Agile Teams (A-Teams)

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Proposers Day

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A-Teams: Design abstractions for agile human-machine (hybrid) teams

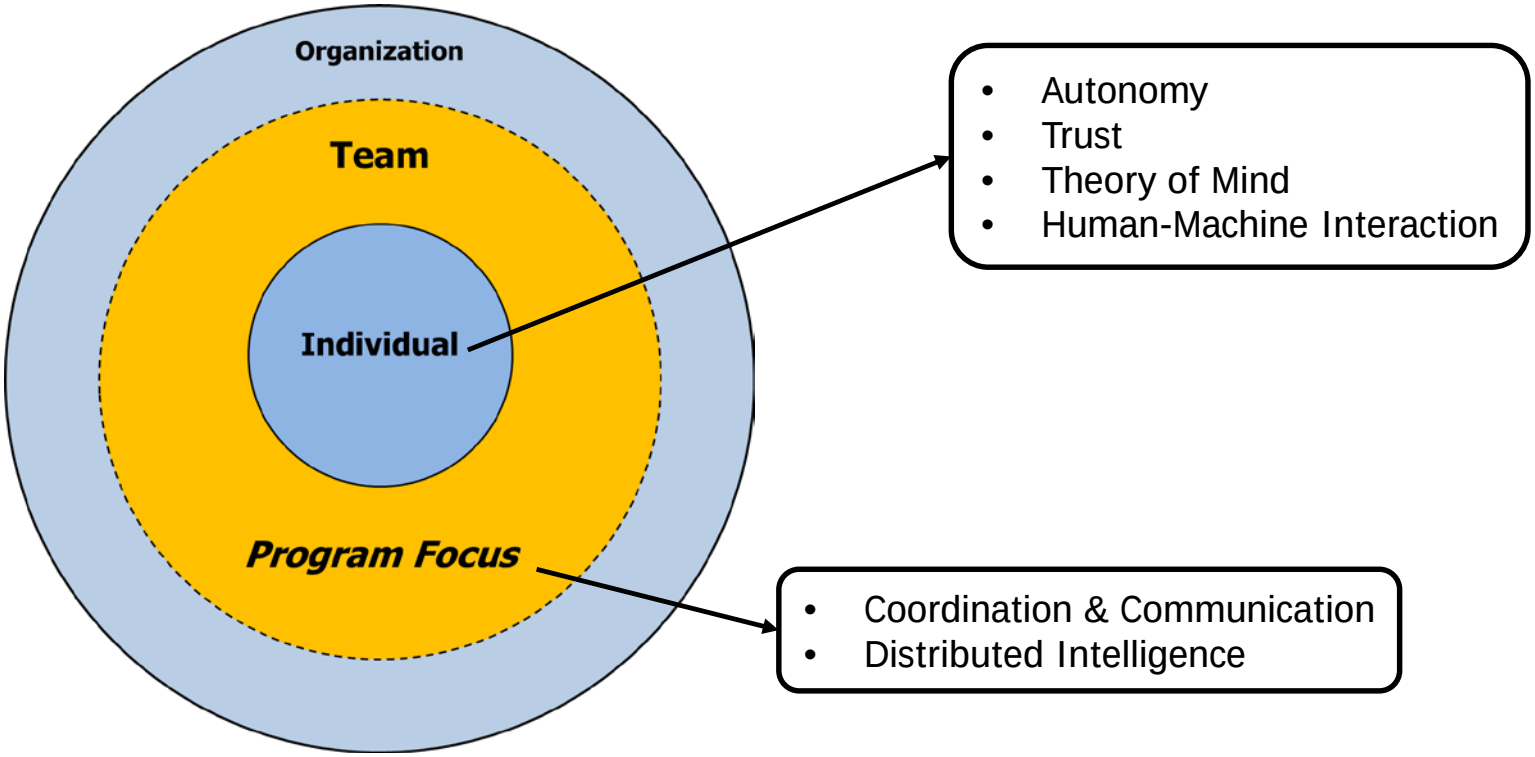
Program Goal:

Discover and test predictive and generalizable mathematical methods for the design of agile teams of humans and intelligent machines (hybrid teams)

Program Outcomes:

1) **Mathematical methods enabling a general purpose design tool for dynamically co-evolving hybrid team structure and problem solving processes**
2) **Experimental capabilities to reproducibly and quantitatively evaluate team architectures in a diverse range of problem contexts**

Machine intelligence and team capability



- **Team Structure:** Given a dynamically changing problem, how should a team of humans and machines be structured? Who should have what role or roles, when and why?
- **Team Problem Solving:** Given an uncertain environment and fluid team structure, how to best use combined human and machine cognitive capability to make decisions?

Hybrid team design is relevant to a diverse set of collective activities

Activity	Team members	Machine elements	
		Today	Tomorrow
Develop complex software	Programmers	Code correction	• Architecture optimizer • System resource emulator
Deliver goods to users through complex network	Logisticians	Scheduling tools	• Plan formulation and diagnosis aids • UxV delivery
Discover new drugs	Chemists Biologists Pharmacologists	High throughput testing	• Automated compound synthesis
Design a space probe	Project leader Subsystem engineers	• Design tools • Modeling and simulation tools	• Automated design • Decision and interaction facilitator
Control and manage an air battle	Planners Pilots	• Decision aids • UAVs	• Automatic Plan formulation • UAV swarm
Conduct infantry operations in a megacity	Squad leader Riflemen	Communications (radios, phones)	• UAV/UGV • Autonomous EW operations

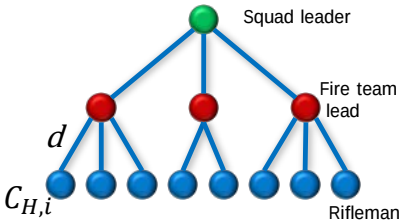
How can we design teams augmented with intelligent machines in a principled way?

Mathematics for team and problem solving design

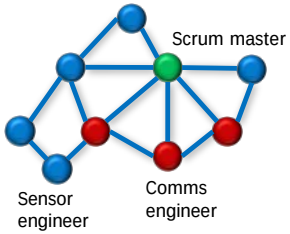
Edge lengths *d* represent compatibility for working together to complete a task or goal

Each human or machine agent node has a *probability distribution* of task capability, $C_{H,i}$ or $C_{M,i}$

Military squad: Hierarchy



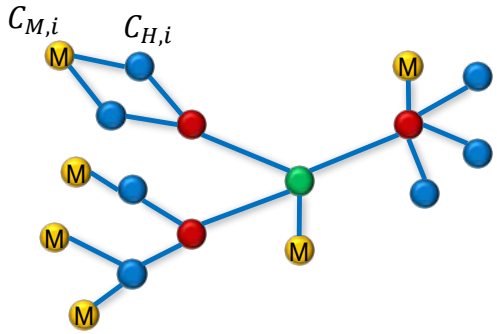
Software: Agile Scrum



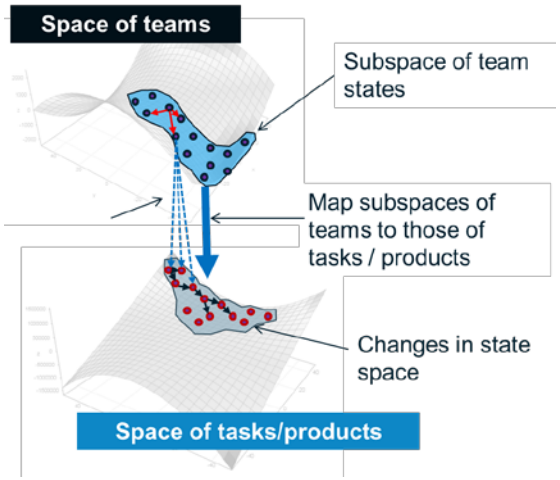
- Team "synergy" is the average of each pair's capability scaled by compatibility
- Graph optimization algorithms can identify team structures for optimal task performance

What about the machines?

Hierarchy with machine agents included



Insight: Machines are not just agents – but a fabric to change overall team and problem states



Are there generalizable mathematical abstractions to capture the dynamic co-evolution of problem space, team structure and performance?

Liemhetcharat & Veloso, "Weighted Synergy Graphs for Effective Team Formation with Heterogeneous Ad Hoc Agents", 2005

Technical Areas

TA1: Dynamic Team Design

- Mathematics
- Organizational theory
- Operations research

TA2: Team Problem Solving

- Planning/scheduling
- Cognitive science
- Human factors

TA3: Experimental Testbeds

- Citizen science
- Autonomy

Theory/Model Building

Minimal models
- Balance rigor with practicality

Moderate team size
- 5-50 human/machine agents

Clear path to TA1/TA2 integration
- No coupling until later stages of program

Testing

Data on team behavior
- Provide high quality data for theory teams

Validation
- Test predictions from TA1 & TA2 teams

Program structure

	Discover	Integrate	Test
TA1: Dynamic Team Design	• What is the best team structure in context for dynamically evolving and interrelated tasks?	• Are there practical encodings of the dynamic co-evolution of problem space, team structure & performance?	
TA2: Team Problem Solving	• How to make optimal joint decisions in uncertain and co-evolving contexts?	• How can you change the team when the problems change?	• How generalizable are the methods? • Can they predict average performance *a priori*?
TA3: Experimental Testbeds	• How does team structure affect outcome? • What about decision making approach?	• What is the impact of intelligent machines in various roles? • How correlated are team structure and problem solving approaches?	
Outcome	Model that predicts and explains performance of top teams	Coupled models that predict structure and behavior for a best performing team	Demonstration that the coupled models are effective in multiple types of team problems

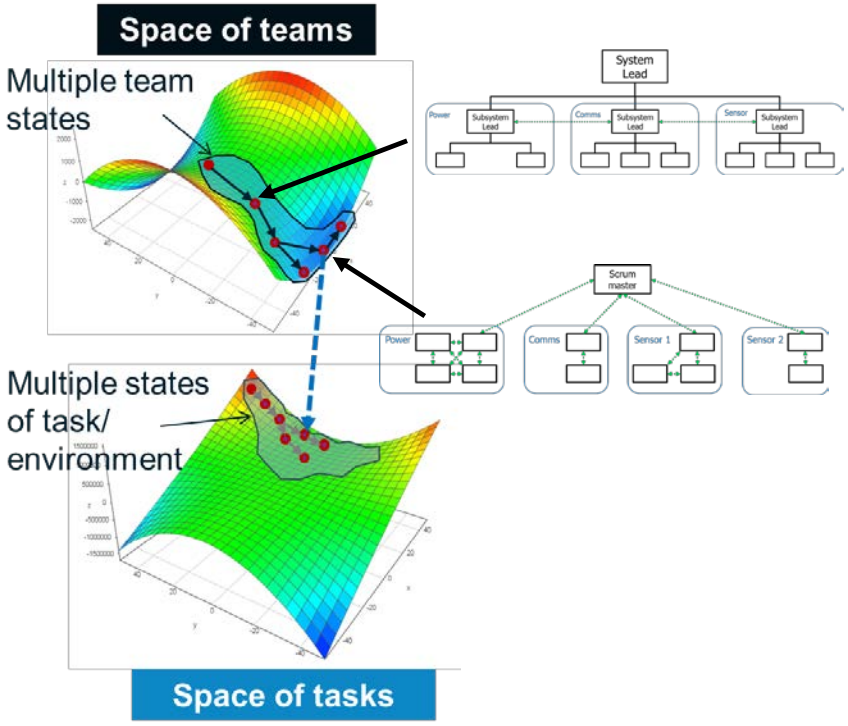
TA1: Dynamic Team Design

Goal: Machine-based “intelligent fabric” that will co-evolve team structure in context with problems

- Abstractions, algorithms, “programming languages,” and architectures
- Must be practical, predictive, generalizable and computable

Must address:

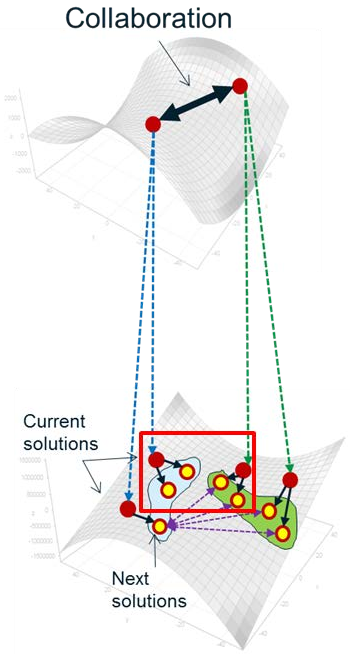
- Decidability and computational complexity
- Encoding of variability in environment, goals, tasks, team interactions, roles, individual characteristics
- How to determine best team structure in dynamic context: what are roles and how will that change
- Coupling to TA2: Team Problem Solving and simultaneous team structure/problem solving evolution



TA2: Team problem solving

Goal: Machine-based “intelligent fabric” that will dynamically mitigate gaps in ability, improve team decision making, and accelerate realization of collective goals

- Abstractions, algorithms, “programming languages,” and architectures
- Must be practical, predictive, generalizable and computable: “minimal models” for human problem solving



Must address:

- Decidability and computational complexity
- Approaches to make optimal joint decisions in uncertain and co-evolving contexts with variable human and machine capabilities
  - Abstractions encoding joint and individual reasoning, decision making
- Communication intensity, information content, latent/intermittent communications, and effect on strategy
- Individual agent and team learning, memory, and sensing
- Coupling to TA1: Dynamic Team Structure and simultaneous team structure/problem solving evolution

TA3: Experimental Testbeds

Goal:
Scalable experimental testbeds to exercise and validate TA1 and TA2 formalisms

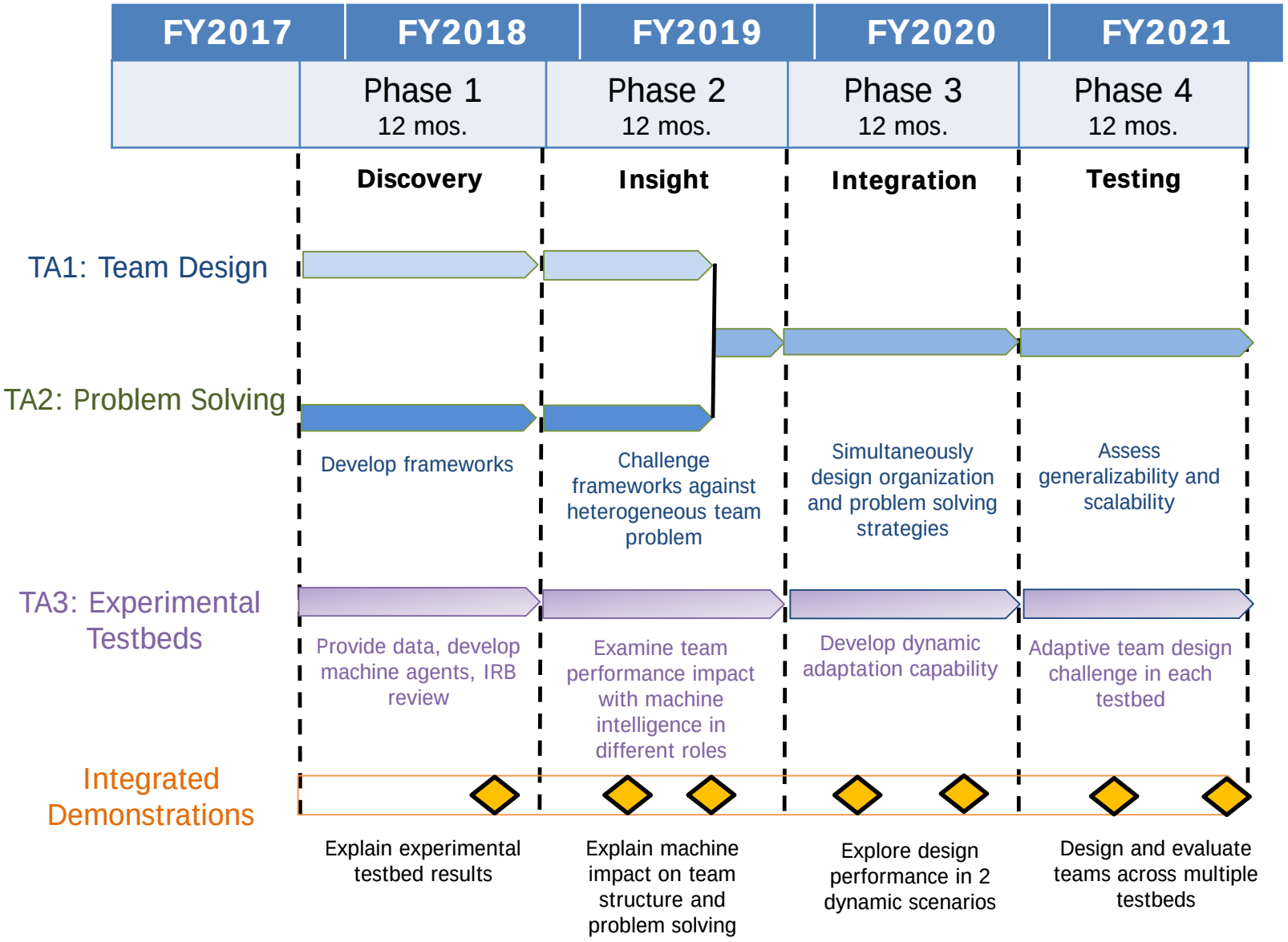
Must have:

- Multiple, selectable intelligent machine elements
  - Ideally embodied in interaction substrate
- Ability to quantitatively measure team progress towards collective goals
- Ability to incorporate qualitative changes that test team adaptability
- Clear strategy for replicability and control experiments
- Clear strategy for TA1 and TA2 integration
- See BAA for other desired features

Other TA3 specific guidance

- *Strongly recommend* local IRB approval prior to proposal submission, including consent for sharing data with third parties
- Must have clear data management plan, as specified in BAA
- If you have data available to share with TA1 and TA2 teams at start of effort, identify the data and measurements/characteristics relevant to TA1 and TA2

Timeline and milestones



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