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Unmanned Aerial Vehicles
A Disruptive Technology

Philip Heermann, Ph.D.

Intelligent Systems, Robotics, and Cybernetics

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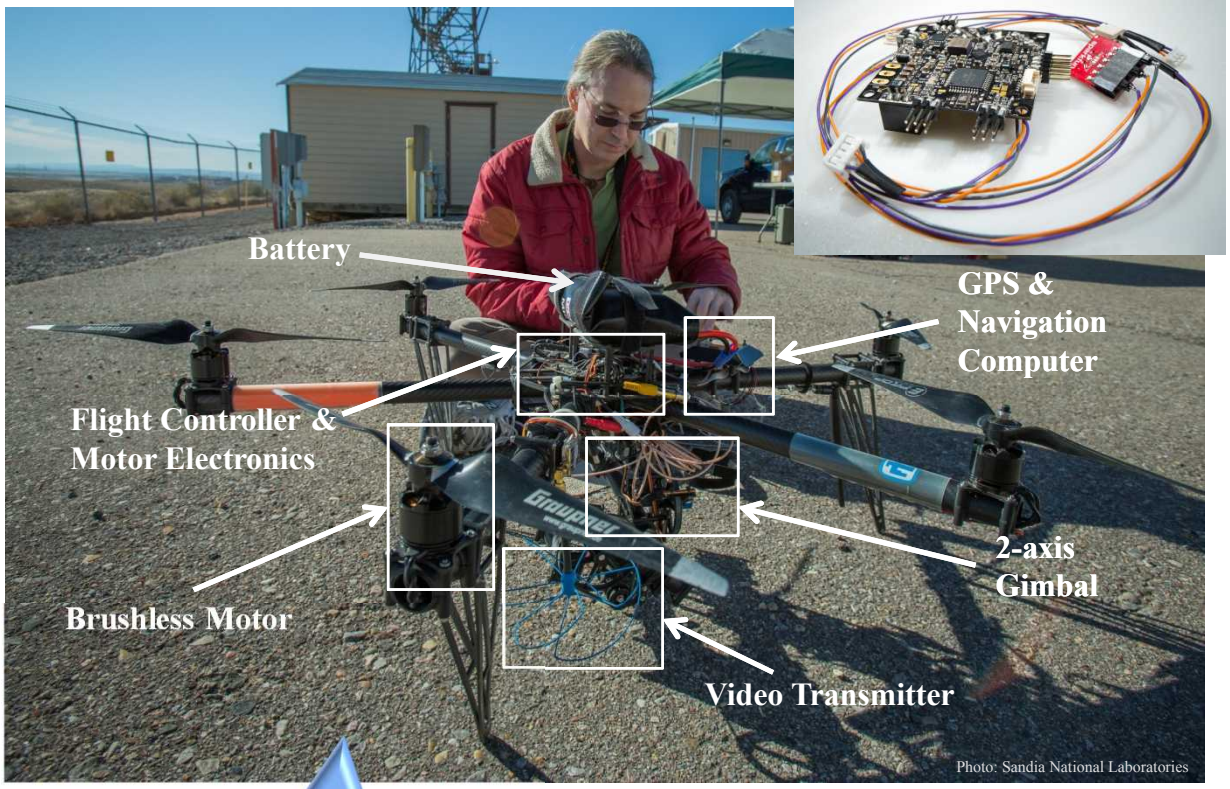

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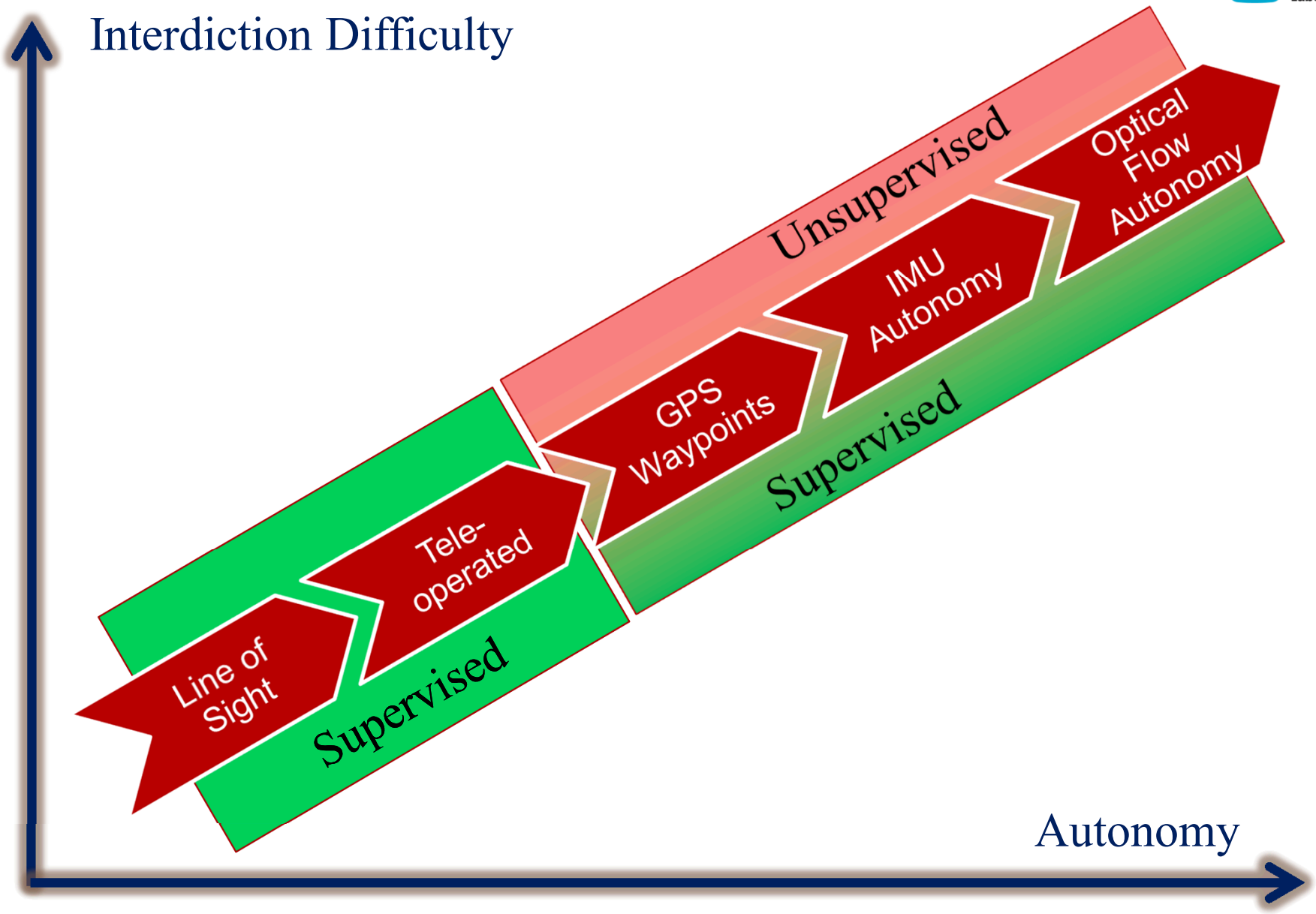
Hexacopter:

- 4lb payload
  - 10-12 minutes
- 10lb
  - 5min

Octocopter:

- 12lb payload
  - 10-12 minutes
- 20lb
  - 5min

Speeds of 70+ MPH


Interdiction Difficulty
Unsupervised
Optical Flow Autonomy
IMU Autonomy
GPS Waypoints
Supervised
Tele-operated
Line of Sight
Supervised
Autonomy

Notional Aircraft Separation

	Visual	Radio	Transponder	Ground Radar	Air Traffic Control	Altitude Separation Regulations
Airport Airspace						
Class Bravo						
Class Charlie						
Class Delta						
Class Echo/Golf						
Inflight						
Class A (+18,000 ft)						
VFR (3000 AGL - 17,999MSL)						
IFR (3000 AGL - 17,999 MSL)						
Equipment Availablity						
Airliner						
Helicopter						
Light Aircraft						
Glider						
Hot Air Balloon						
Advertising Ballon						
Hang Glider						
Kite						
Crane						

Mandatory

Optional

This is a simplification of airspace separation - See FAA regulations for details

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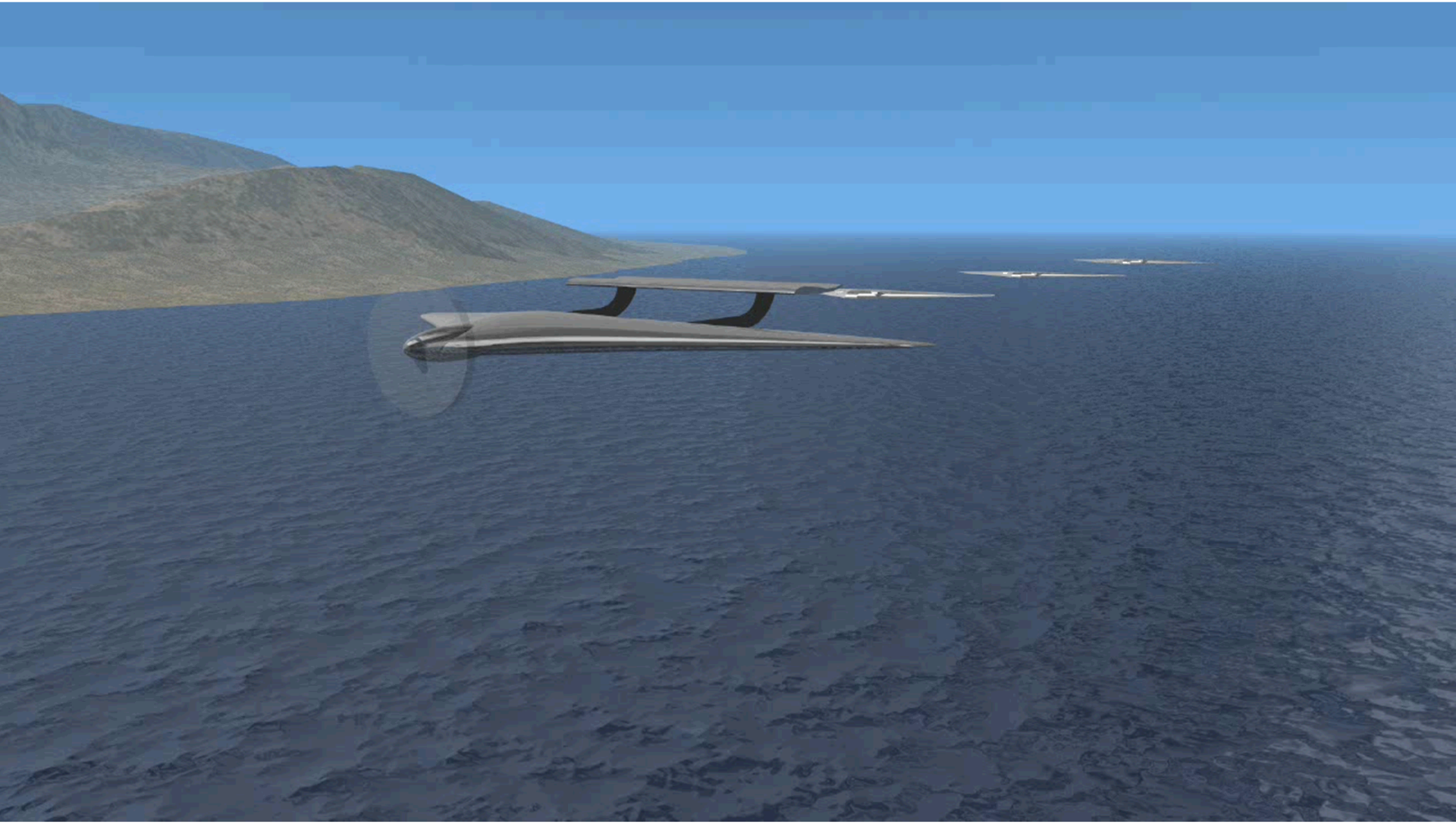
ABQ Photo courtesy Bill Tondreau www.sumnerdene.com

Multi-modal Robotics: Volant



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Questions?

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Changes in Perspective: Looking to the Future

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Current Perspective	Future Perspective
Few High Value Robots "Everything Must Work Perfectly"	• Many Low Value Robots • Okay to have a few fail
Inherit Manned Approach "High rate of action, must bring sufficient energy"	• Free of manned requirements • Variable rates of action • Harvest energy from environment

The Next Arms Race may be a Control Algorithm Race

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Majority of discriminating technology can transfer and remove Pilot induced limitations

However, pilot Training, Tactics and Procedures (TTPs) are key discriminators

F35 – Manned Fighter Source: U.S. Air Force

X-45C UCAS

For an Autonomous UAV, Tactics and Procedures are Control Algorithms
(training is trivial)

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Hierarchy of Control Algorithms

Government Domain

Strategic

Asset allocation and establishment of tactical objectives

Tactical

Objective completion, multi-unit coordination

Industry and Academia Domain

Behavioral

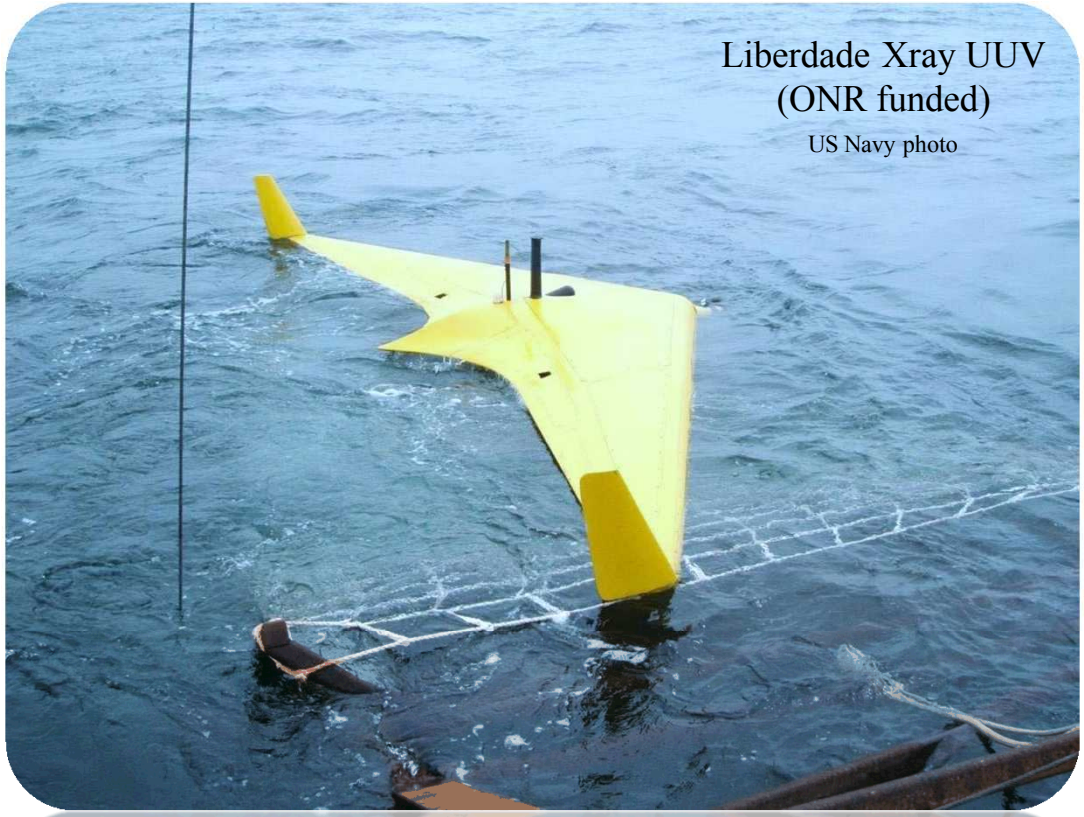
Transit, avoid net, hide,…..

Autonomic

Basic functions: dive, communicate, …

Internal Functional (low-level)

Control thruster motor speed



Liberdade Xray UUV
(ONR funded)
US Navy photo

A New Force Projection Paradigm?

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Diplomacy --- Unmanned Systems --- Prompt War

Long Duration Sustainable
Indirect Destruction

Shorter Duration
Direct Destruction

Slow Persistent War

A Branch of Cyber?

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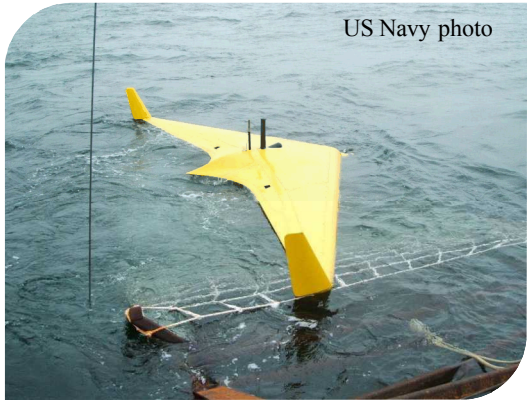

Virtual Space Fixed Assets Mobile Assets

Spectrum of Cyber Effects