Multi-Agent Decentralized Planning for Adversarial Robotic Teams

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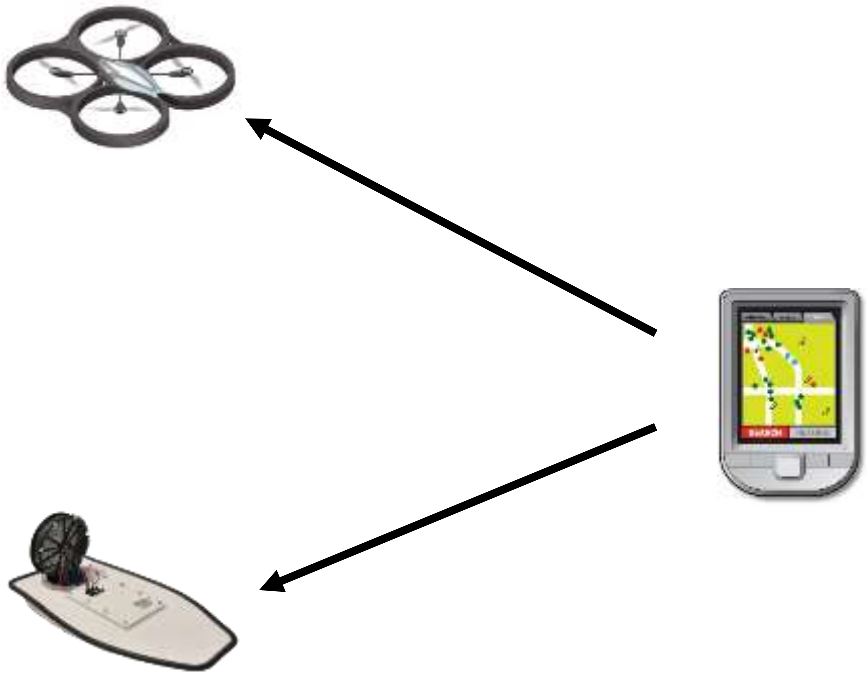
Challenges in Modern Unmanned Systems



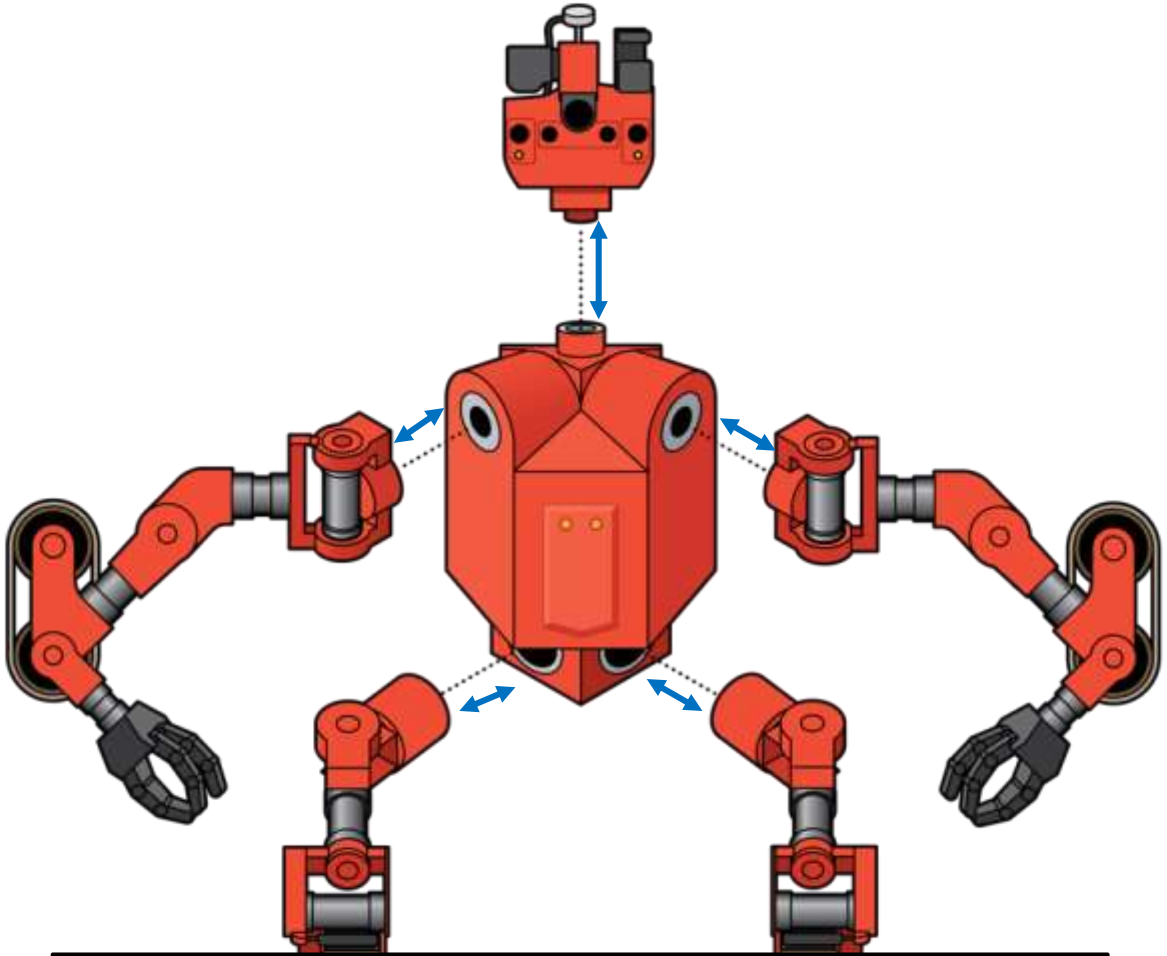
High Level Takeaway

The current unmanned system practice of the DoD is one of micromanagement

Static AI is bad for dynamic adversaries

- Current unmanned systems (UAS) are **individually controlled** by a handful of pilots and potentially dozens of analysts **micromanaging every** aspect of the **device**
- This control paradigm results in **poor scalability** and **high training costs**
- A **centralized control** station is also prone to **failure, bottlenecks, and enemy attacks** taking out all UAS managed by that station
- **Environments and missions change** but AI tends to be static and preset
  - Most unmanned systems **use automated waypoints for missions**

Micromanagement of Autonomous Systems is Pervasive



The arm, leg, head, etc. may be composed of dozens to hundreds of message queues

The State of Autonomy Middleware

- Robotic systems are built from the ground up
- Message queues are created between robotic components and controllers
- Autonomy developers must compose message-passing systems into something that supposedly works at a higher level
- No obvious way to check overall behaviors much less emergent behaviors
- ROS, UCS FACE (ARL), OMS (AFRL RCO) all force robotics developers to program around message queues

Our Autonomy Objectives

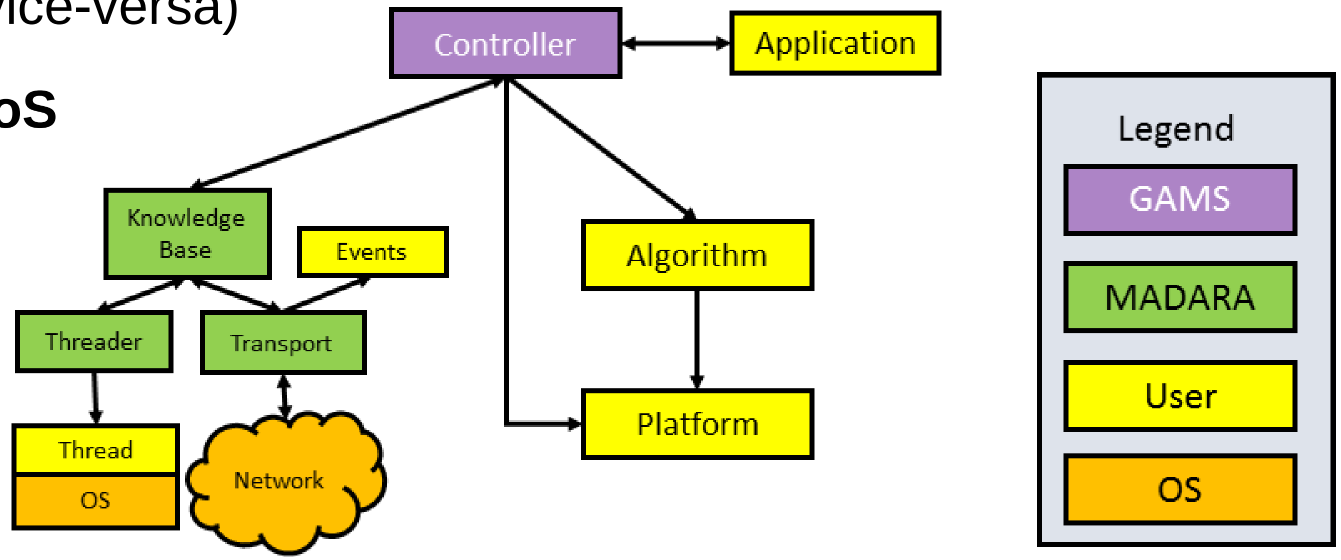
- Allow **one person** to **command an entire swarm** of UAS to do mission-level tasks
- **Focus on 1) scalability**, 2) bringing **simulated capabilities to reality**, and providing 3) **predictable control** of UAS logic, threads, sensors, actuators and software components
- **Open source release** of middleware and software via BSD-style licenses at Sourceforge and GitHub (**GAMS/MADARA**)

MADARA http://madara.sourceforge.net/
GAMS http://jredmondson.github.io/gams/

FY16 MADPARTS extends research development from FY13 SMASH, FY14 GAMS, FY15 ELASTIC

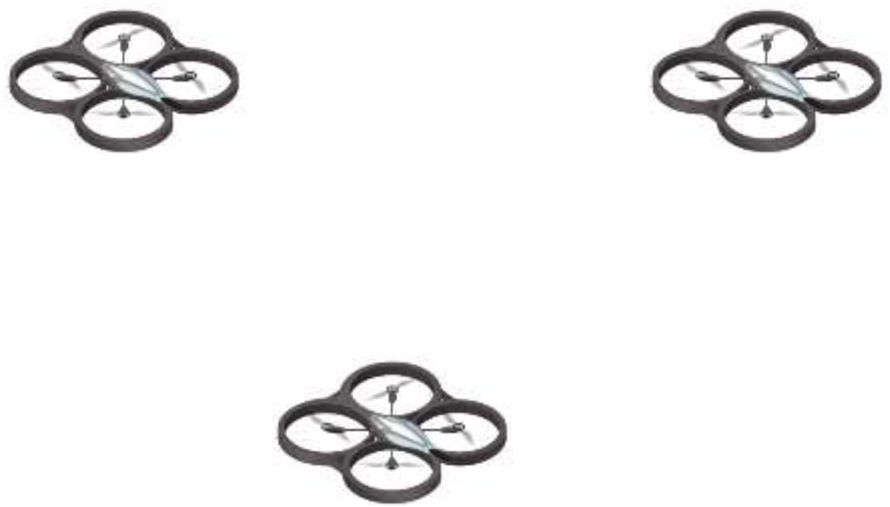
Our Autonomy Process

- Users write an application in C++ or Java
  - Developers **read and write to knowledge** handled by the underlying middleware
  - **Platforms have standardized interfaces** that algorithms interact with
  - **No interaction with message queues** (handled under the hood)
- Users only have to **focus on** the **their algorithm or platform**
- Built-in translations between **simulation and real-world**
  - Pose system (Cartesian to GPS and vice-versa)
- High **consistency, predictability and QoS**
  - **Important for verification**



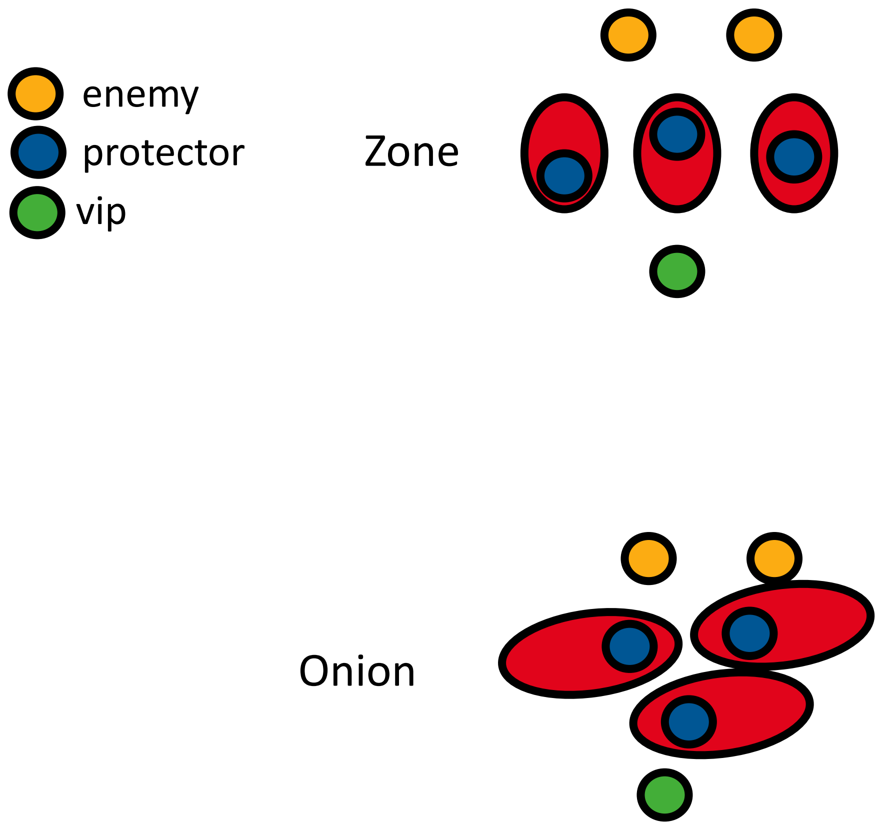
The result is rapid prototyping and verifiability of distributed autonomy in robotics (FY16 DART, SMC for Swarms)

Adversaries in MADPARTS



- Adversaries **try to get line-of-sight** on an important target (base, VIP vehicle, etc.)
- **Adversaries move around** a target, looking for an opening
- The **goal** of the new algorithms is to **prevent line-of-sight** on these targets
- **Adversaries are** modeled as **agents**
- Agents have **self-interest** and **present information in the knowledge base like location** to use in algorithm logic
  - Essentially a **persistent tracking system is assumed** for tracking adversary position

Defensive Schemes



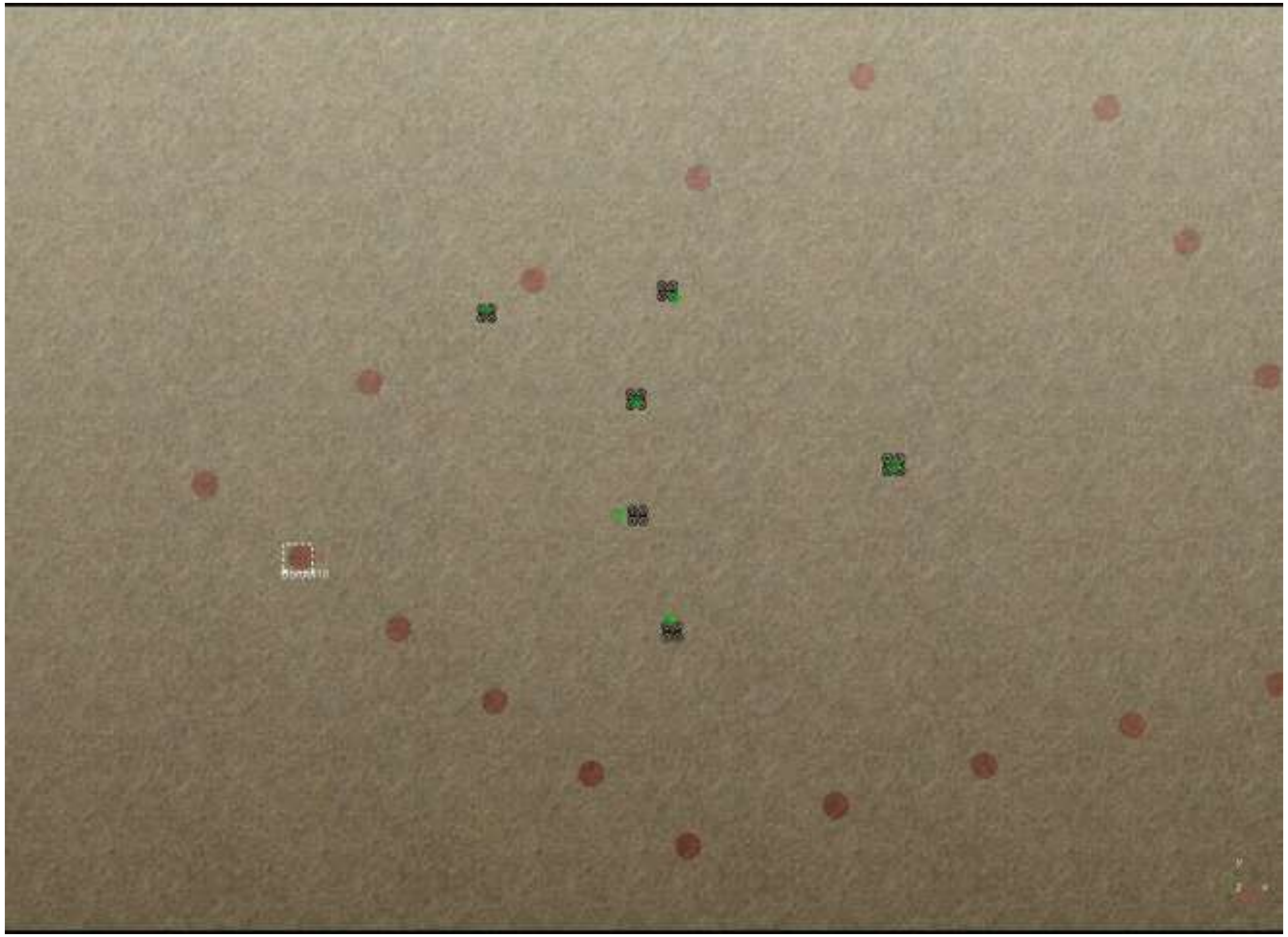
- We took some **inspiration** from American football and **robot soccer**
- **Zone defense:** Protector **agents** move to assigned zones **between** a **vip and** the **enemy**
  - **Useful for holonomic robots** like quadcopters
- **Onion defense:** Protector agents layer a defense between vip and enemy
  - Useful for **non-holonomic robots** like **fixed-wing planes and boats** that drift

Results: Simulations

- Algorithms were coded in C++ and made available via factory methods in GAMS (can be called remotely)
- The defensive algorithms were **evaluated in VREP** simulations
- The algorithms were evaluated in the FY16 SMC for Swarms Project (next talk) early in FY16
  - **With just 5 protectors, Line-of-sight was prevented at >99%**

	Initial Disperse	Detect Range	Failure	Trials
Scenario 1	Loose	Long	0.11%	265,896
Scenario 2	Loose	Short	0.35%	114,912
Scenario 3	Tight	Short	0.28%	114,504
Scenario 4	Tight	Long	0.00%	400,000+

http://coppeliarobotics.com/



Results: Real World Demonstration

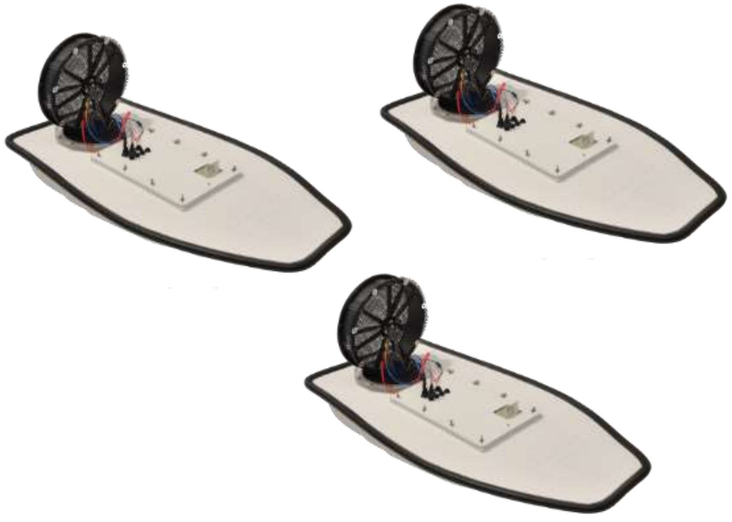
Transition (ALW)

- PWP in place for AFRL Autonomy of the Loyal Wingman FY17-FY18
  - Core software candidate for autonomous F-16 wingmen for a human pilot
  - Algorithm creation for target defense and prosecution

https://en.wikipedia.org/wiki/General_Dynamics_F-16_Fighting_Falcon

Transition (NATO)

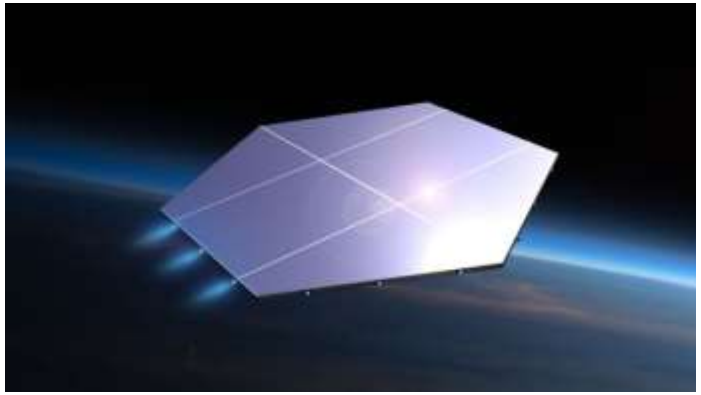
- Invitation to participate in NATO CMRE REP17-Atlantic exercise
  - REP17 is a joint exercise between Portuguese Navy, NATO CMRE, and the University of Porto
  - Current plan is for our autonomous boats to participate in the joint exercises

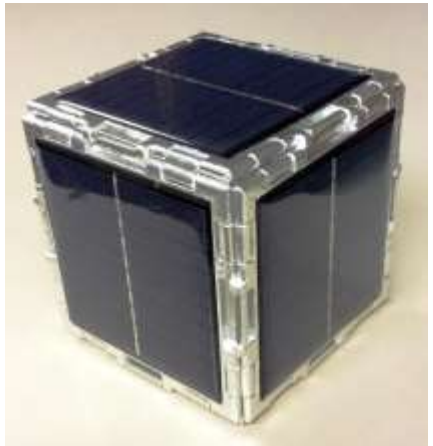


Boat images courtesy of Platypus LLC

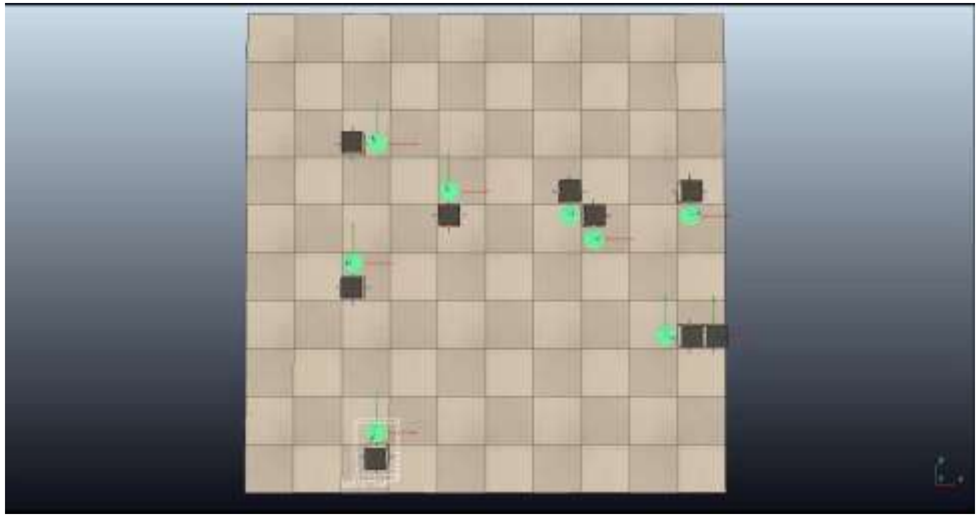
Transition (Multi-Planetary Smart Tile)

- GAMS and MADARA are core software architecture for the Keck Institute for Space Studies' Phase 1 Multi-Planetary Smart Tile
  - Hardware prototyped by GE GRC and Biovericom
  - Separate offers to launch into LEO by United Launch Alliance and NASA
  - Phase 1 is expected to perform simple autonomy experiments in low-earth orbit for up to 1 year





Images courtesy of Anna Nesterova and Kelvin Ma



- **Goal** of project is to create a distributed, **renewable power infrastructure** for solar system that **scales to tens of thousands** of interacting robotic systems

Conclusion

- Current autonomy practice suffers from:
  - Micromanagement of individual devices
  - Non-intuitive high-level behavior design and analysis
  - A distinct lack of verification tools
- Our middleware provides
  - Rapid prototyping capability for distributed autonomy
  - Full integration with DART and DEMETER (SMC for Swarms) for verification
- The MADPARTS defensive algorithms were successful
  - Prevented line-of-sight to target over 99.6% in all tested scenarios
  - Tested in unmanned surface vehicles in lakes near Pittsburgh

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Open Source Project Sites

MADARA: http://madara.sourceforge.net
GAMS: http://jredmondson.github.io/gams
DART: http://cps-sei.github.io/dart

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