Challenge

Challenge is to communicate a human-machine teaming paradigm that inherently incorporates three drivers of HMT within the 2040+ (Advanced Intelligence; Superhuman Decisions and Actions; and Rapid Technological Adaptation)

The paradigm is intended to be a shareable/virtual platforms with usability, cost, access, data sharing, virtual collaboration all critical factors

Paradigm Competition Details

Submission is a 5 min max video with any content

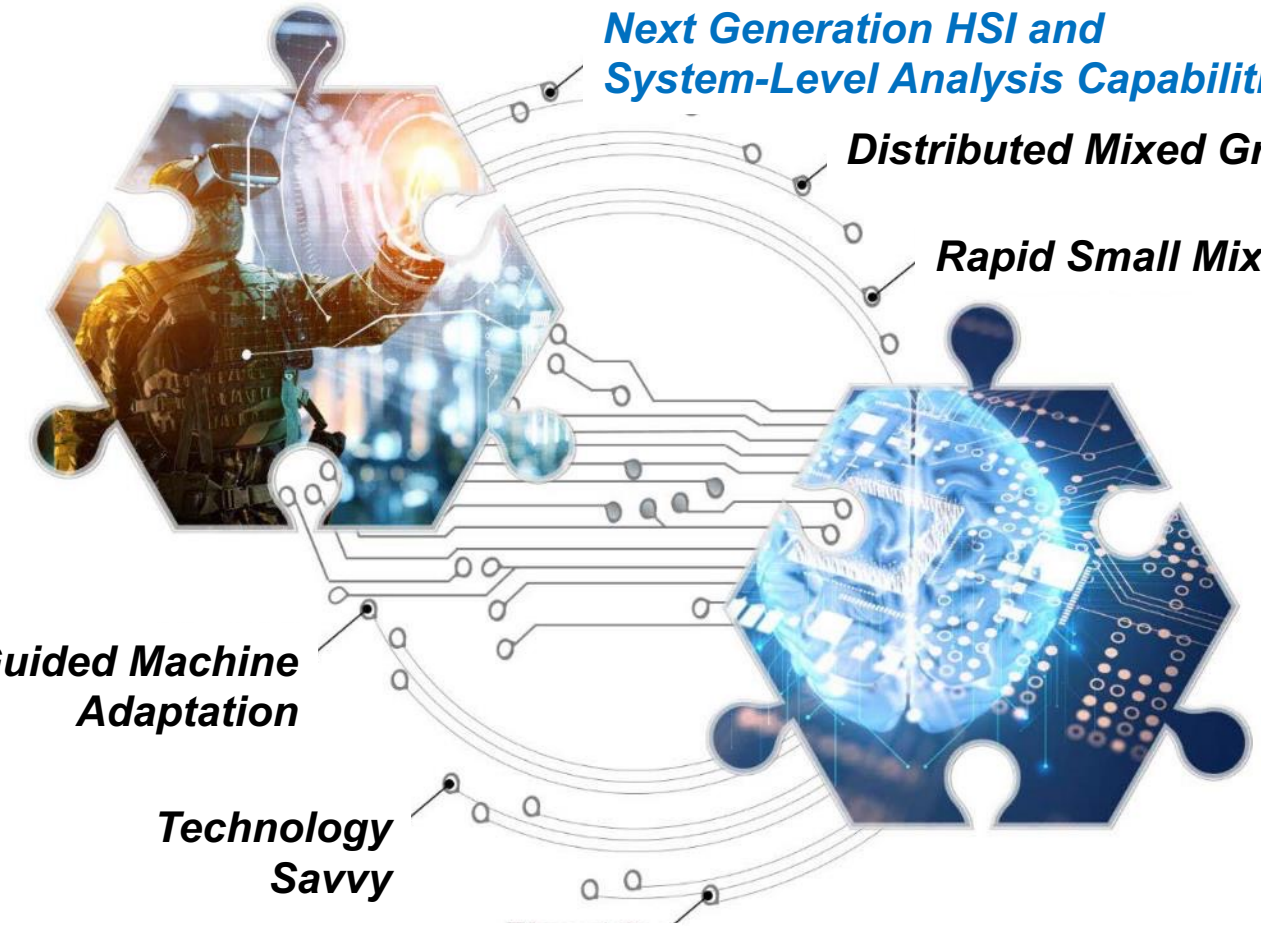
Videos will be judged on 3 factors:

- Potential to Represent Drivers of HMT in the 2040+ time frame
- Potential to Address a Broad Range of Critical Scientific Questions
- Potential for Broad Community Usage

The Hybrid Team Mega-Tetris Baseline can be expanded, or any other paradigm can be proposed

Award for Overall Winner and honorable mentions at the judging panels discretion

CHALLENGE 2: HUMAN-SYSTEM ADAPTATION RESEARCH THRUSTS



Next Generation HSI and System-Level Analysis Capabilities

Distributed Mixed Group-Influenced Adaptation

Rapid Small Mixed Team Adaptation

Human-Guided Machine Adaptation

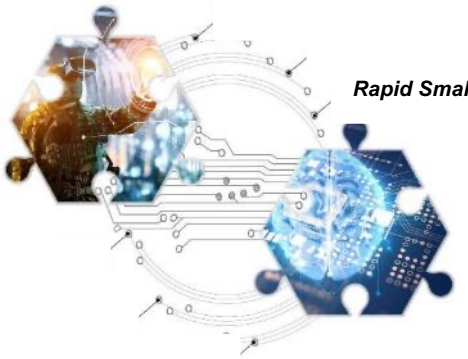
Technology Savvy

Hybrid Human-Machine Thinking

General Concept

Ensure Tetris's "Future" Gaming Environment enables S&T in each area critical to Human-System Adaptation.

RESEARCH THRUST: RAPID SMALL MIXED TEAM ADAPTATIO



Rapid Small Mixed Team Adaptation

Research Outcome:

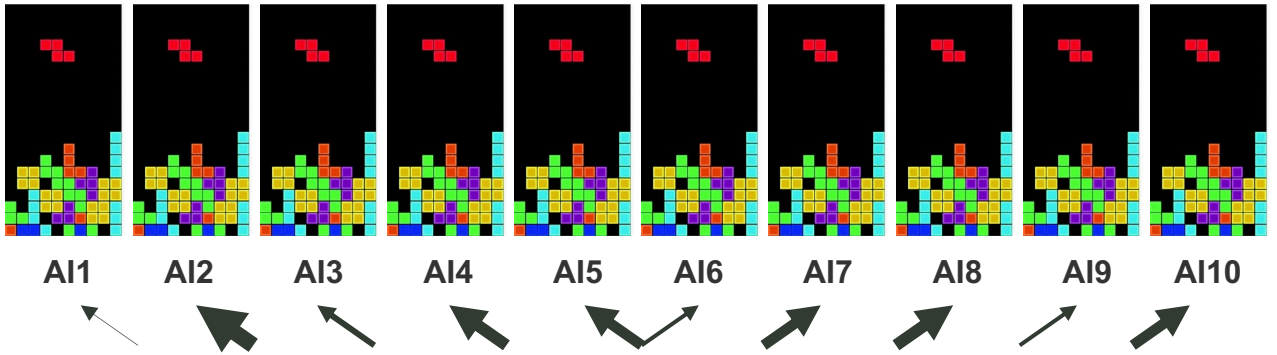
- Small teams with the capability to effectively and cohesively adapt to mission changes and team member replacement at greatly increased speeds compared to current

Challenges:

- Creating effective on-the-fly human-technology task-switching capabilities in response dynamic demands of mission and environments
- Creating flexibility in teams that allows humans to moves away from fixed roles and towards on-demand mission roles
- Rapidly optimizing team-level SA, decision making, and action under conditions of team member replacement
- Rapidly reconfiguring high performing teams to meet the demands of novel mission.

Example Use Case:

- Game set-up includes: 2+ human players with 10 human-guided AIs playing simultaneous games that are challenged intermittently with technological change. Human interacts by way of analyzing discrete screenshots or mini-videos, while being able to communicate with team. Humans and an intelligent system aid in selecting how the humans organize to guide the AI systems.

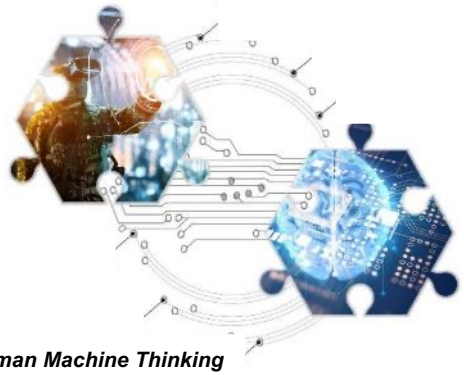


Human Team Dynamically Organizes to Guided AI

Tetris Challenge:

- Team interaction designs to effectively enable/build team cohesion, effectiveness, and SA across complex, dynamic game play

RESEARCH THRUST: HYBRID-HUMAN MACHINE THINKING



Hybrid-Human Machine Thinking

Research Outcome:

- Optimized humans thinking within complex human-machine ecosystems that maximizes human potential to influence decisions believed to be outside of human capabilities.

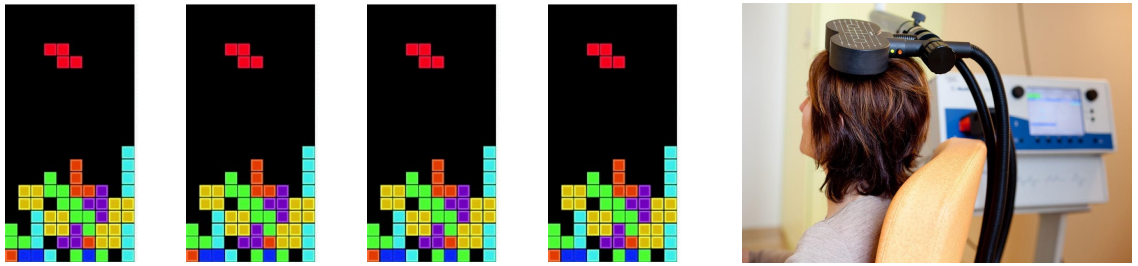
Challenges:

- Bridging neuroscience, computational sciences, psychology, applied math, and bio-engineering.
- Effectively extracting unique capabilities of human teams while integrating “super human” technologies.
- Developing approaches for humans to effectively evaluate complex models of military operations ranging from tactical to strategic.
- Pushing the bounds of human neural processing sufficiently to allow for the dramatic improvements in ideation, making decisions, and rapid adaption.

Example Use Case:

See Difficulty adjustments (Soiel, Bertel & Kayali 2017; 3rd Int. Reinforcement Learning Competition 2009); Tetris AI records ~= 100*human records (StackRabbit – Greg Cannon 2021)

- Game set-up includes: 1 human player with 10 human-guided AIs playing simultaneous games that are challenged intermittently with technological change. Human interacts by way of analyzing discrete screenshots or mini-videos, while being “hyperfocused” via neurostim. Screenshots are auto-selected to feed low performing AIs. AIs run continually and human-guidance is incorporated as it becomes available. Comparisons are between performance of this hybrid system, human-only, and AI without human-guidance.



Tetris Challenge:

- Interaction designs to effectively convey game SA and technological change across complex, dynamic game play

RESEARCH THRUST: HUMAN-GUIDED MACHINE ADAPTATION

Human-Guided Machine Adaptation

Research Outcome:

- Deployable form of machine intelligence that adapts to and with human intent.

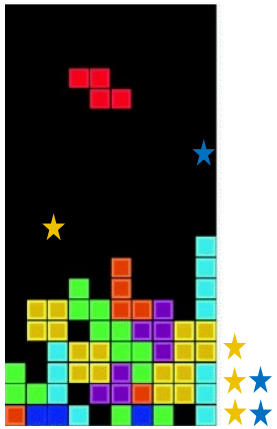
Challenges:

- Effectively extracting and integrating human capabilities including: leadership, common sense, emotional intelligence, situational understanding
- Developing mixed approaches that optimally leverage expertise from a wide variety of operators with different skills and capabilities
- Enabling humans to comprehend “exotic” forms of machine intelligence sufficiently to reliably predict outcomes.
- Developing the appropriate capabilities to validate and verify technology learning and adaptation in the field.

Example Use Cases:

See Keyboard-driven TAMER (Knox, Stone 2008);
Facial recognition-driven interactive RL & Gesture recognition-driven gesture RL (Lin, Zhang at al 2020)

- Game introduces a “star” on screen. Human player recognizes a tetromino that falls through the star “captures it” and that it can be activated to slow down the game. Human player uses one of many available tools to “teach” system to capture and deploy stars.



Tetris Challenge:

- Contribution of human intelligence: leadership, common sense, emotional intelligence, situational understanding

RESEARCH THRUST: DISTRIBUTED GROUP-INFLUENCED ADAPTATION

Distributed Mixed Group-Influenced Adaptation

Research Outcome:

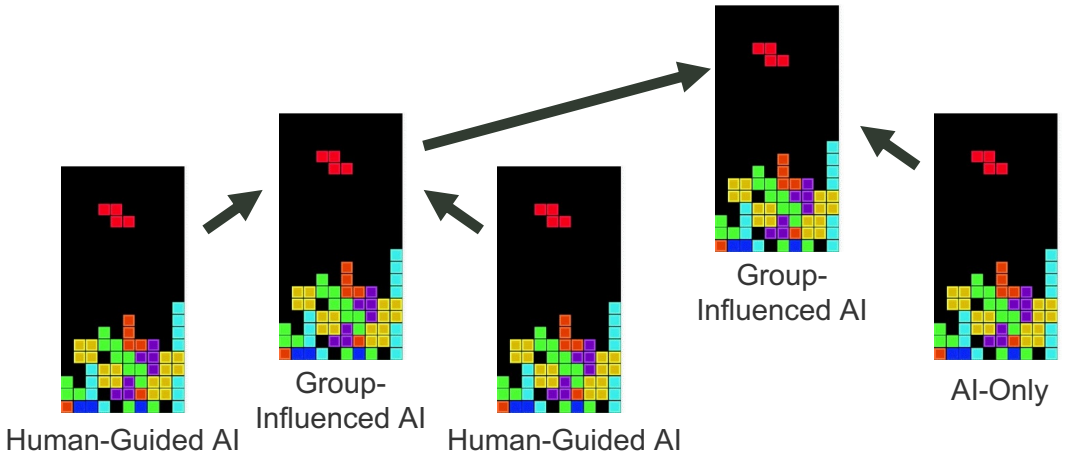
- Distributed deployable form of machine intelligence that adapts to multiple, distributed humans.

Challenges:

- Effectively extracting human inputs across different human roles, intents and missions
- Developing mixed approaches that account for or leveraged cross role/intent/mission inputs to create effective, robust behaviors
- Enabling humans to understand machine behaviors that are guided from different role/intent/mission
- Enabling humans to understand and effect “indirect” influence

Example Use Case:

- Game set-up includes: 2+ human players with multiple AIs playing simultaneous games that are challenged intermittently with technological change. Human can only interact with a subset of Ais. Other Ais are influenced by the human-guided AI or by non-human-guided AI. Game intent is maximize scores of AI not directly guided by humans.



Tetris Challenge:

- Effectively merge inputs from multiple games being executed in parallel.

RESEARCH THRUST: TECHNOLOGY SAVVY

Technology Savvy

Research Outcome:

- Capabilities to track and improve human knowledge, skills, and behaviors (KSBs) needed for future human-AI partnerships and dynamically optimize their deployment across teams

Challenges:

- Predicting the individual and team KSBs needed in for future human-AI partnerships and the natural adaptation of population KSBs over time
- Individual differences in KSB improvement (training, aids) and degradation (stressors)
- Developing optimal approaches to deploy limited and specialized personnel within teams to match evolving task demands
- Developing the capabilities to create critical elements of future partnerships with today's technology for human experimentation

Example Use Case:

See Configured into cognitive skills research platform – Meta-T: Tetris (Lindstedt & Gray, 2015); Integrated eye-tracking (Jermann, Nussli & Li 2010); Mobile platform (Li, Hung, Whiteson, Knox, 2014) (Ki, Whiteson, Knox, Hung, 2017)

- Game is distributed on a mobile platform and played by 1000s of gamers. Game metrics used to discover "future" gaming environment modifications (with an emphasis on technological change) associated with broad player variance. Platform tailored to optimize the study of KSBs underlying "future" game performance.

Tetris Challenge:

- Expanding human cognition required to complete task beyond visuospatial processing

HSA EXPERIMENTATION CHALLENGE

Thurs June 30	Kick-Off that 1) proposes the future problem space, 2) explains the 6 lines of research, 3) shares Hybrid Team Mega-Tetris openly as an initial baseline paradigm, and 4) details the challenge rules
Mon Aug 1	Deadline for Registering
Tues Aug 9	*In-Person Science-Fair Style Judging of Submissions*
Wed Aug 10	***Top Talks give presentations***

Experimentation Challenge

Challenge is to communicate a human-machine teaming sequence of experiments (3 to 5) using a single experimental platform that addresses ***a*** critical scientific question in one or more of the 5 current research thrust areas (HGML, Tech Savvy, Hybrid Thinking, Rapid Adaptable Small Teams, Distributed Teams)

The experimental set-up (team interactions) should be demonstrated potentially with judge participation

The experimental paradigm is intended to be a shareable/virtual platforms with usability, cost, access, data sharing, virtual collaboration all critical factors

Experimentation Competition Details

Submission is an in person 15 min max science-fair style presentation/demonstration max – potentially with multiple presentation to different groups of judges

Presentations/Demonstrations will be judged on 3 factors:

- Criticality of the Scientific Question
- Potential for the Experimental Sequence to Answer the Scientific Question
- Potential for Broad Community Usage

The Hybrid Team Mega-Tetris baseline or any other paradigm can be developed into an experimental set-up

Award for Overall Winner and honorable mentions at panels discretion

HSA HACK-A-THON

Wed Aug 10	*Kick-Off that details the hack-a-thon rules*
Fri Aug 12	Submission deadline/Hack-a-thon live competition

Hybrid Team Mega-Tetris Challenge

- Challenge is to win a “Hybrid Team Mega-Tetris” tournament by forming the best team of human and AI Mega-Tetris players
- The game will be played live on the final day of the competition with up to 3 human players
- The intention is to provide a challenge that needs both human and AI to work together successfully. A base version of the game will be sufficient for the competitors to use the following strategies to potentially win:
  - Improving AI Play
  - Improving Human-AI interactions
  - Improving Human Play

Hackathon Competition Details

Hybrid Team Mega-Tetris will be used for the competition
- Options for Overall High Score or Knock-out-Bracket

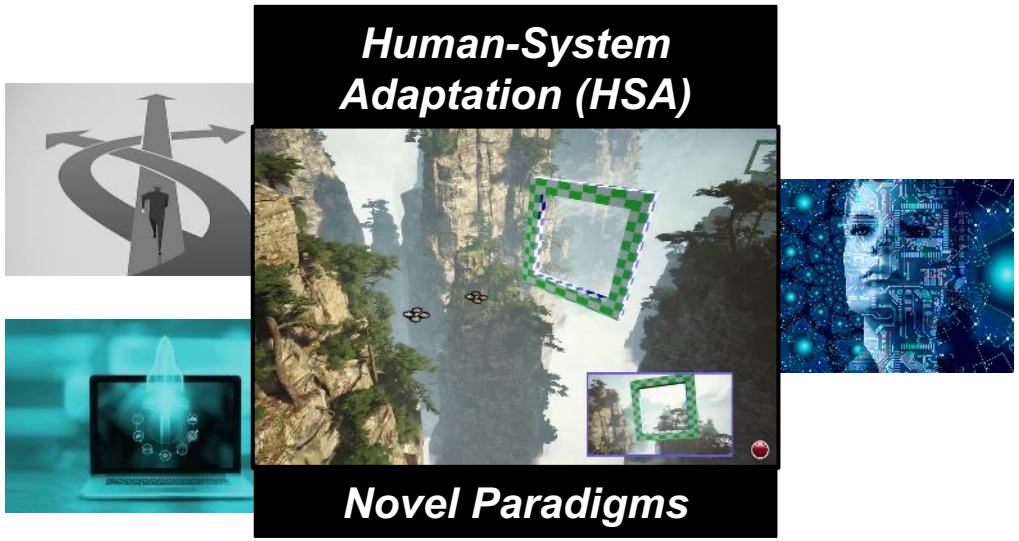
The game can be played with provided Software.
- The version of the game played with include elements of teaming, advanced intelligence, superhuman requirements, and will adapt during game play
- The specific details and adaptations of the final game will not be known by the competitors until the tournament starts.
- Portions of the game will be locked – but the competitors will have access to the AI governing “moves” and access to select “open” game states that are determined by the competition

Award for Overall Winner and honorable mentions at panels discretion

HUMAN-SYSTEM ADAPTATION (HSA) PARADIGM WEEK

Dates Are Notional

June 30	9am – 11am	<u>HSA Paradigm Challenge Kick-Off</u> <u>HSA Experimentation Challenge Kick-Off</u>
Aug 1	5pm	<u>Deadline for Registering for In-Person Participation including Experimental Challenge and Hack-a-thon</u>
Aug 8	12pm	<u>HSA Paradigm Submissions Due</u>
	12 pm– 1pm	**Paradigm Week Kick-Off**
	1pm – 2pm	**Open Discussions**
	2pm – 5pm	**HSA Paradigm Judging**
Aug 9	9am – 12pm	HSA Experimentation Ideation and Setup
	12pm – 1pm	<u>HSA Top Paradigm Submissions Video discussion</u>
	1pm – 5pm	*HSA Experimentation Judging (Science Fair)*
Aug 10	10am – 11am	**HSA Top Experimentation Talks**
	11am – 12pm	*HSA Hack-a-thon Kick-Off*
Aug 11	12pm – 1pm	**HSA Paradigm Speakers**
	1pm – 2pm	**Open Discussions**
Aug 12	12pm – ?	*HSA Hack-a-thon Judging*



<u>Underlined = Virtual Participation</u>
BOLD = Hybrid Participation
ITALICS = In-Person Participation