First orbiting satellite. The satellite was not a threat, but the level of technology indicated that the Soviet Union possessed superior capability for intercontinental reconnaissance and bombing.

The Defense Advanced Research Projects Agency (DARPA) was established in 1958 to **prevent strategic surprise** from negatively affecting U.S. national security and **create strategic surprise** for U.S. adversaries by maintaining the technological superiority of the U.S. military.

To fulfill its mission, the Agency relies on **diverse performers** to apply multi-disciplinary approaches to both advance knowledge through basic research and **create innovative technologies** that address current practical problems through applied research.

As the DoD’s **primary innovation engine**, DARPA undertakes projects that are finite in duration but that create **lasting revolutionary change**.
DARPA Culture

Flat organization
Little hierarchy to ensure the free and rapid flow of information, ideas and decisions

Outstanding program managers
DARPA hires creative, independent people with big ideas and empowers them

Project-based assignments
Projects organized around a challenge model and typically last three to five years; longer if necessary to facilitate transition

No DARPA labs
Majority of the research is sponsored in industry and universities with a small amount in government labs

Flexible outsourcing of staff and performers
Great talents and ideas from industry, universities, and government labs with technical, contracting and administrative services from other commercial and government agencies
### DARPA Technical Offices

<table>
<thead>
<tr>
<th>BTO</th>
<th>DSO</th>
<th>I2O</th>
<th>MTO</th>
<th>TTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Technologies Office</td>
<td>Defense Sciences Office</td>
<td>Information Innovation Office</td>
<td>Microsystems Technology Office</td>
<td>Tactical Technology Office</td>
</tr>
</tbody>
</table>

#### DARPA Technical Offices

- **Physical Sciences**
  - Neuroscience
  - Materials
  - Mathematics
  - Biology
- **Cyber**
  - Data Analytics at Massive Scale
  - ISR Exploitation
- **Electronics & Photonics**
  - Imaging
  - PNT
  - Computing
  - Engineering Biotech
  - Biological Microsystems
- **Battle Management, Command & Control**
  - Communications and Networks
  - Intelligence, Surveillance and Recon
  - Electronic Warfare
- **Ground, Maritime, Air, & Space Systems**
- **Agile Development**
- **Cooperative Autonomy**
- **Unmanned Systems**
- **Power and Energy**

#### Objectives

- **Restore and Maintain Warfighter Abilities**
- **Harness Biological Systems**
- **Apply Biological Complexity at Scale**

#### Supporting Offices

- **Information Innovation Office (I2O)**
- **Microsystems Technology Office (MTO)**
- **Strategic Technology Office (STO)**

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TTO Legacy – A Quick Overview

**Air Systems**
- **1977**: Have Blue
- **1982**: Tacit Blue
- **1990**: X-31
- **1998**: Global Hawk
- **2002**: X-45/46/47
- **2003**: A-160
- **2008**: Damage Tolerant Controls (DTC)
- **2011**: Falcon HTV-2

**Maritime Systems**
- **1967**: MK 50 Torpedo Propulsion System
- **1969**: Sea Shadow
- **1984**: Unmanned Undersea Vehicle (UUV)
- **1988**: Submarine Technology (SUBTECH)
- **1997**: BigDog

**Ground Systems**
- **1967**: M16 (Project Agile)
- **1982**: Tank Breaker
- **1984**: Army Tactical Missile System (Assault Breaker)
- **2002**: Talon
- **2003**: Boomerang
- **2003**: Netfires
- **2008**: BigDog

**Space Systems**
- **1985**: Global Low Orbiting Message Relay (GLOMR)
- **1990**: Pegasus
- **1995**: DARPASAT
- **1997**: Taurus
- **2003**: Falcon Small Launch Vehicle
- **2006**: MiTEX
- **2007**: Orbital Express (OE)
- **2013**: Space Surveillance Telescope (SST)

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Collaborative Operations in Denied Environment (CODE)
Operating in the Emerging Denied Environment

EMS: Electromagnetic Spectrum

- Long Distances
- Contested EMS
- Mobile Targets
- Decoys
- High Threats
- Integrated

Stealth
Speed
Numbers
Poison (EW)

Collaboration
CODE seeks to develop and demonstrate the algorithms to expand the mission capabilities of legacy assets through autonomy and collaborative behaviors.

Envisioned benefits:

a) New mission capabilities
b) Leveraging of existing assets
c) Reduced staffing
d) Increased mission efficiencies

Focus Areas:

a) Vehicle-level autonomy
b) Collaborative autonomy
c) Supervisor interface
d) Open architecture
Program Structure

Track A: System integrators

Track B: Critical Technology Developers

Common architecture and software development environment

System integration and capability development

Release 1: Single vehicle autonomy & virtual multi-vehicle demonstration

Release 2: Collaborative autonomy with few vehicles

Release 3: Advanced supervisory interface and additional vehicles

Release 4: Full mission demonstration (Live-Virtual-Constructive demonstration using 6 or more real vehicles and others simulated)
CODE's Envisioned Benefits for Strike Missions

**Denied Environment**

- **Long Distances**
- **Contested EMS**
- **Mobile Targets**
- **Decoys**
- **High Threat**
- **Integrated**

**End-to-End Engagement Sequence**

1. **Get access**
   - Increased range through formation flight
   - Smaller vehicles easier to deploy
   - Local C3
   - Shared navigation

2. **Find target**
   - Increased coverage area
   - Increase bi-static angle
   - Mix of long range sensors

3. **Identify target**
   - Mix sensor phenomenology
   - Mix of sensor field of view
   - Ensure appropriate human oversight

4. **“Survive” engagement**
   - Simultaneous attack
   - Overwhelming numbers
   - Leverage other systems strengths

5. **Reduce overkill/underkill**
   - Dynamic target re-assignment
   - Real time BDA
   - Re-attack, divert to secondary targets

---

Possible benefits of collaborative autonomy

EMS: Electromagnetic Spectrum
BDA: Battle Damage Assessment
C3: Command, Control and Communications

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11
Four Focus Areas–Three Representative Missions

- Collaborative Autonomy
- Vehicle-level Autonomy
- Supervisory Interface
- Open Architecture for Distributed System

Armed Reconnaissance
Artist's Concept

Destruction of Enemy Air Defense
Artist's Concept

Anti–Surface Warfare
Potential Technical Approach

<table>
<thead>
<tr>
<th>Port data exploitation algorithms</th>
<th>Leverage advanced rule engines</th>
<th>Leverage advanced path planning algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feature-based tracking and navigation</td>
<td>X-45</td>
<td>Rapidly exploring random trees</td>
</tr>
</tbody>
</table>

Examples

- Heterogeneous Airborne Reconnaissance Team
- Automated Scheduling and Planning Environment
- Advanced contingency planning and management for lost link scenario
## Technology: Collaborative Autonomy

### Current Practice
- Pre-planned synchronization
- Centralized control
- Reliable communication

### Potential Advanced Capabilities
- Collaboration at the tactical edge robust to
  - Intermittent, low-bandwidth communication
  - Complex mission objectives
  - Dynamic changes

### Potential Technical Approach

<table>
<thead>
<tr>
<th>Examples</th>
<th>Develop world model fusing onboard and offboard data</th>
<th>Develop behavioral models of target and teammates</th>
<th>Develop advanced tactical planner based on stochastic beliefs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-mode sensors</td>
<td>Heterogeneous Unmanned Networked Teams</td>
<td>Play book approach to enable rapid planning and replanning in real time</td>
<td></td>
</tr>
<tr>
<td>Decentralized and Autonomous Data Fusion Service</td>
<td>Avatar-based planning and coordination</td>
<td>Autonomous Detection, Tracking, and Following by Small UAS</td>
<td></td>
</tr>
</tbody>
</table>
Current Practice

Predator Ground Control Station

What we are proposing to do

- Change from pilot/operator to supervisor
- Break linear operator-platform scaling
- Leverage human capabilities as critical system element
- Support multiple levels of interactions

Potential Technical Approach

<table>
<thead>
<tr>
<th>Improve situational awareness display</th>
<th>Develop Commanders Intent interface using natural language</th>
<th>Use voice, eye tracking, tactile control</th>
</tr>
</thead>
</table>

- Heterogeneous Airborne Reconnaissance Team
  - Sketch understanding
  - Multi-modal input enables natural interaction

- Persistent Close Air Support
  - Natural language understanding
  - Video game industry

Examples

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Why Open Architecture for CODE?

- Leverage a broad community of interest in developing autonomy
- Create an environment for continuous improvement
- Create an environment for open competition with no barriers to entry

An open architecture for the CODE system would enable:

- Adaptability
- Rapid integration
- Testability supporting
  - early modeling and simulation, to Live-Virtual-Constructive flight test,
  - software instrumentation, and
  - injections of virtual air vehicles, threats, and targets, as well as mission contingencies (GPS and Communication denial, simulated failures of sub-systems)
- Transition including security, flight safety, and business considerations