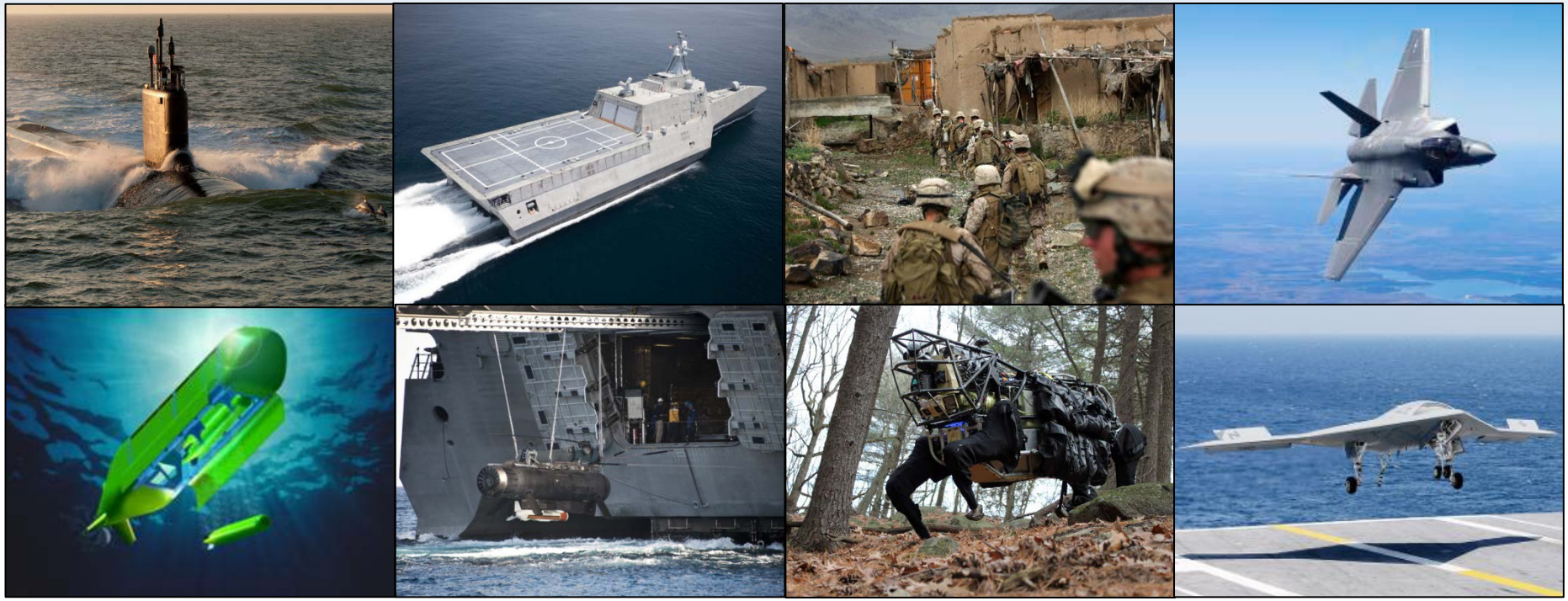
Focus Area Forum: Unmanned Systems & Autonomy

Rear Admiral Matthew L. Klunder
Chief of Naval Research
January 15, 2014

Our Goal: an *Affordable* Hybrid Manned & Unmanned Force



The Unmanned Systems Must Be Affordable

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What do we need?

We are looking for ideas that go beyond "dull, dangerous and dirty" missions:

- ***Systems that work as teams with warfighters***
- ***Scalable systems as solutions to ensure access to maritime domains***
- ***Solve intelligence and logistics challenges***
- ***Provide decision support in complex adversarial environments***

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Key Naval Challenges for Autonomous Systems

- Dynamic & uncertain environments
- Optimal manning
- Complex missions
- Unique communications
  - Potentially very limited and/or intermittent
- Rapid and dynamic responses to operational changes
- Wide range of warfighter users/customers

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Budget Realities

The Department of the Navy must always consider the total cost of our new technological advances while working within the constraints of our budget realities

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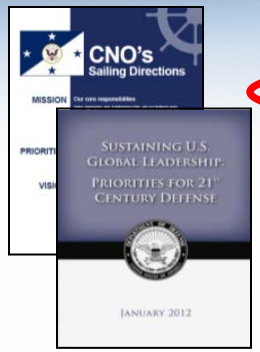
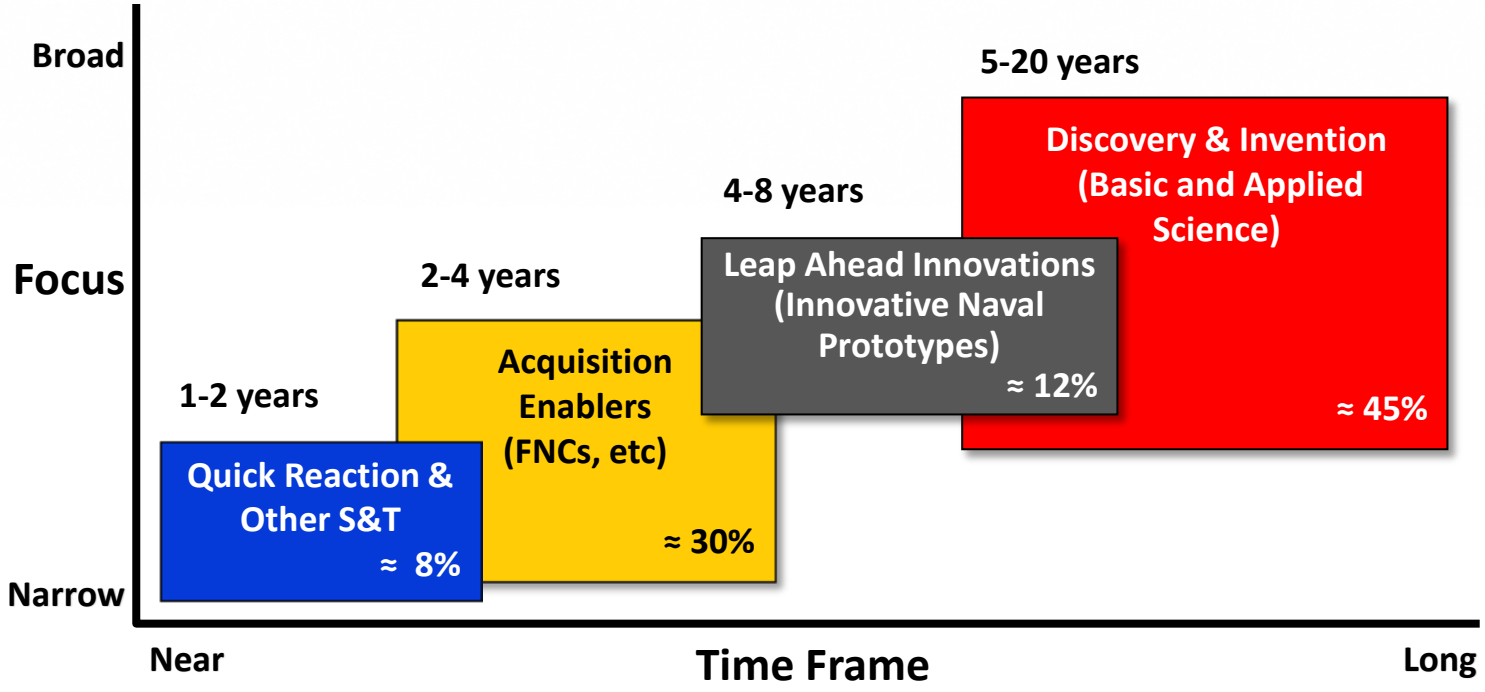
Naval S&T Strategic Plan



- *Assure Access to Maritime Battlespace*
- *Autonomy & Unmanned Systems*
- *Expeditionary & Irregular Warfare*
- *Power Projection/Integrated Defense*
- *Information Dominance*
- *Power & Energy*
- *Platform Design & Survivability*
- *Total Ownership Cost*
- *Warfighter Performance*



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You have questions …

- What are ONRs research priorities for autonomous systems?
- Which ONR programs (besides Science of Autonomy) are funding research on agent transparency?
- What navigation issue is ONR focused on?
- Expectations for both the vehicle as well as the Payload?
- What are the current capability needs for adjustable autonomy, mobile manipulation, and cloud robotics?
- How will the Navy operate in A2AD environments?
- How can free flight energy harvesting help meet future green Navy needs?
- What are some of the futures goals for using teams of multi-/cross-domain unmanned vehicles?
- What opportunities exist for support of Quantum study of SFW?
- What advances are currently being made to address GPS Jamming and Spoofing and Non cooperative Sense and Avoid?
- What is your need for indoor UAS?
- Research topics regarding OSS in Navy UAV programs?

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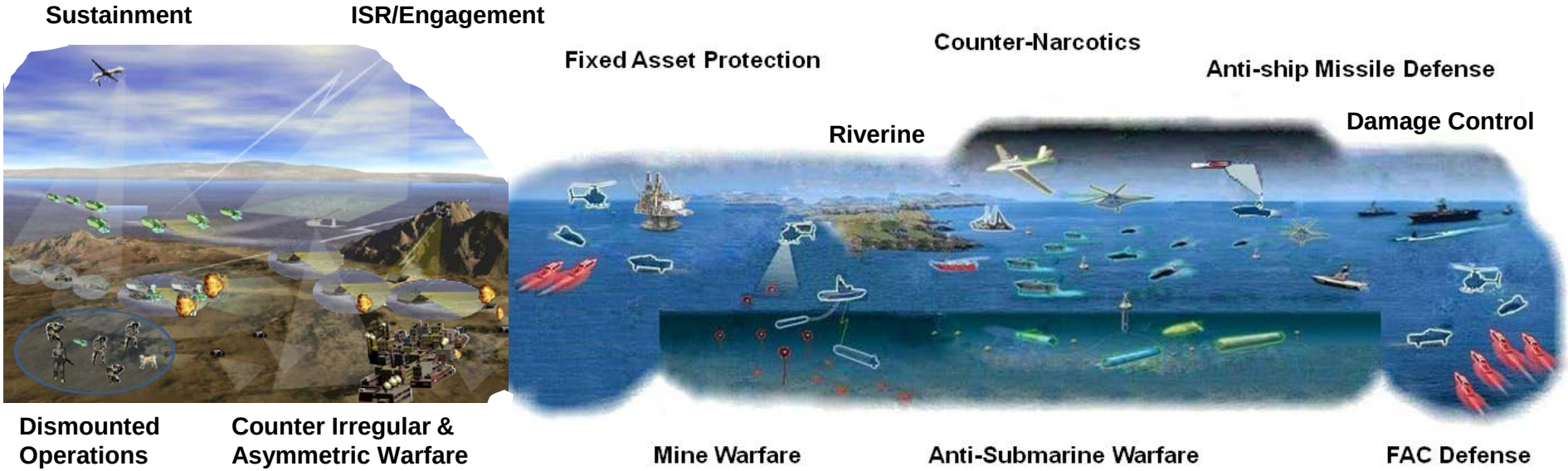
Science of Autonomy

Marc Steinberg
Program Officer, Science of Autonomy
15 January, 2013

ONR-Wide Vision



Autonomous systems will be applied to many operating domains, used for many missions, and incorporate many systems

Basic Research
Science of Autonomy

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Long-Term Goals

Human Interaction	Greatly reduced manning requirements (numbers & skill/training); Human/machine hybrid teams as (or more) effective as human/human ones
Perception & Intel. Control	Adapt to complete mission tasks at operationally useful speeds & increasingly challenging environments with greatly reduced need for human intervention
Scalable Collaboration	Scale approaches to greater numbers of systems, more complex mission tasks, & larger areas while reducing communications requirements
Intelligent Architectures	Reasoning, learning, decision-making in increasingly contested, unstructured, & uncertain environments; Tighter integration with perception & control

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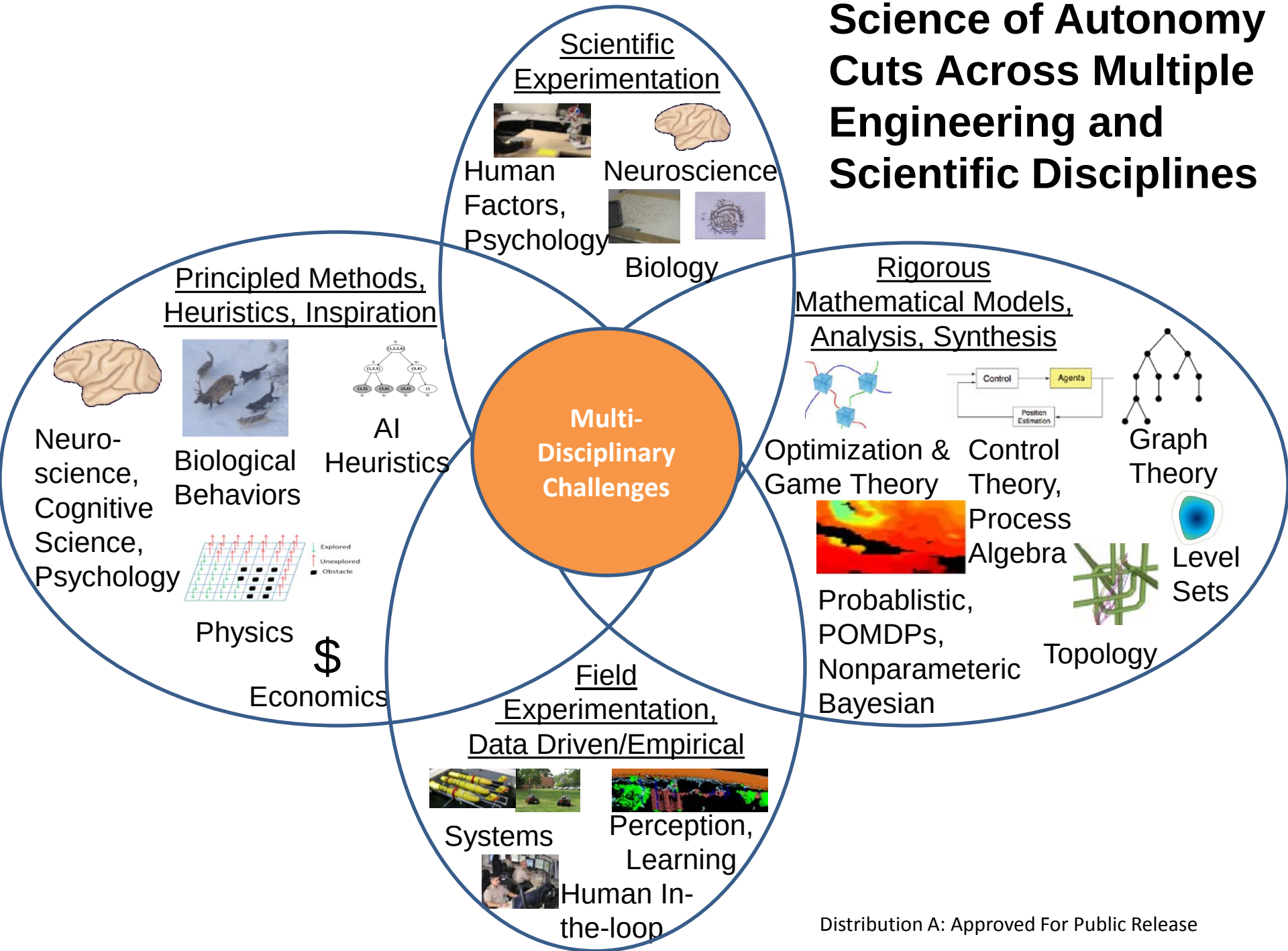
Science of Autonomy Cuts Across Multiple Engineering and Scientific Disciplines



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Human/Unmanned Systems Collaboration Challenges

- More natural modes of interaction
- Understand intent and recognize deception
- Cognitively compatible behavior during interaction to minimize human cognitive load
- Dynamically changing levels of autonomy and interaction
- Shape and redirect the capabilities and behaviors of large numbers of heterogeneous entities

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Perception & Intelligent Control Challenges

- Adjudicate between wide area exploration and exploitation
- Learning context (environmental) and scene understanding to semantic level for presentation to a system or person
- Perception-based decision-making & control in complex, uncertain environments
  - Rapid appraisal of how sensed information will impact on ability to achieve goal
  - Representations that span from perceptual/behavioral processes through high-level reasoning
  - Understanding what is the minimum perception necessary

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Scalable & Robust Distributed Collaboration Challenges

- Scalable, self-organizing, organizational structure/hierarchy appropriate to mission tasking
  - Robust to limited communications and uncertainty
  - Deals with intelligent adversaries.
- Task allocation/assignment, planning, coordination & control
- Airspace/Waterspace/Ground Traffic management
- Rigorous mathematical methods and tools for predicting behaviors of large numbers under realistic assumptions
  - Identify scalability “break points”
  - Verification & Validation

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Intelligence Enablers & Architectures Challenges

- Integrated Architectures
  - Integrate approaches seeking high-level (e.g., human) intelligence with approaches designed to enable a system to survive and adapt in real environments of naval interest
  - Inter-agent command, collaboration and communication

- Reasoning - Identification of common representations, semantics and inference procedures

- Scalable Planning and Replanning
  - Partially known environments and partially known objectives
  - Plan recognition
  - Unpredictable adversaries/coalitions

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Intelligence Enablers & Architectures Challenges (cont.)

- Learning
  - Complex concepts/tasks, relationships, group behaviors
  - Long periods of time
- Social Cognition and Metacognition
  - Collaboration, dialogue participation, quick strategy adaptation, socially-guided acquisition of knowledge, policy/ethical issues
- Intelligence for Decentralized Systems

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Moving Towards Applied Research & Technology Demonstration

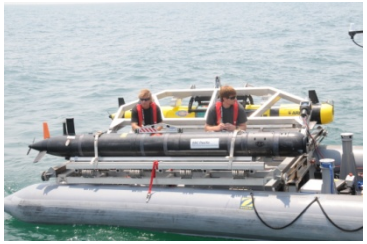
Near Term → Mid-Term → Far-Term

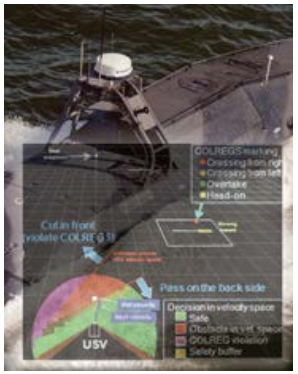
Individual or small numbers of systems, low ops tempo, moderate manning, simple environments

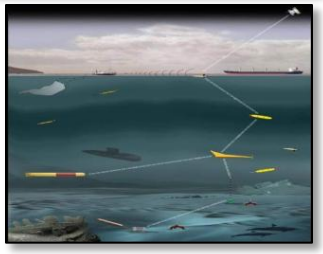
Increased operational envelope, autonomous planning & control with reduced need for human intervention

New operational concepts, longer term missions with much more effective manning

Human/Machine & Machine/Machine Teaming, More Distributed C2, New Mission & Tactics







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Relevant Program Officers

Program	Program Officer	Code
Cognitive Science	Paul Bello	34
Expeditionary/UGV Systems	Jeff Bradel & Keith Hammack	30
Unmanned Sea Surface Systems	Bob Brizzolara	33
Long Duration Undersea Systems	Dan Deitz	32
Machine Intelligence & Reasoning	Behzad Kamgar-Parsi	34
Hybrid Human Computer	Julie Marble	34
Neuroscience, HRI, Bio-Inspired Systems	Tom McKenna	35
Physical Oceanography, Undersea Networked Systems	Terri Paluszkiewicz	32
Mine Counter Measures Data Understanding	Jason Stack	32
Science of Autonomy, UAS Autonomy	Marc Steinberg	35

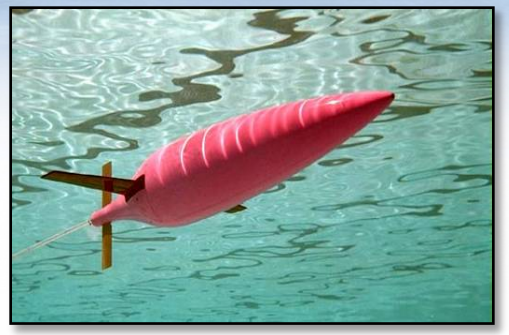
…and many others listed in the applications panel session presentations

Undersea Autonomous Systems

Dan Deitz, Terri Paluszkiewicz, & Jason Stack
Program Officers, Ocean Battlespace Sensing
15 January, 2013

Undersea Autonomous Systems

Goal: Exploit the ocean environment to our tactical advantage

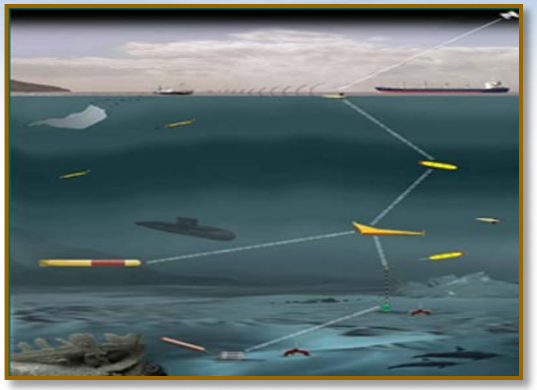


- Mobile autonomous environmental sensing
- Predictive capabilities at tactical and strategic scales
- Adapt warfighting systems to environmental variability

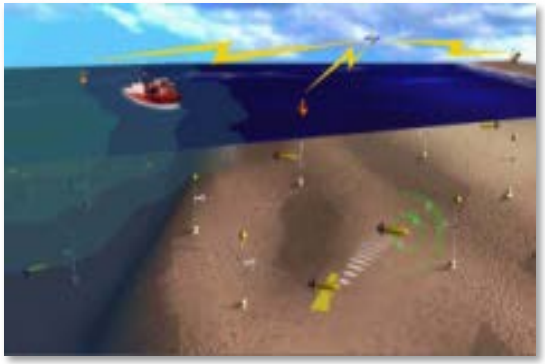
Domains of Interest

Mine Clearance

Long Endurance

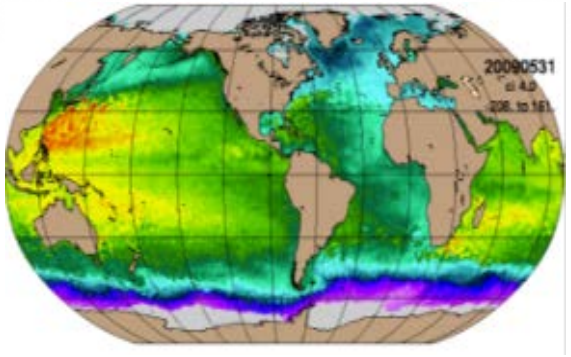


Antisubmarine Warfare



Persistent Surveillance

Artic & Global Prediction

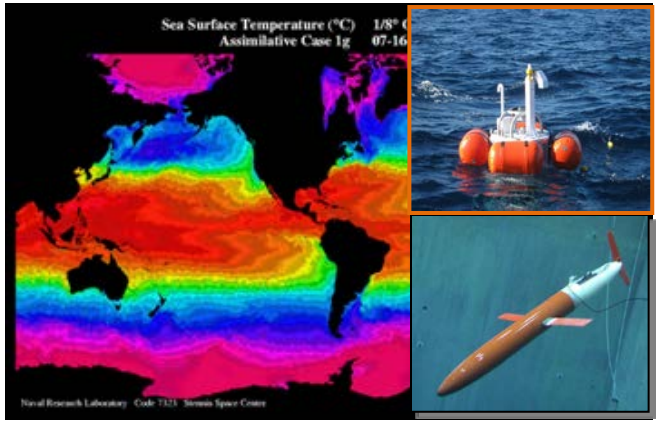


Operational Environments

Future Research Directions of Interest

- Tighter coupling between automated perception and autonomous platform behaviors

- Enable extended duration missions
  - Multiple goals & unanticipated events per sortie
  - Mission time >> a priori situational awareness
  - Mission time commensurate with platform subcomponent reliability times



- Enable purely autonomous sorties with rich and rapid human-machine inter-sortie knowledge and supervisory exchanges

Relevant Program Officers

Program	Program Officer	Code
Antisubmarine Warfare (ASW)	Johnson, Tague	32
Arctic & Global Prediction	Harper	32
Long Duration UUV	Deitz	32
Mine Countermeasures (MCM)	Swean, Stack	32
Persistent Littoral Undersea Surveillance (PLUS) Increment 2	Paluszkiewicz	32

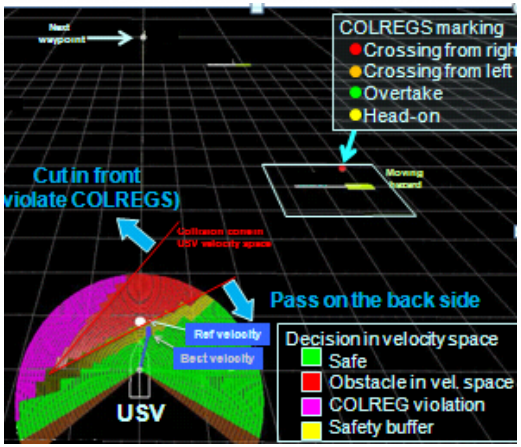
Autonomous Surface Vehicles

Bob Brizzolara
Sea Platforms and Weapons Division
15 January 2014

Autonomous Surface Vehicles

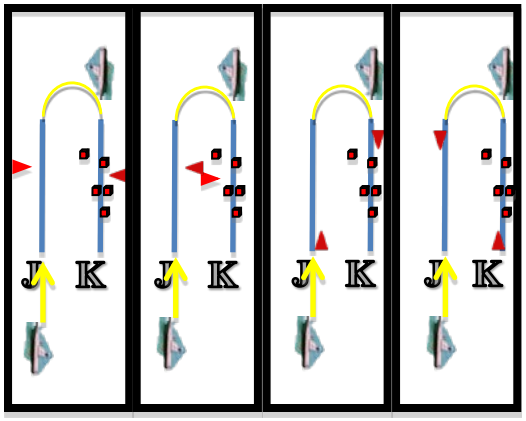
Goal: USV autonomy for long, complex missions in dynamic, unpredictable and harsh environments

- **Perform complex tasks in a complex environment, without human intervention**
- **Respond effectively to dynamic situations**
- **Perceive environment, internal and external**



State-of-the-Art:

- **On-water demonstrations of autonomous hazard avoidance and collision regulations compliance, daytime, with (1) own-ship speeds of ~30 kts, or (2) in sea state 2**
- **tactically relevant autonomous behaviors**



Domain of Interest: Challenges of the Sea Surface

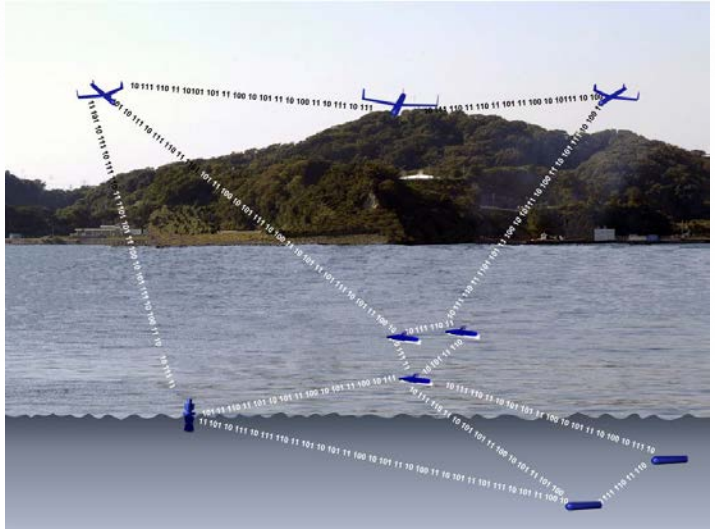
- **Accurate world model/perception**
  - **Intermittency of perception**
    - **Motion of USV and target affect sensor operation**
    - **Wave crests and troughs intermittently obscure contact**
    - **Green water over arch intermittently obscures sensors**
  - **Detection of hazards in sea surface clutter**

- **Response Time**
  - **Own-ship and traffic vessel speeds**
  - **Detection range**
    - **Hazards often not detected until close-aboard**

- **Complexity of mission/task**
  - **Tasks with multiple, competing objectives**
  - **Contact density**

Future Research Directions of Interest

- Efficient and effective algorithms and approaches for handling multiple competing objectives
- Intent determination, activity recognition and motion prediction of maritime vessels
- Improved situational awareness and accuracy of world model in degraded conditions such as high sea state, poor visibility, etc
- Cooperative decision-making amongst groups of USVs, and USVs and other UxV types
- Accurate and fast fusion of sensor information including decentralized data fusion across several USVs, and other UxV types



Relevant Program Officers

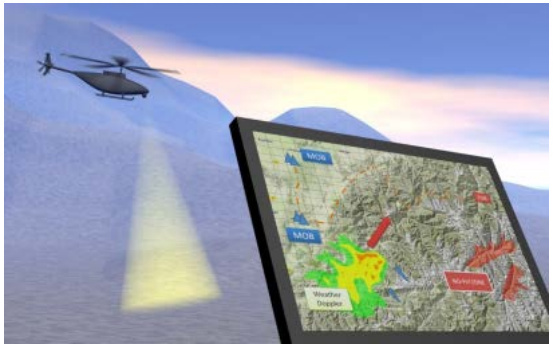
Program	Program Officer	Code
Autonomy for USVs	Bob Brizzolara	333

Aerial Autonomous Systems

Marc Steinberg
Program Officer, Science of Autonomy
15 January, 2013

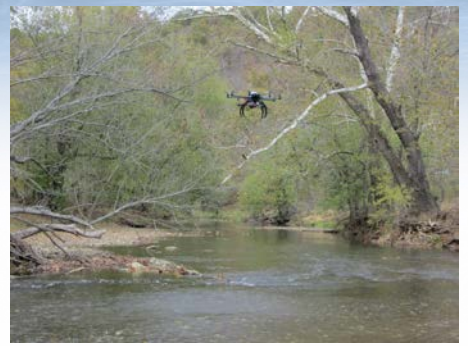
Aerial Autonomous Systems

- Safe & high ops tempo in the maritime/shipboard environment
- Effective collaboration with the warfighter (from operators to customers & teammates)
- Increased operational envelope & tactical role with greatly reduced need for human intervention



Domains of Interest

Cargo/Casualty Evacuation



Complex Environments: Riverine, Shipboard, Under the Canopy, Urban

Persistent ISR, Force Protection, “Swarms”

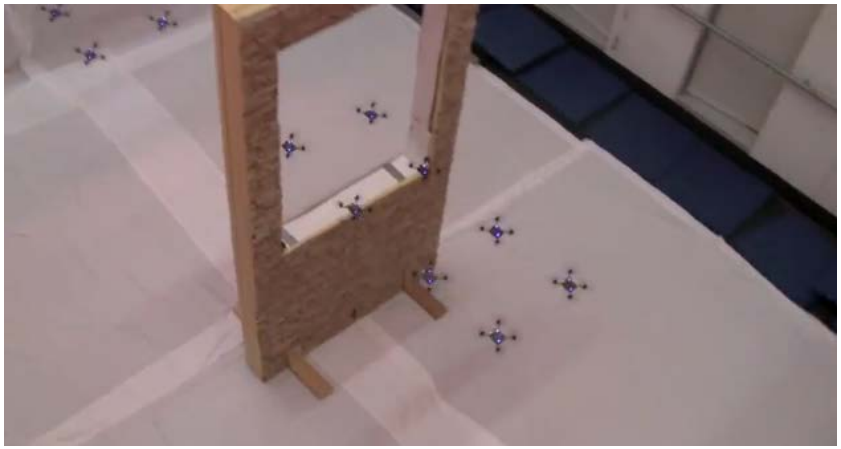
“Wingman” for Dismounts, Support for UGV, USV, UUV

Air Combat, Collaborative Engagement, multi-UxV C2

Shipboard Landing and Flight Deck Ops

Future Research Directions of Interest

- Agile flight/semantic understanding in complex & GPS degraded environments with inexpensive/ low SWAP sensing
- Increasingly automated shipboard operations with fewer personnel needed on the flight deck
- Longer-duration/larger area ops with many inexpensive UAS
- Manned/unmanned teaming
- Human interaction with large numbers of heterogonous systems
- V&V for both safety & mission competence



Relevant Program Officers

Program	Program Officer	Code
UxV Fuel Cells/Electrochemical Materials	Michelle Anderson	33
Automated Deck Operations, Sea-based Automated Launch and Recovery System	John Kinzer	35
Human Interaction & Decision Support	Julie Marble	34
Autonomous Aerial Cargo/Utility System (AACUS)	Max Snell	35
Science of Autonomy Basic Research, UAS Autonomy Applied Research	Marc Steinberg	35
Intelligent Collaborative Engagement	Roger Sullivan	35

Expeditionary Autonomy and Unmanned Systems

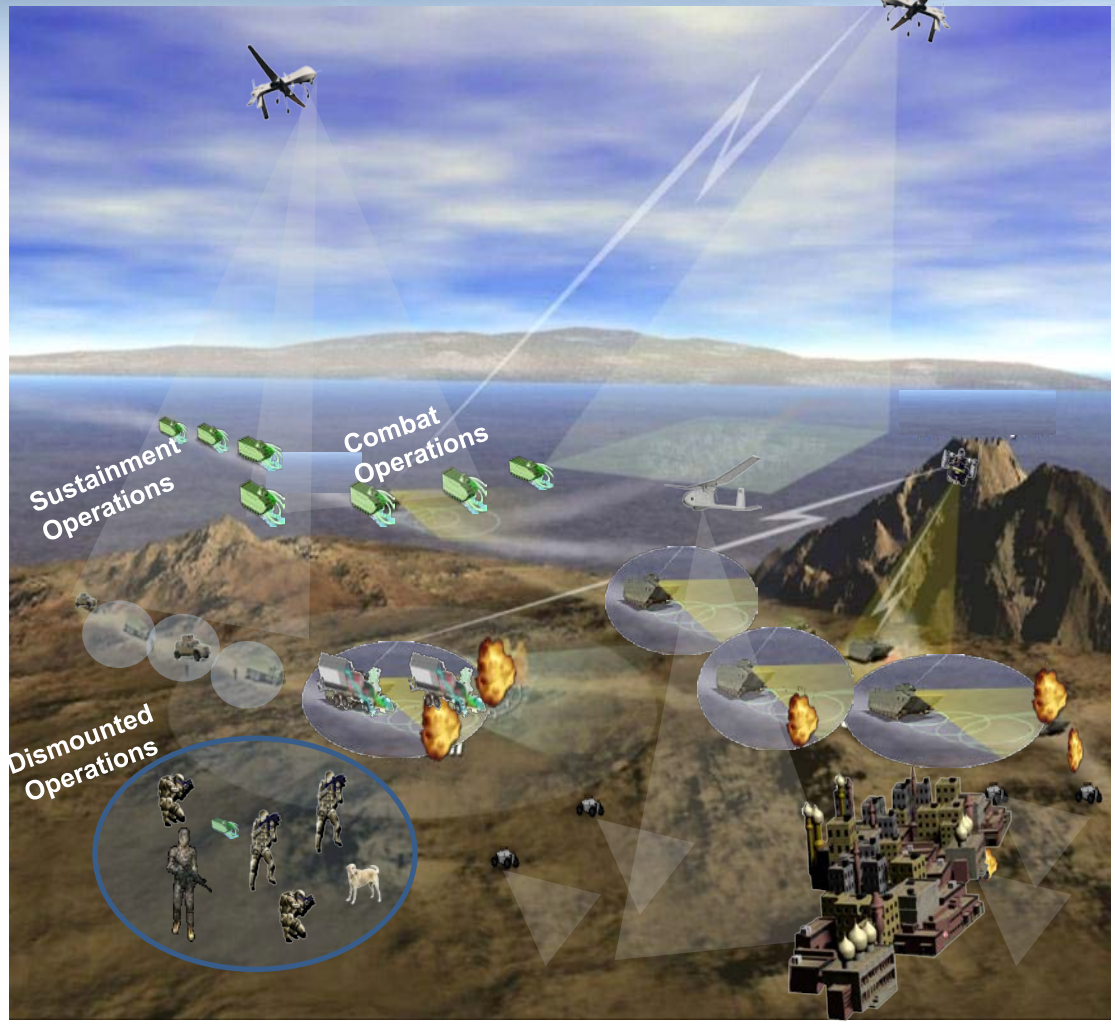
Jeff Bradel, Keith Hammack, & Lee Mastroianni
Program Officers, Expeditionary Maneuver Warfare and Combating Terrorism
15 January, 2013

Distribution statement

Expeditionary Autonomy

- **Goal: Autonomy in Support of Expeditionary Operations**
  - Reduce exposure of personnel to hazardous missions/threats
  - Increase operational tempo and freedom of Maneuver
  - Enable efficient logistical resupply in support of Future Maritime Operations
  - Lighten the load of the MAGTF and serve as a force multiplier

Domain of Interest: Expeditionary



- Encompasses land, sea/surf zone, and air environments
- Highly complex, unstructured on-road, off-road, and surf zone terrains
- Includes a wide range of dismounted and mounted/vehicular threats

Autonomy from Ship to Inland Objective

Future Research Directions of Interest

- Affordable Platform Agnostic Modular Autonomy Kits for current and future fleet vehicles

- Seamless and Natural Visual and Verbal Human Robot Interaction (doctrinally correct understanding and behavior)

- Multi-platform collaboration in support of Explosive Hazard Defeat

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Relevant Program Officers

Program	Program Officer	Code
Maneuver and Ground Autonomy	Jeff Bradel	30
Maneuver and Ground Autonomy	Keith Hammack	30
Force Protection and Explosive Hazard Defeat	Lee Mastroianni	30
Logistics	CAPT Frank Furman	30
Human Performance Training and Education	Dr. Peter Squire	30
Semi-Autonomous Fires	Dan Simons	30
Command, Control, Computers, Communication	John Moniz	30
Intelligence, Surveillance, Reconnaissance	Martin Kruger	30

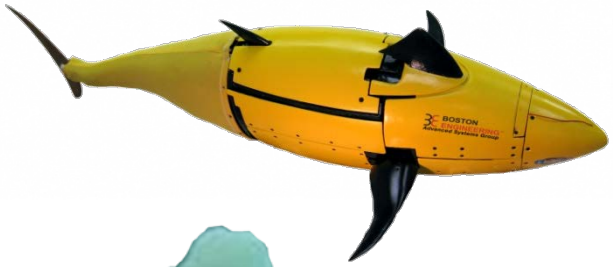
Novel Platforms

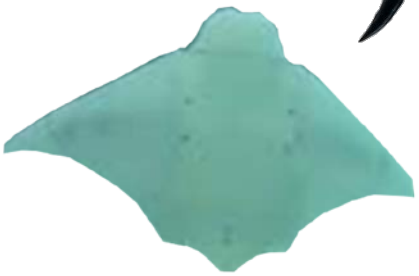
Thomas McKenna
Program Officer, Human & Bio-Engineered Systems
15 January, 2014

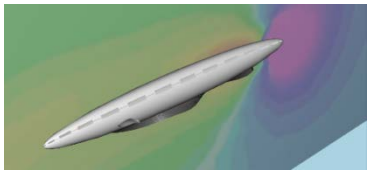
Distribution statement

Novel Undersea Vehicles

- Goal: Develop stealthy, highly efficient, highly maneuverable vehicles – exceeding current engineering
- Approach: Exploit biological principles of propulsion, sensing and control in aquatic animals
- Payoff: Underwater vehicles that operate autonomously in harbors & rivers – swimmer defense, ISR, covert missions



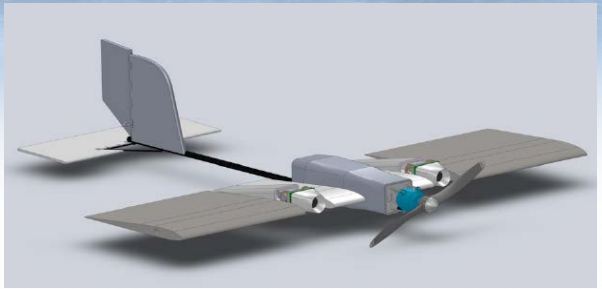




Novel Air Vehicles

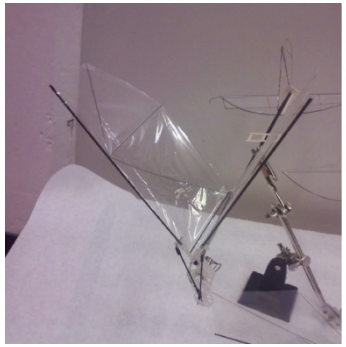
Goal: Develop air vehicles capable of agile maneuver through clutter - under tree canopy, inside buildings & ships

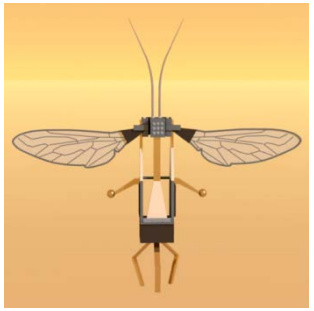
Approach: Exploit sensing, control and biomechanics of flying animals



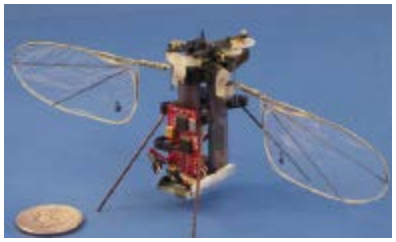
Tedrake MIT - Agile wingeron that can do knife edge maneuver to fly through clutter

Lentink Stanford bio-inspired folding wing to fly through small gaps/clutter





Harvard fly



UMD flapping wing

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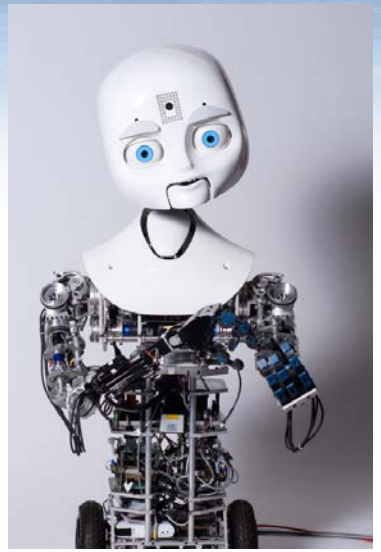
Humanoid Robots



Goal: Develop robotic teammates capable of dangerous missions (fire fighting, building recon) and relieving sailors of time-consuming low-level tasks (maintenance inspection, roving watch).

Approach: Exploit biomechanics, advanced machine perception and control to develop advanced humanoid robots

Develop natural human robot interaction technologies so that robot can be tasked as a sailor/marine.

Future Research Directions of Interest

- Closed loop control using biosensing (optic flow, biosonar, electrosense, lateral line) and interactive perception (undersea and air)
- Fundamental understanding of the hydrodynamics of high efficiency bio-inspired underwater propulsion
- Compact, low power perception and mapping for nano-UAVs
- Muscle-like actuators and multifunction material control surfaces (undersea and air)
- Natural human robot interaction (natural language, gesture)
- Higher level control of reaching, grasping and manipulation (humanoid, undersea)

Relevant Program Officers

Program	Program Officer	Code
Bio-Inspired Autonomous Systems & Humanoids	Tom McKenna	34
Bio-inspired underwater propulsion	Bob Brizzolara	33
UAS Autonomy	Marc Steinberg	35
Advanced Undersea Vehicles	Tom Swean	32
Mine Sensing with Autonomous Undersea Vehicles	Jason Stack	32