# Distributed and Collaborative Intelligent Systems and Technology (DCIST)

## Collaborative Research Alliance (CRA)

U.S. ARMY RDECOM®

# Distributed and Collaborative Intelligent Systems and Technology (DCIST)

ARL

## Vision:

Develop the underpinning science to extend the reach, situational awareness, and operational effectiveness of Intelligent System/Soldier teams against dynamic threats in complex and contested environments and provide technical and operational superiority through fast, intelligent, resilient, and collaborative behaviors.

## Research Areas:

- Distributed Intelligence
- Heterogeneous Group Control
- Adaptive and Resilient Behaviors
- Cross Disciplinary Experimentation

## Payoff:

- Speed of battle decision making, operation, and adaptation for highly distributed and collaborative heterogeneous teams of intelligent systems and Soldiers in complex and contested environments.
- Augmented capability of the collective team well beyond that of any one component.

# DCIST Research Architecture

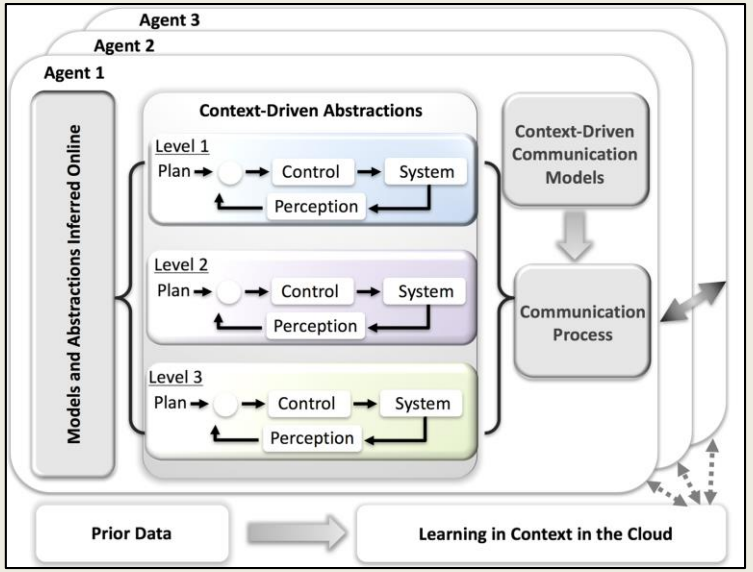
## RA1 - Distributed Intelligence
- Hierarchical and composable models and abstractions
- Collaborative inference and decision making
- Distributed perception action communication loops

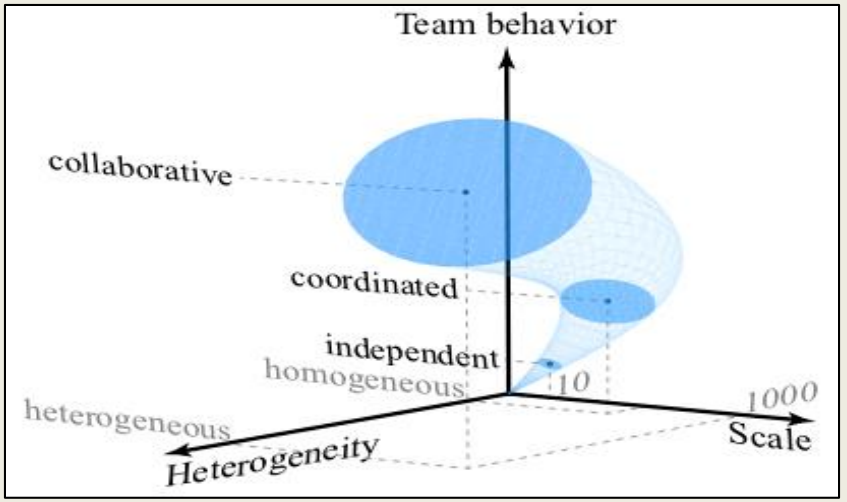
## RA2 - Heterogeneous Group Control
- Contextual Abstractions for Heterogeneous Groups
- Synthesis of group behaviors and interactions
- Algorithms for Control of Heterogeneous Groups

## RA3 - Adaptive and Resilient Behaviors
- Robust perception action and learning
- Information and adaptation for resilience
- Macro scale resiliency

## CDE - Cross-Disciplinary Experimentation
- Open testbeds and common software interfaces
- Simulation and testbed-based experiments
- Explore and discover interdependencies across research areas.

## Cross Cutting Themes:
- Learning and Autonomous Networking

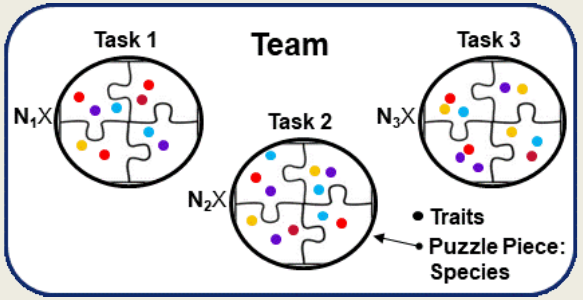


# Some Expected Outcomes

## New Theories for Composable Autonomy in Heterogeneous Groups

- Develop abstractions of species by decomposing them into a collection of re-composable traits.
- Develop abstractions of composable human traits, which accommodate general and evolving individualized profiles




## New Approaches for Mission Planning with Large Scale Heterogeneous Teams

- Dynamic methods of mapping high-level mission requirements to abstractions (traits) used to synthesize action plans & task requirements for distributed agents

## Human-Agent Collaborative Control of the Swarm

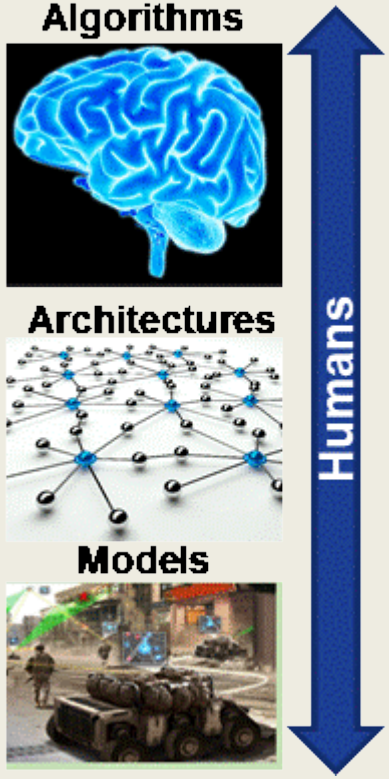
- Interaction architecture that makes large scale swarms amenable to human control in dynamic, stochastic, and partially observable environments.

## Heterogeneous Hierarchical Autonomous Networks

- Develop the tactical cloud thru the exploitation of heterogeneous communications strategies & computing capabilities

## Large Scale Multi-Level Optimization and Fast Response to Changing Mission Requirements

- Enable multiple users influence of swarm organization.



# Some Expected Outcomes

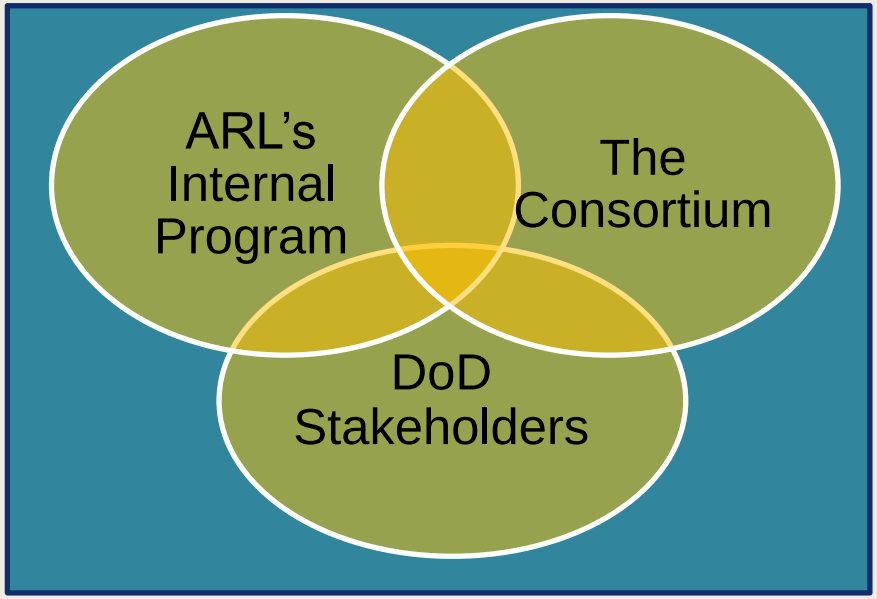
- **Dynamic online learning** that responds to rapid changes in the environment and is resilient to unexpected and adversarial information
- **Adaptive agent-based behaviors** that reason over rich representations of uncertainty to trade off performance and risk
- Techniques to ensure **macro-scale resilience** as a function of mobility, swarm size, heterogeneity, sensing, and communication.

## Impact

Distributed systems that are able to **engage in complex, time-varying, and contested environments** to accomplish Army missions by leveraging a mix of online adaptation and system-wide resilience.

# The Alliance

- Collaboration between Consortium and Government researchers is integral to the execution and success of the CRA.
- The Consortium, ARL, and external stakeholders together form the Collaborative Research Alliance.
- ARL will fund in-house staff and align in-house research to foster highly collaborative partnerships between Consortium and Government researchers.




**Expectations:**

- Sharing of Data
- Staff Rotations
- Joint Experimentation
- Joint Publications

**The Alliance**

# DCIST CRA: The Consortia

**LRO: University of Pennsylvania**

**LRAO RA1 – MIT**
**LRAO RA2 – Georgia Tech**
**LRAO RA3 – UPenn**

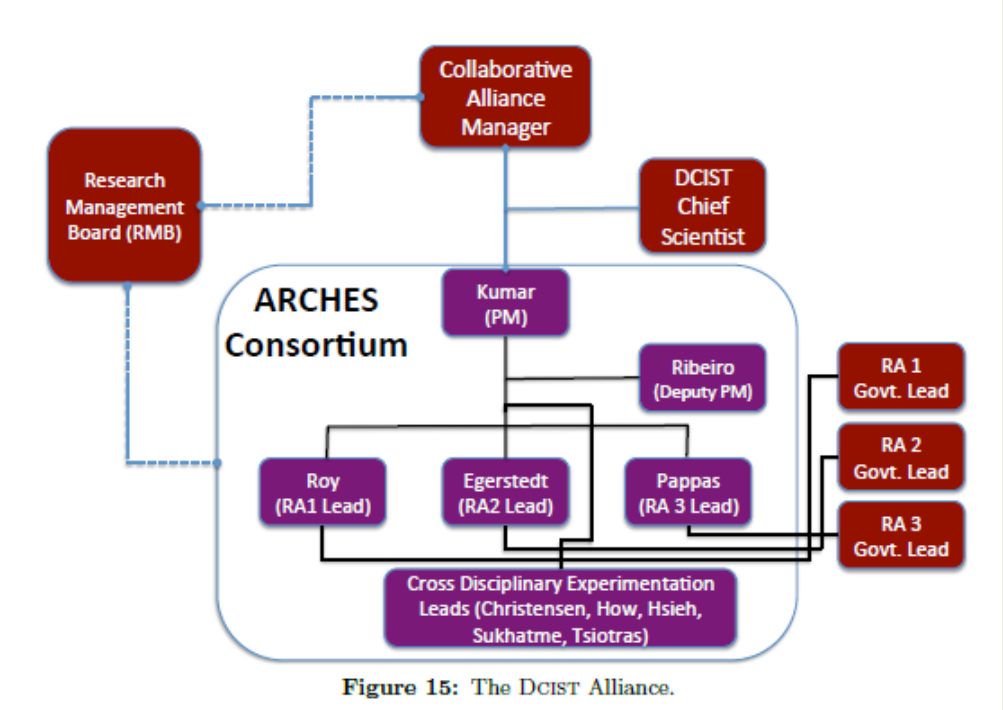



**Figure 15:** The DCIST Alliance.

## 6 Institutions – 20 Researchers

**UPenn:** Drs. Bassett, Daniilidis, Kumar, Pappas, Ribeiro, and Hsieh

**MIT:** Drs. Roy, Carlone, How, Shah, and Karaman

**Georgia Tech:** Drs. Chernova, Egerstedt, Romberg, and Tsiotras

**USC:** Drs. Ayanian and Sukhatme

**UCB:** Dr. Levine

**UCSD:** Drs. Christensen and Atanasov

## Status

- Initial Program Plan in preparation
- 6.1 Basic Research Funding
- 5 years, renewable for 5 years

**Consortia + ARL + DoD Stakeholders = The Alliance**

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# Technical Management Group (TMG) ARL

| | ARL Leadership | Consortium Leadership |
|---|---|---|
| | Brett Piekarski<br>(410) 278-9158<br>brett.h.piekarski.civ@mail.mil | Vijay Kumar (UPenn)<br>(215) 898-3630<br>kumar@seas.upenn.edu |
| | Brian Sadler<br>(301) 394-1239<br>brian.m.sadler6.civ@mail.mil | Alejandro Ribeiro (UPenn)<br>(612) 889 9217<br>aribeiro@seas.upenn.edu |
| | Allison Mathis<br>(301) 394-5518<br>allison.m.mathis2.civ@mail.mil | Caitlin Coad (UPenn)<br>(215) 898-2729<br>ccoad@seas.upenn.edu |
| | | |
| **RA1 Distributed Intelligence:** | Ethan Stump<br>(301) 394-1222<br>ethan.a.stump2.civ@mail.mil | Nicholas Roy (MIT)<br>(617) 253-2517<br>nickroy@csail.mit.edu |
| **RA2 - Heterogeneous Group Control** | Christopher Kroninger<br>(410) 278-5690<br>christopher.m.kroninger.civ@mail.mil | Magnus Egerstedt (Ga Tech)<br>(404) 894-3484<br>magnus.egerstedt@ece.gatech.edu |
| **RA3 - Adaptive and Resilient Behaviors** | Jonathan Fink<br>(301) 394-5616<br>jonathan.r.fink3.civ@mail.mil | George Pappas (UPenn)<br>(215) 898-9780<br>pappasg@seas.upenn.edu |
| **Cross Disciplinary Experimentation** | Jonathan Fink<br>(301) 394-5616<br>jonathan.r.fink3.civ@mail.mil | TBD |

## Research Area 1 (RA1): Distributed Intelligence

RA1.A1 The Swarm's Knowledge Base: Contextual Perceptual Representations

RA1.A2 Hierarchical, Composable, and Adaptable Learning

RA1.A3 Hierarchical and Composable Planning for Sufficient Optimality

RA1.B1 Distributed Learning, Inference and Planning

RA1.B2 Collaborative Learning in Multi-Agent Networks

RA1.B3 Interaction with Human Teammates

RA1.C1 Joint Resource Allocation in Perception-Action-Communication Loops

RA1.C2 Resource-Aware Perception-Action-Communication Loops

RA1.C3 Adaptation and Learning in Wireless Autonomous Systems

## Research Area 2 (RA2) : Heterogeneous Group Control

RA2.A1 Abstraction of Task Diversity

RA2.A2 Modeling Human Traits

RA2.A3 Composable Autonomy in Heterogeneous Groups

RA2.B1 Human-Agent Collaborative Control of the Swarm

RA2.B2 Heterogeneous Hierarchical Autonomous Networks

RA2.C1 Task Assignment

## Research Area 3 (RA3): Adaptive and Resilient Behaviors

RA3.A1 Robust Adaptive Machine Learning

RA3.A2 Robust Self-Improving Inference, Perception, and Action

RA3.B1 Adaptive Swarm Behaviors for Uncertainty Mitigation

RA3.C1 Resilient Situational Awareness

RA3.C2 Resilience to Failures of Subsets of Networ

## Cross Disciplinary Experimentation (CDE)

CDE.1 Plug-and-Play Interfaces for Experimental Platforms

CDE.2 Integration of Wireless Communication Simulators

CDE.3 Develop Common Test Environments and Cases

CDE.4 Mobile Autonomous Networks

# Program Funding

## 6.1 Basic Research Program:

- Funded by a cooperative agreement
- 5 year initial program
  - Option for 5-year extension
- Enhanced Research Program
  - Supplemental Research Tasks

| Funding Category | Core Research Program ($M) Fiscal Year | | | | | |
|---|---|---|---|---|---|---|
| | FY18* | FY19 | FY20 | FY21 | FY22 | Total (10yr) |
| Basic Research (6.1) | 3.6 | 5.2 | 5.5 | 5.7 | 6.1 | 26.1 |

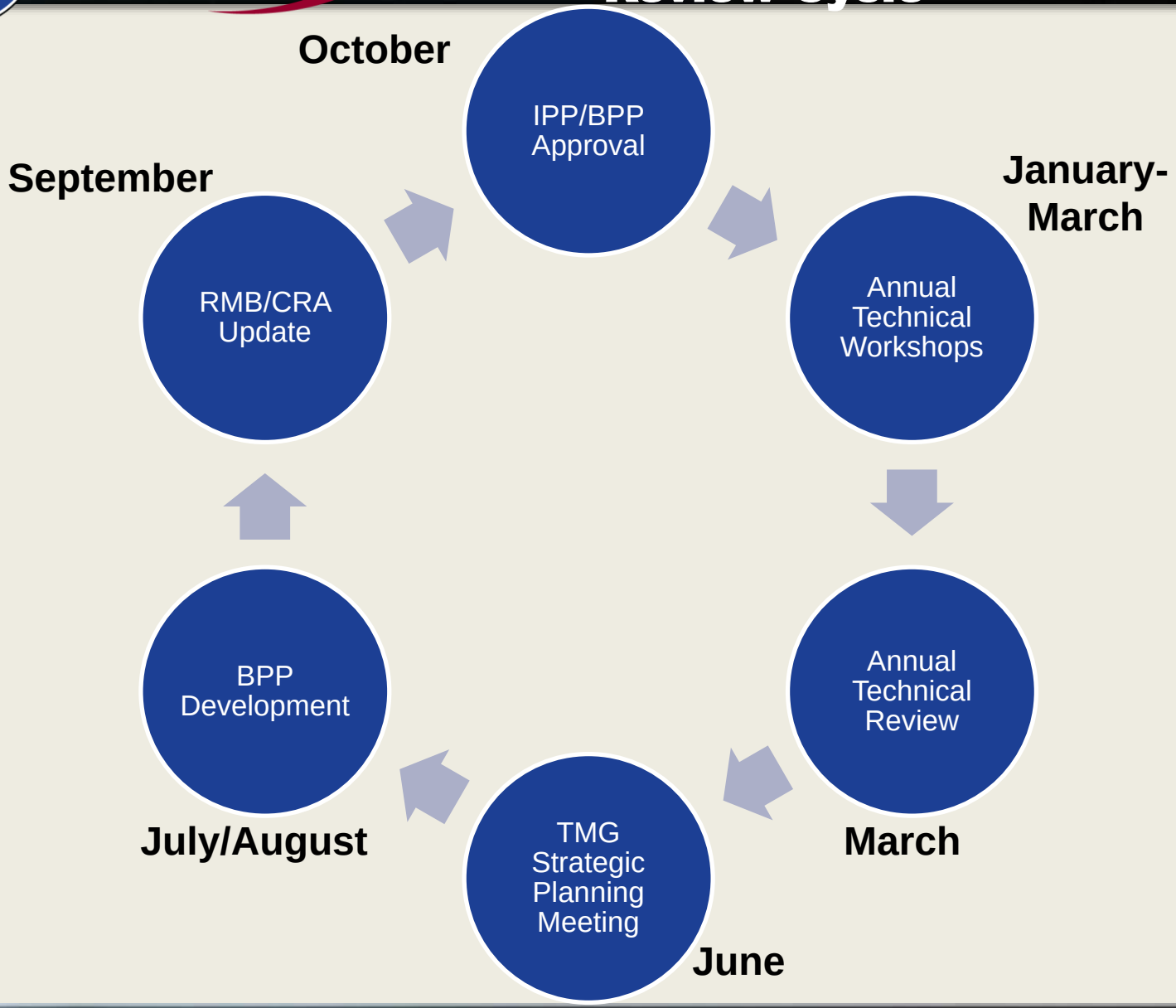
- BPP funding is subject to the availability of funds.
- Estimated funding levels are for the Basic Research (6.1) Core Research Program.
- Funding execution is reviewed against OSD obligation and expenditure goals.

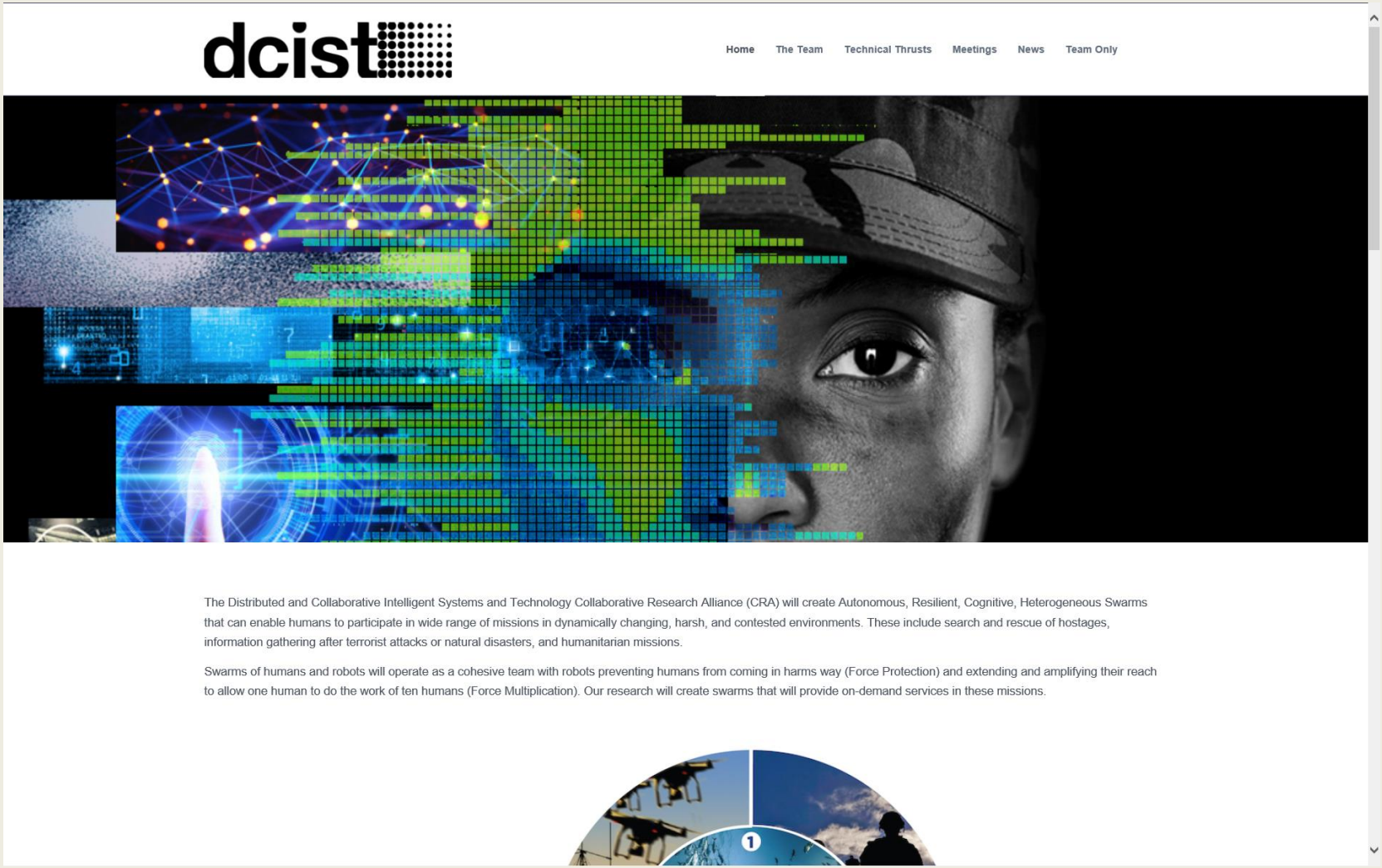
## Enhanced Research Program

- Should additional funding for the DCIST CRA become available from ARL and OGAs, an Enhanced Research Program Funding provision is included for Budget Activity 1 and 2.
- Provides a mechanism for growth and enhancement within the CRA.
- May be basic and/or applied research dollars.
- This Enhanced Research Program will leverage and/or transition the research, technology and capabilities from the Core CRA Research Program.

| | Enhanced Research Program ($M) | | | | | |
|---|---|---|---|---|---|---|
| | FY18* | FY19 | FY20 | FY21 | FY22 | Total |
| Basic Research (6.1) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 5.0 |
| Applied Research (6.2) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 10.0 |
| Enhanced Total | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 15.0 |

# DCIST CRA Planning and Review Cycle



# DCIST CRA

https://www.dcist.org/