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Draper Autonomy:
All Domain Execution & Planning Technology (ADEPT)

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The Charles Stark Draper Laboratory, Inc.
555 Technology Square, Cambridge Mass. 02139-3563
CAGE Code: 51993

Draper Overview

- Independent, not-for-profit lab
- Mission:
  - *Applied research and development*
  - *Technology transition: turning technologies into capabilities*
  - *Advanced technical education*
- Headquartered in Cambridge, Massachusetts
- >$660 million in fiscal 2020
  - *1,900 employees*
  - *1,200 technical*

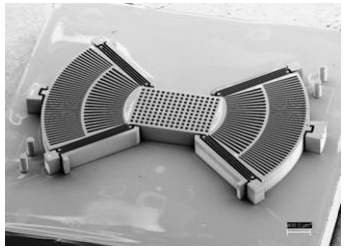
Apollo Guidance Computer

Orion Reentry Guidance

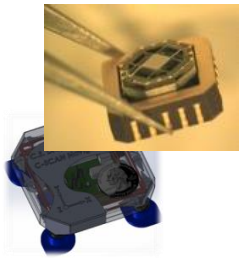
Digital Fly-by-Wire

Unmanned System Autonomy

Strategic Guidance Systems

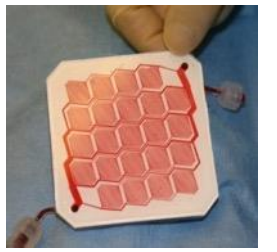


MEMS

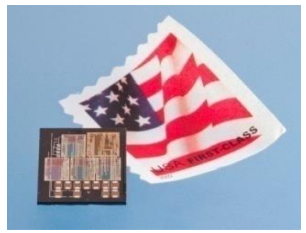


Cold Atom Sensors

RF-addressable Micro Neural Stimulator



Micro Fluidics



Ultra-High Density Electronics

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Draper's Autonomy Solutions Span the Air, Space, Undersea, and Terrestrial Domains

Autonomy for Low SWAP platforms

TRN & Hazard Avoidance for Lunar landing

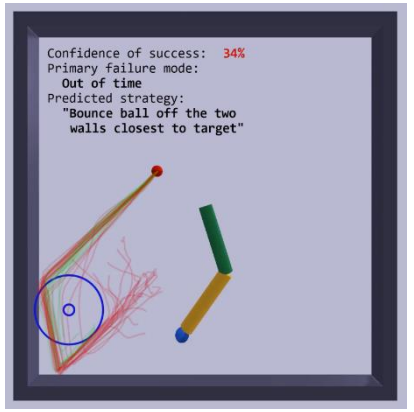
Autonomous Resupply

Registered AR for Dismounted Operations

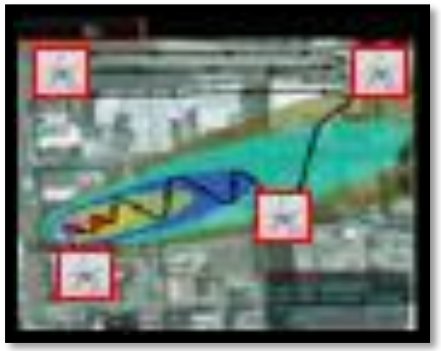
Autonomy for Group 1+ UAVs

Autonomy for Unmanned Underwater Vehicles

Autonomy for Mobile Manipulators



Competency Aware Machine Learning for Autonomy



Aerial Autonomy for CBRN Missions

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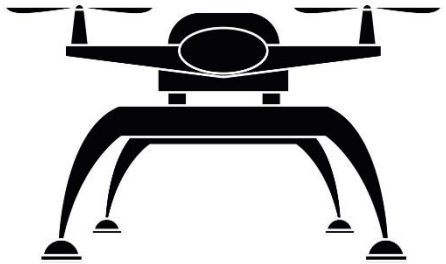
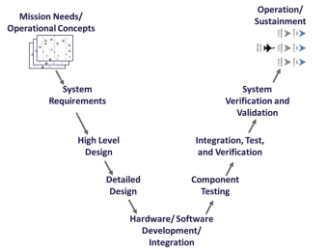
Autonomy is a Confluence of Technologies

Platform



Development & Test Capabilities



Perception & Autonomy SW

Mission autonomy function: Target tracking

Mission perception function: Object recognition

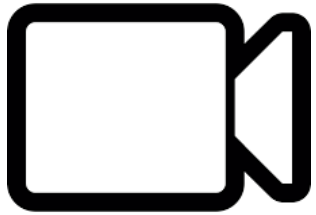
Core autonomy function: Motion Planning

Core Perception function: VIO

Mission manager

Autonomy Architecture

Sensors



C2/User Interface

Autonomy is a Confluence of Technologies

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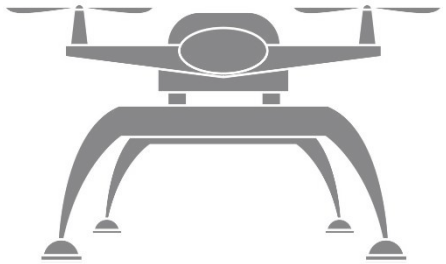

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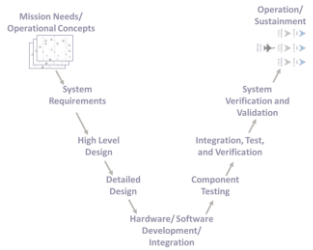

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ADEPT Mission manager

Autonomy Architecture

Sensors

C2/User Interface

Autonomous Mission Management

Requirements

1. Ability to take high level operator mission definitions
2. Ability to plan complex missions in real-time
3. Ability to monitor mission execution and re-plan as necessary
4. Ability to integrate with various sensor modalities & platform types
5. Ability to quickly reconfigure to address various missions types

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ADEPT Mission Manager

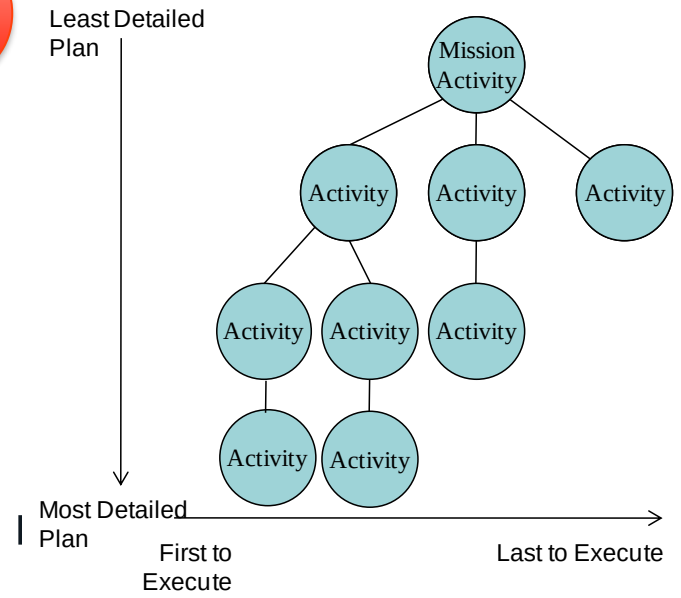
- Missions are made up of functional blocks that abstract low-level autonomy functions
- Hierarchical mission decomposition enables fast planning times for even most complex & long-duration missions
- Closed-loop planning via OODA loop enables mission monitoring & re-planning
- Implementation separates autonomy function from sensor & platform interfaces
- Each autonomy functional block is reusable across missions, enabling fast reuse

Draper Autonomous Mission Management:

All Domain Execution & Planning Technology

1. Hierarchical task decomposition
   - Allows user to specify high level goals which are broken down into low level simple tasks the system can execute
   - Simple tasks facilitate re-use
2. Sense-reason-act paradigm of intelligence
   - Each functional block is implemented in a closed loop fashion, allowing for dynamic re-planning as needed
   - Plan/Execute/Monitor/Diagnose
3. Modular, re-usable object oriented software
   - Sensor and platform abstraction layers allow for easy re-use

1



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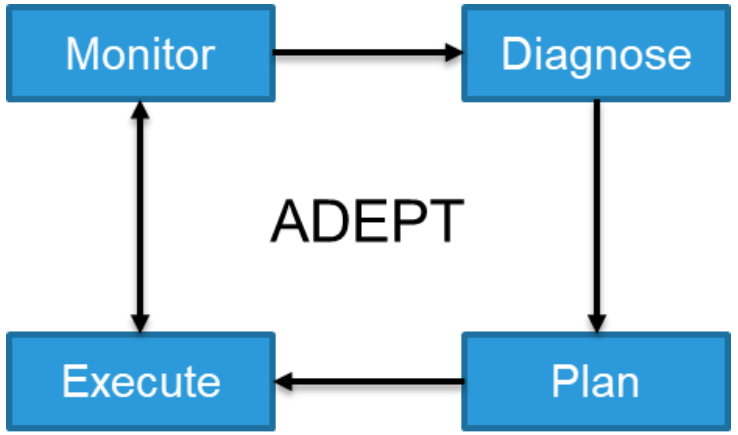

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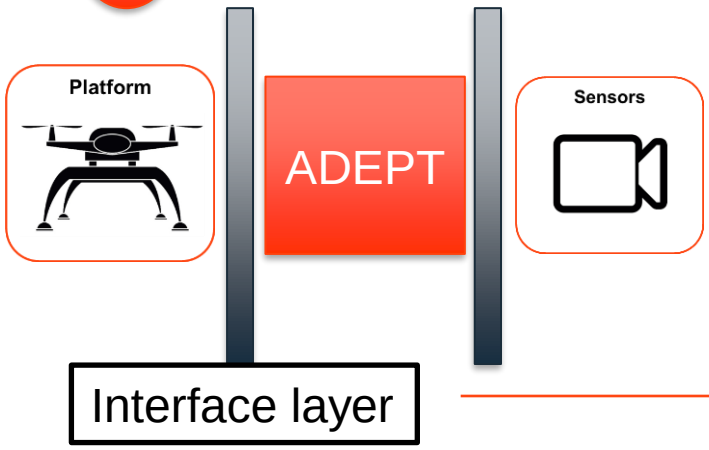

ADEPT Mission Manager Codebase History

2019-2020 and Beyond

2014
Small autonomous UGV

2018
UGV for precise navigation of complex environments with no human intervention

2015 *UAV for precision emplacement*

2017
Counter drone interceptor

2015 Squad-X- *UAV & UGV Human-Machine Cooperation*

2018 Counter UAS
Counter drone interceptor with net launching system

Robotic Autonomy

2019 Robotic autonomy baseline code
For general use

UAS Program

2018
UAV for autonomous tracking and geolocation

CBRN UAV
Autonomous search and contour mapping of CBRN hazards

Counter UAS
Counter drone interceptor with onboard radar seeker

Low SWAP UAS
Indoor obstacle avoidance, GPS-denied localization, and 3D mapping

Legged Platform
Integrate mission manager onto legged UGV

UAV for precision landing and payload delivery

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ADEPT in Action

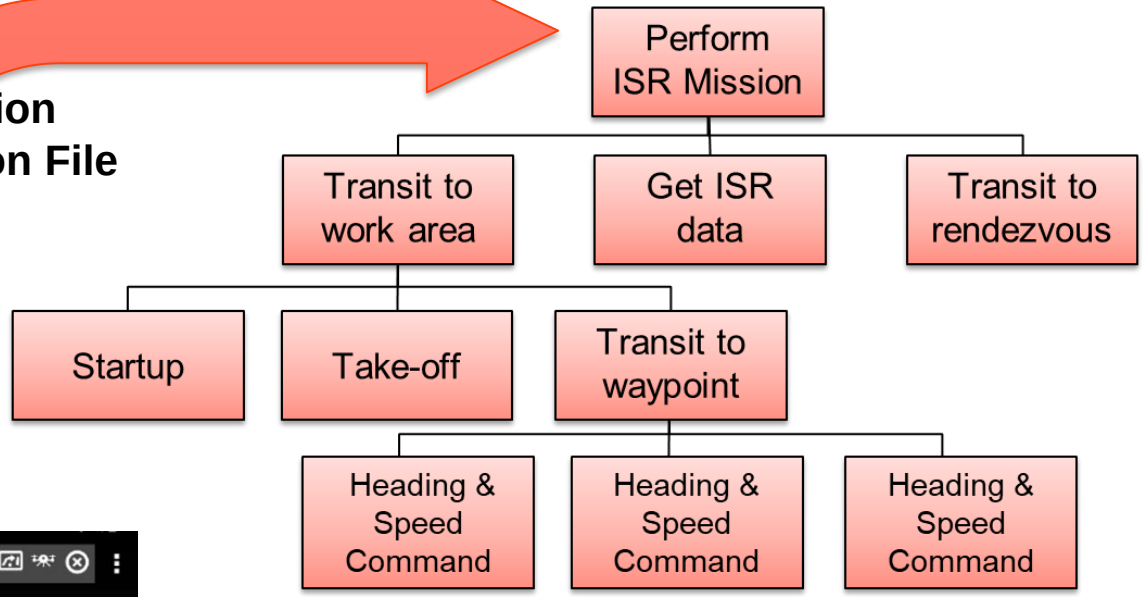
Transit to work area, do wide area search, notify me if red cars are found

Parametrized Mission Data

1

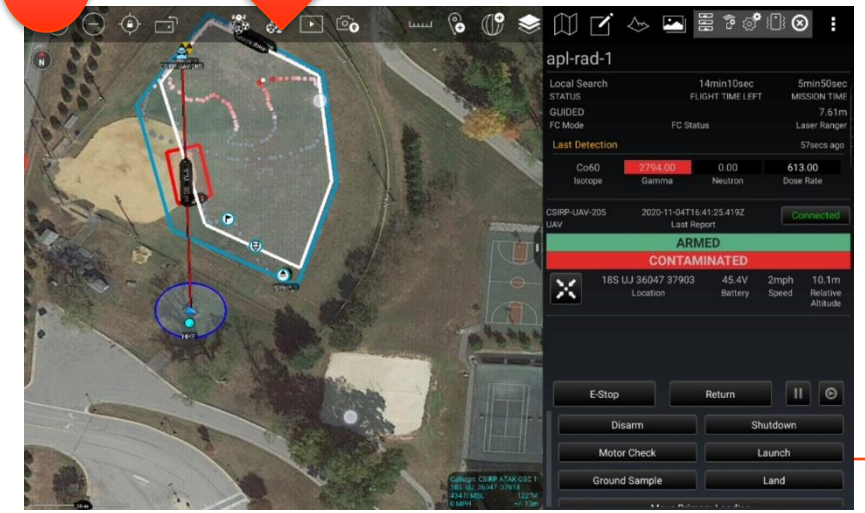
2

Mission Definition File



Mission Monitoring & Re-planning

3



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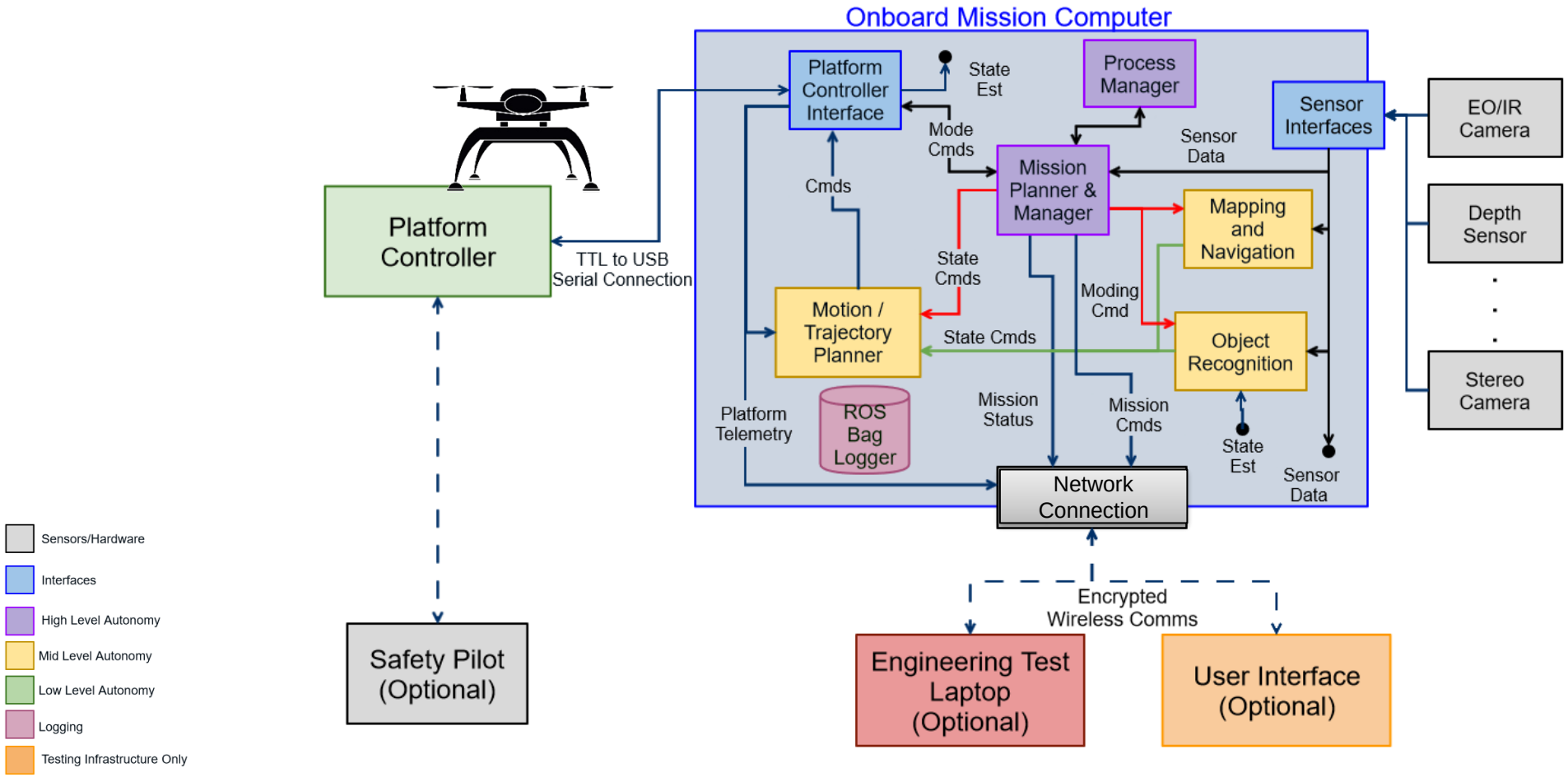
Nominal ROS Architecture

- Architecture flexible and dependent on platform and/or system requirements



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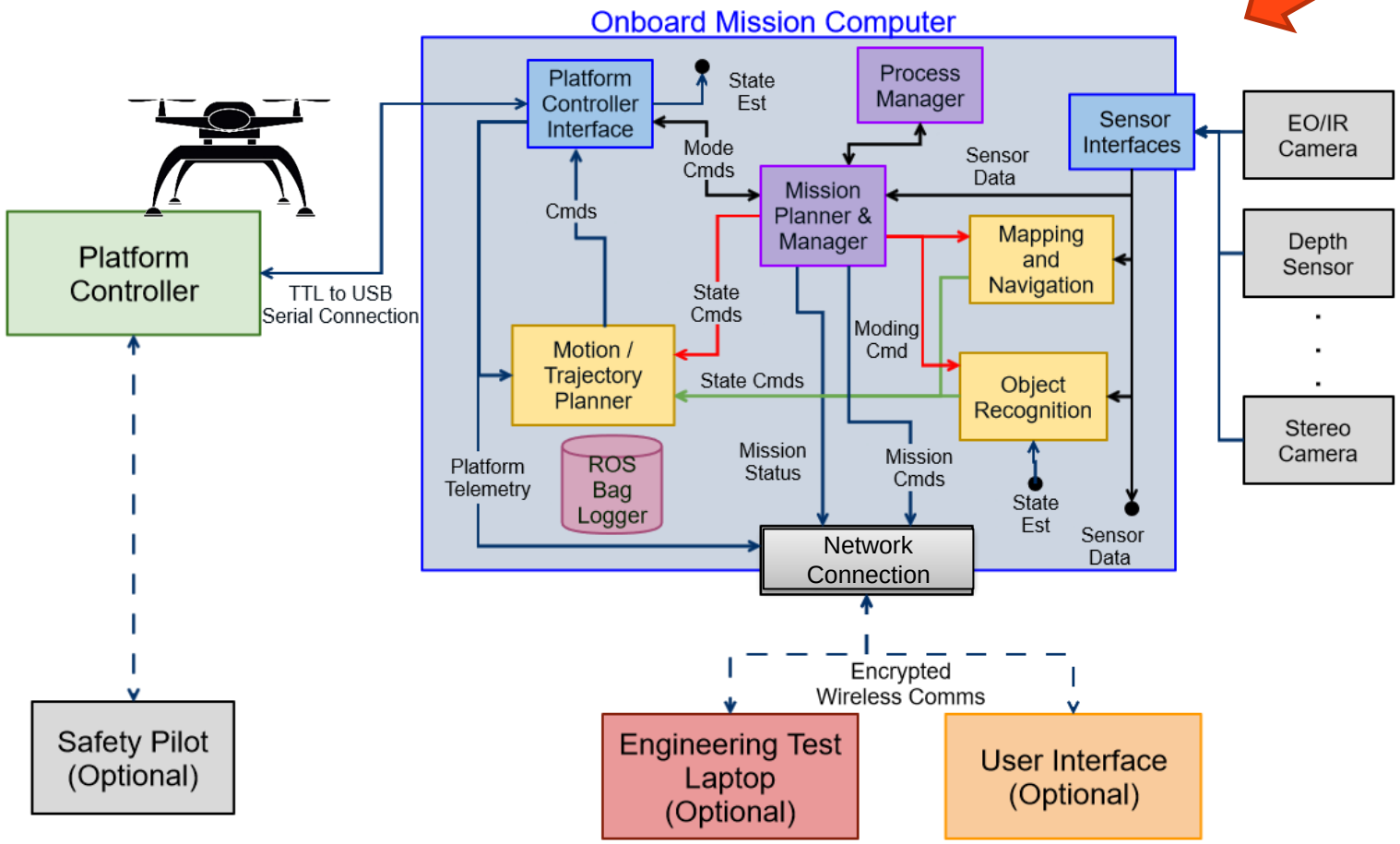

Onboard mission computer with Ubuntu OS runs ROS.

- Functional blocks represent one or more ROS nodes

Examples:

- Intel NUC
- NVDIA Jetson TX2
- NVDIA Jetson Xavier
- Qualcomm Snapdragon
- ModalAI Voxl
- Odroid XU4
- Raspberry Pi 3B+

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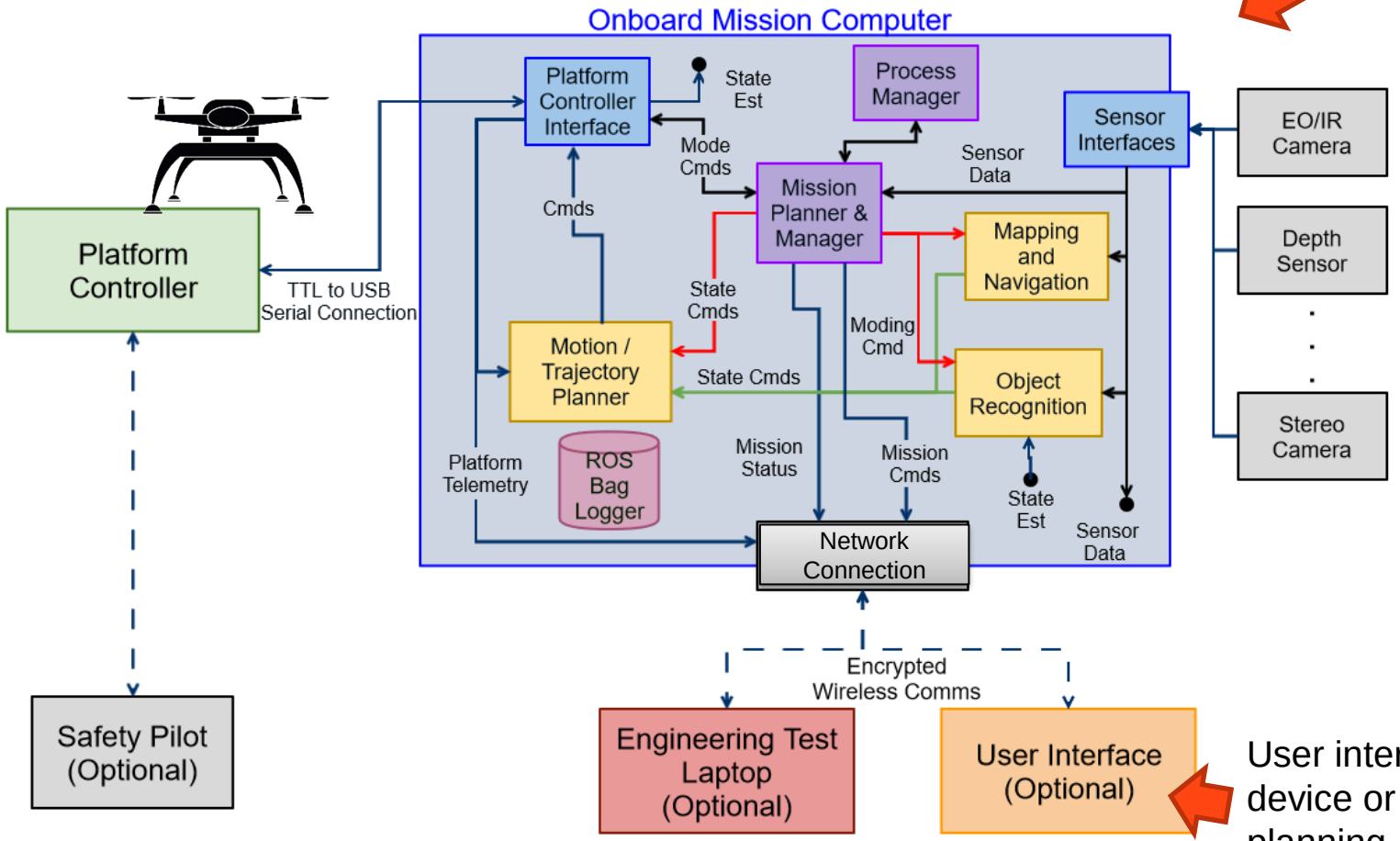

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User interface running on ATAK device or laptop for mission planning, monitoring, and/or C2 over encrypted connection

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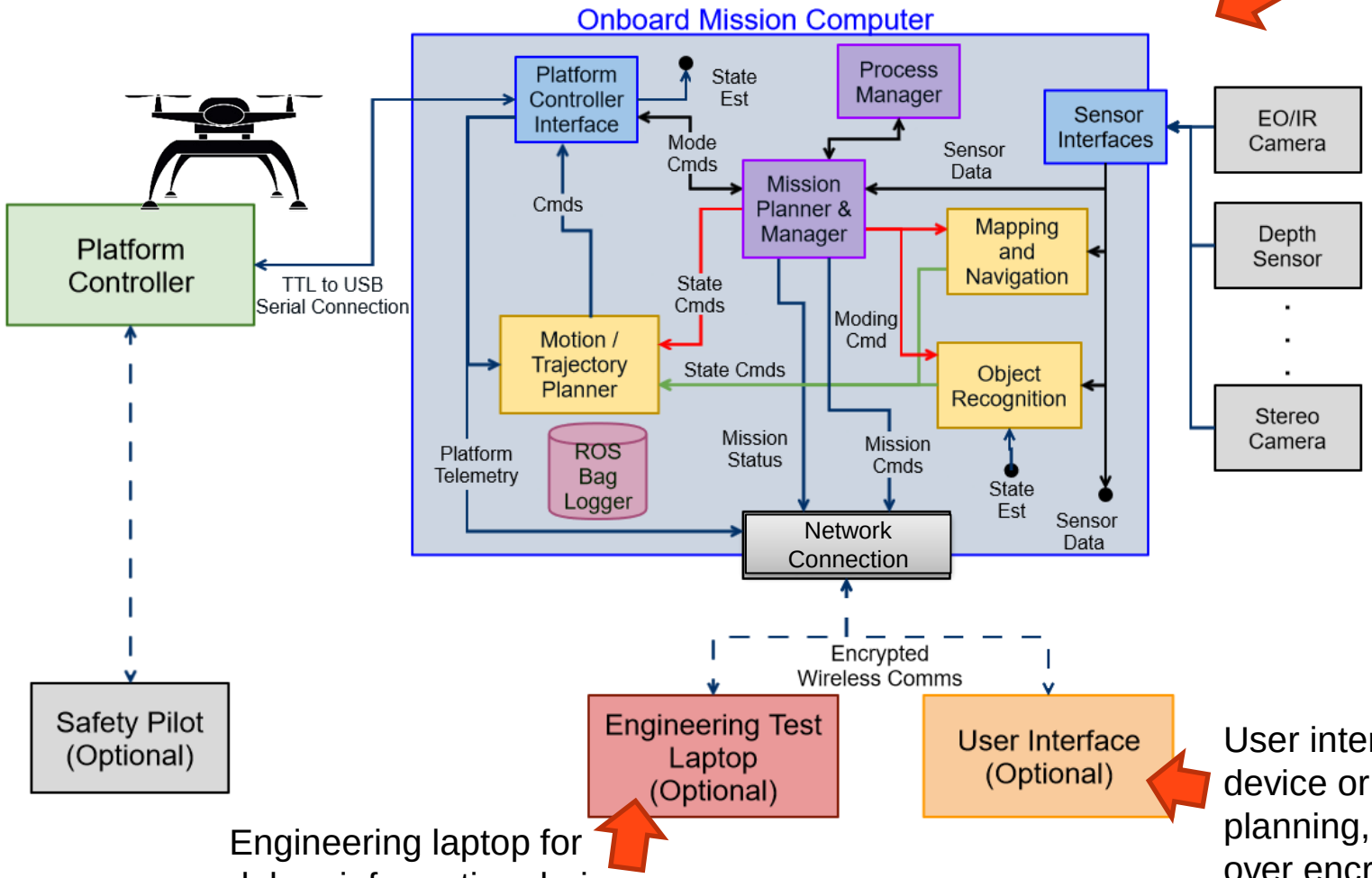

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Engineering laptop for debug information during developmental testing

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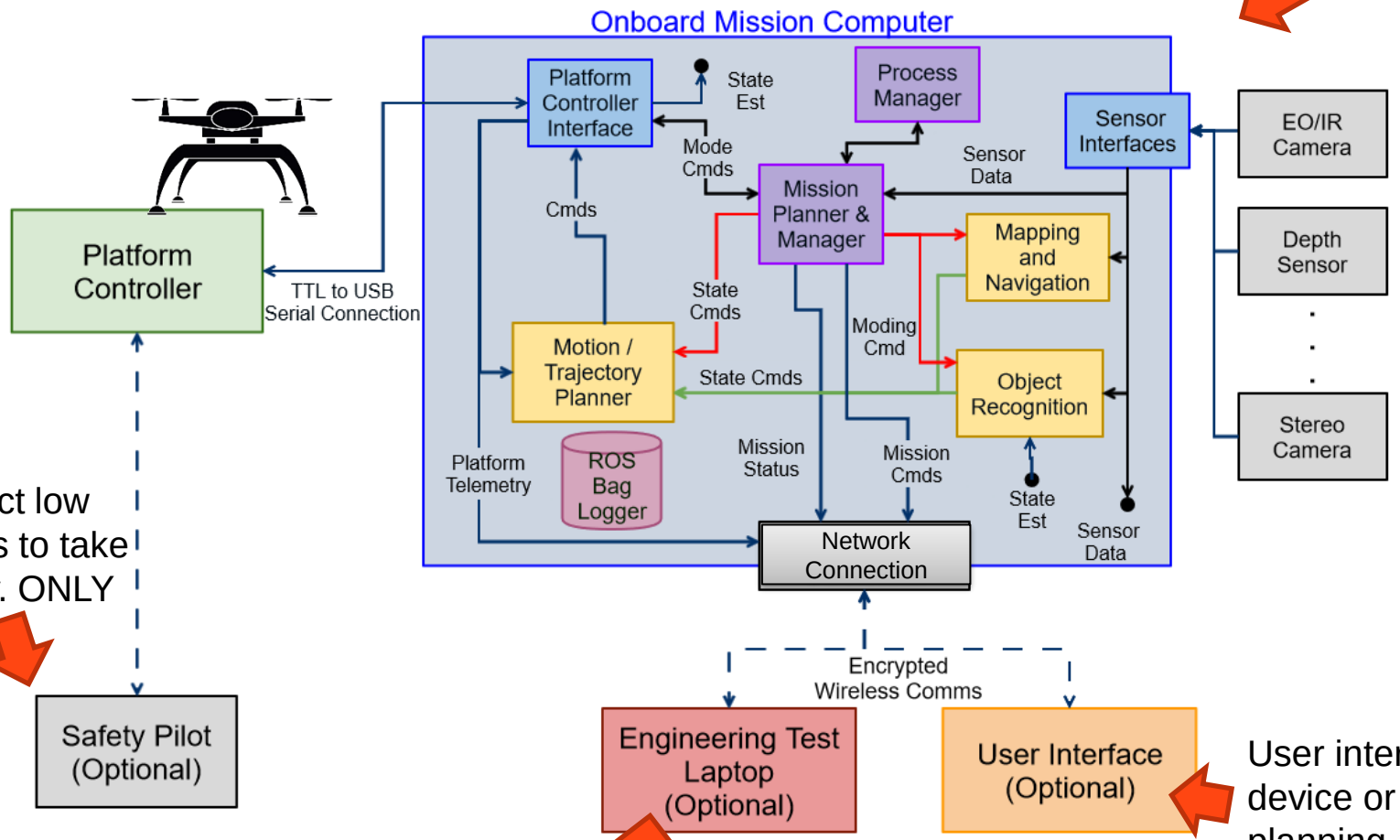

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Safety pilot has direct low level control if needs to take over from autonomy. ONLY FOR TESTING

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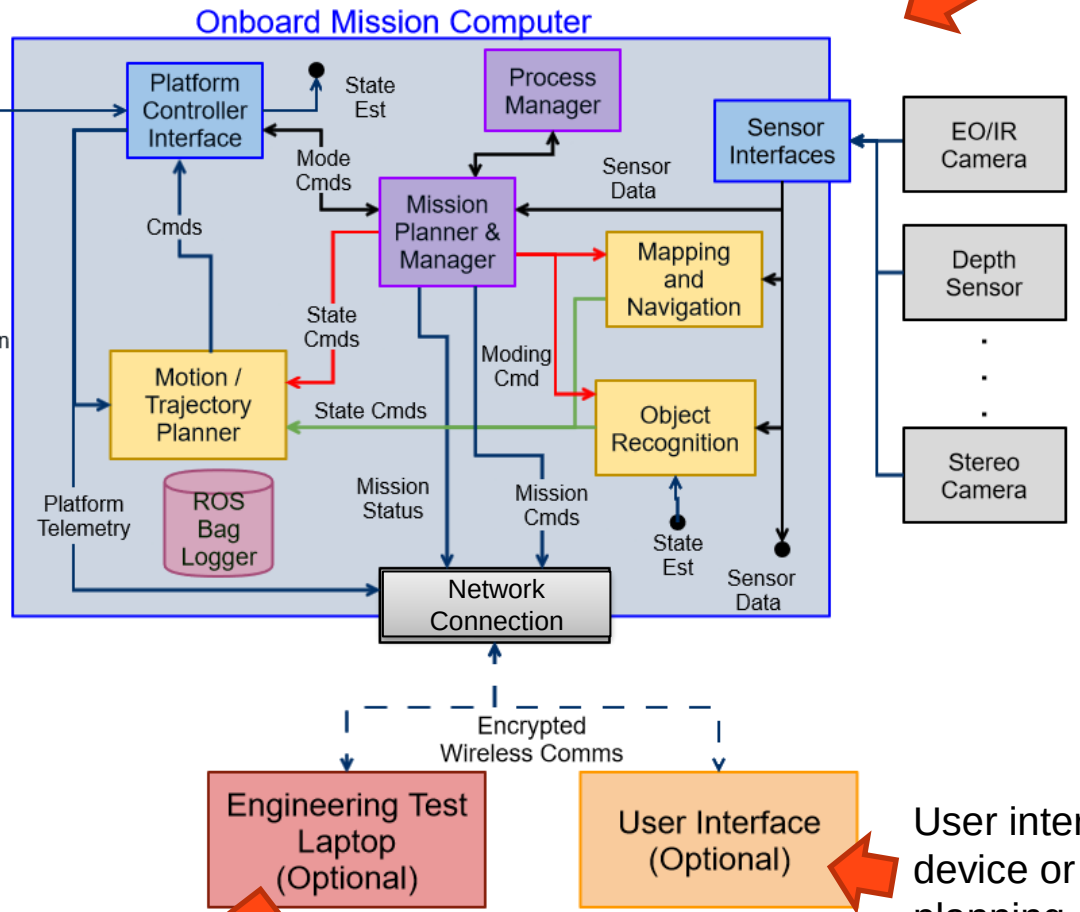
Platform controller handles stabilization and low level control

Examples:
- Pixhawk 2.1
- CubeBlue
- mRo
- Custom UGV controllers



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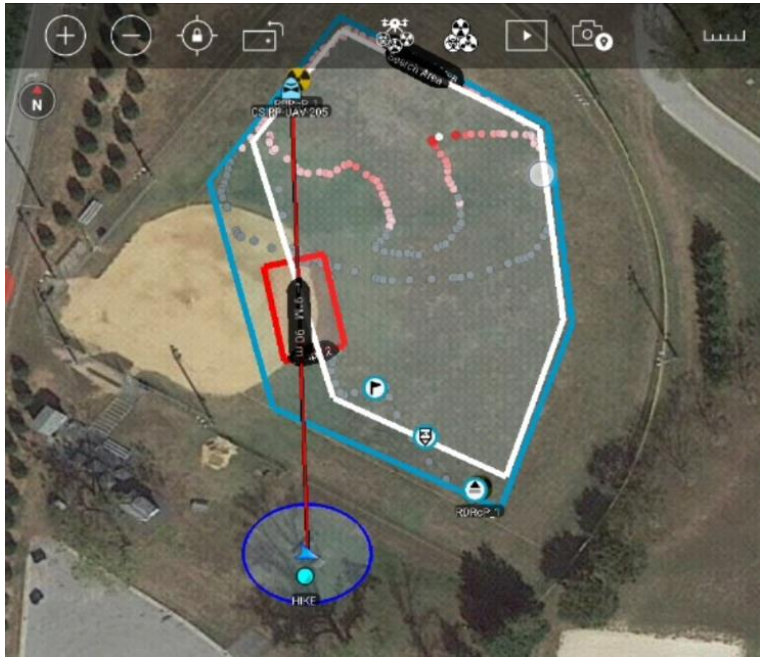
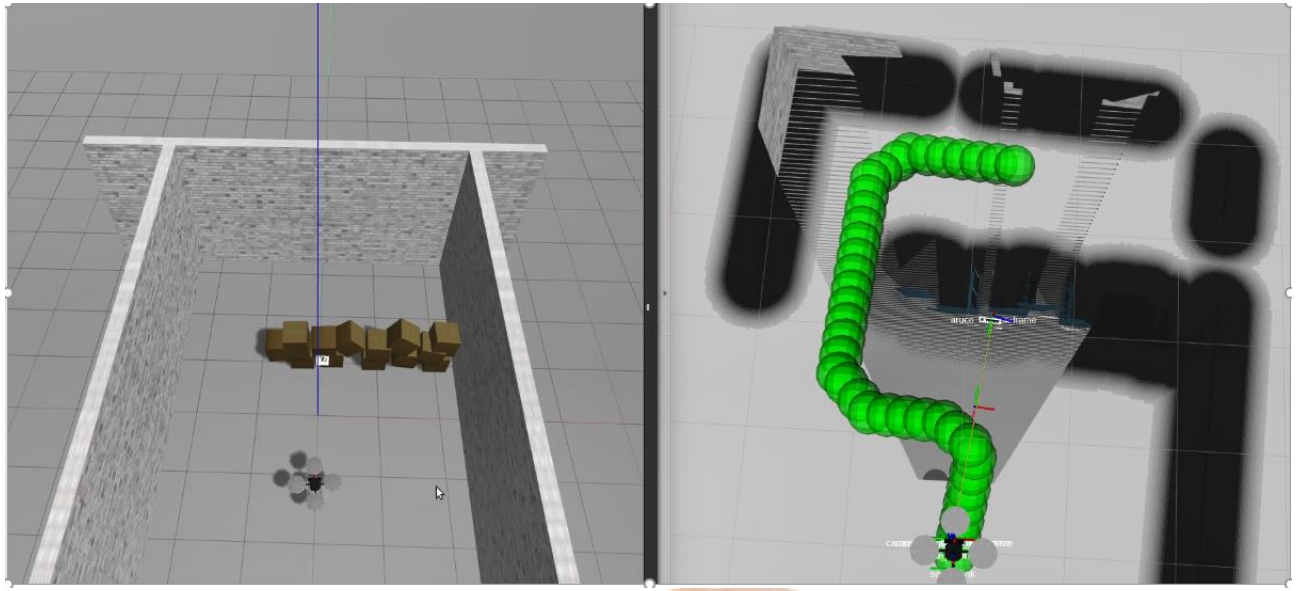
Example Mission: CBRN Hazard Mapping

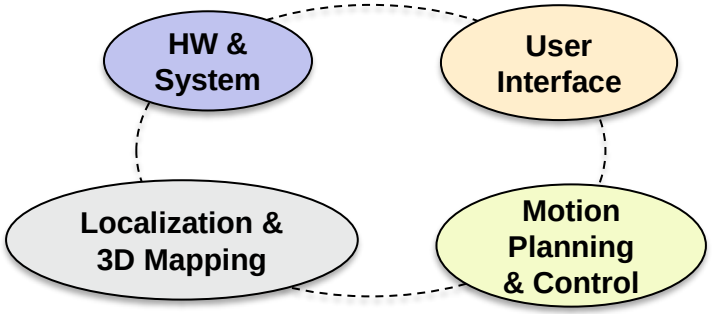
- Multirotor UAV for autonomous search for and mapping of chemical or radiological hazards to protect dismounted forces and fixed sites
- Integrated sensors:
  - *Chemical & Radiological sensors for CBRN mapping*
  - *EO camera for ISR*
  - *Anemometer for improved chemical searches*
- User defined search area drives generic lanes or “lawn mower” search until hazard is detected
- Intelligent smart search drives hazard contour mapping or source localization
- Custom ATAK Plugin provide rapid mission planning, monitoring, and semi-autonomous user control
- Extensive field testing with chemical and radiological sources

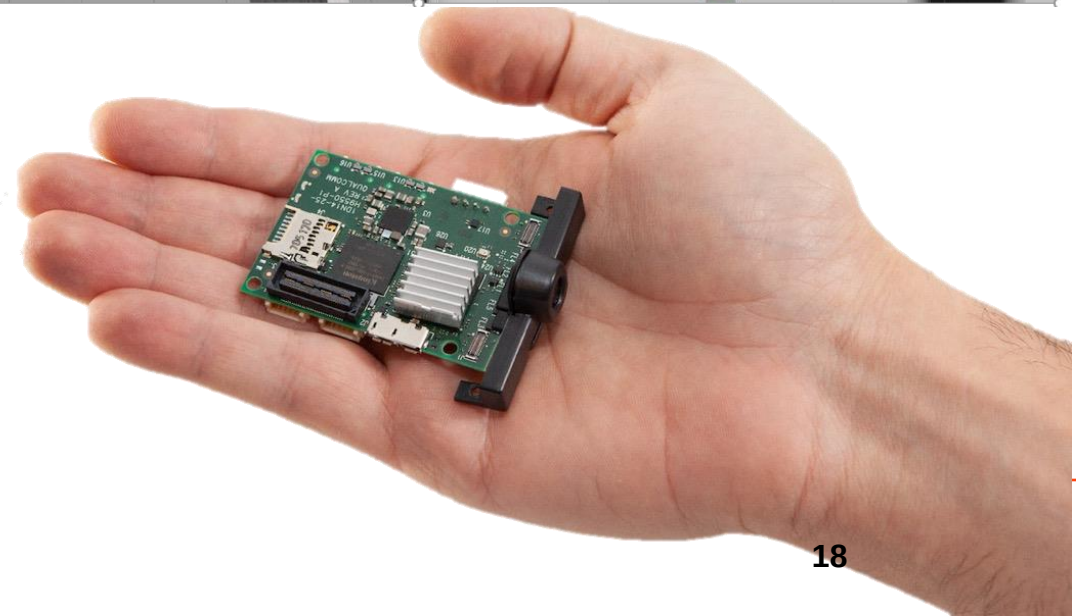


Example Mission: Low-SWAP ISR

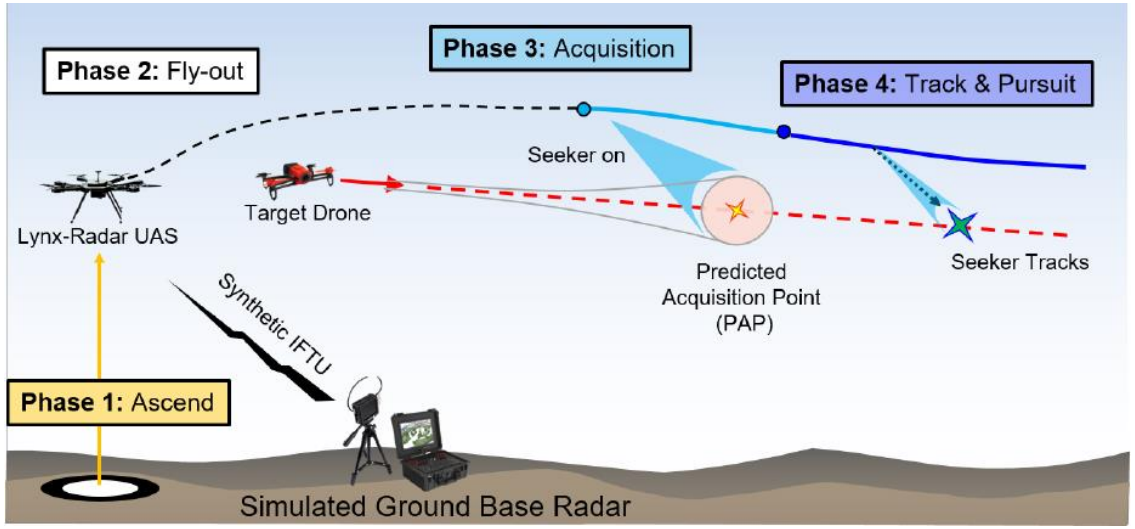
- Advanced perception and navigation of low-SWAP UAS
- Outdoor and indoor operation
- **Included technologies:**
  - *GPS-denied localization in unknown environments*
  - *Depth perception to known/unknown obstacles*
  - *Reliable motion planning and safe avoidance*
- Ensure full on-board processing
- Intuitive Graphical User Interface (GUI)

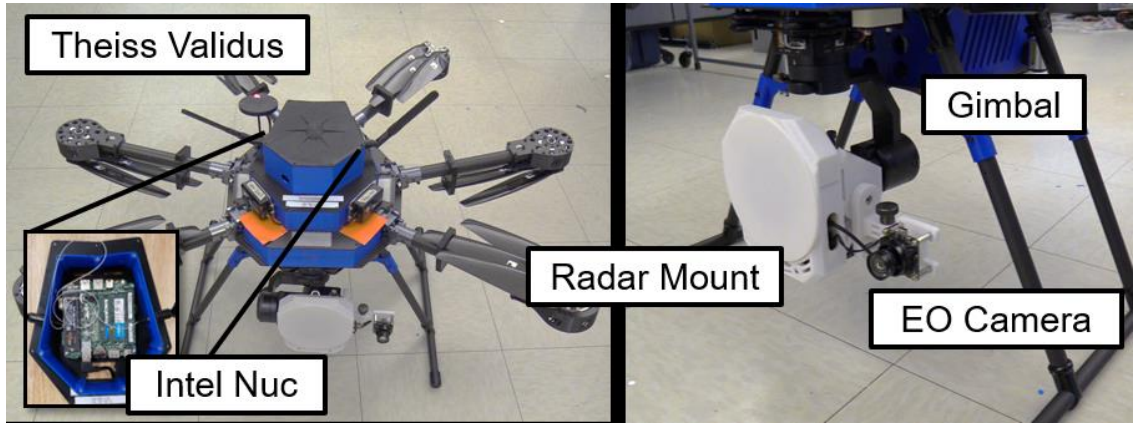


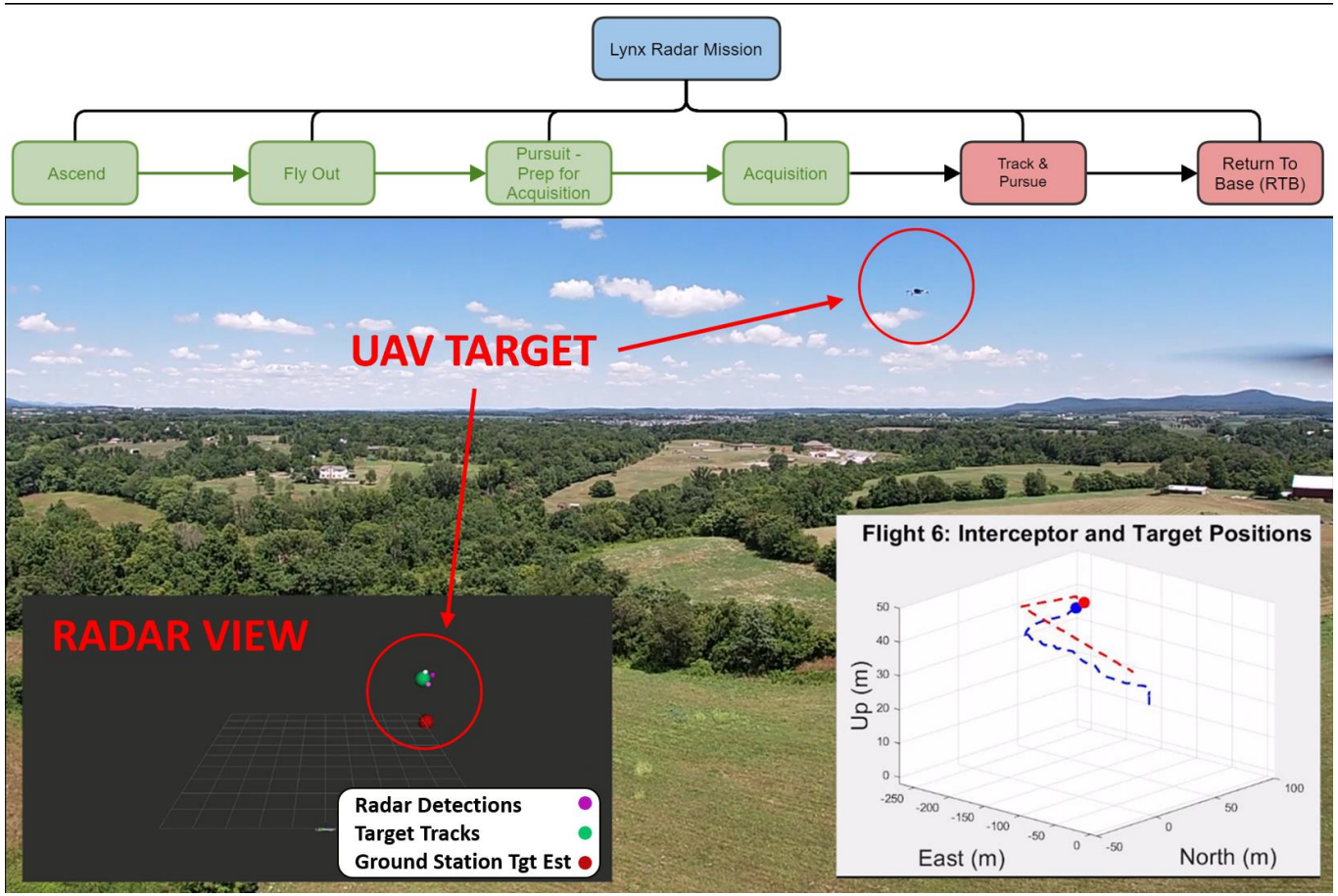




Example Mission: Counter-UAS





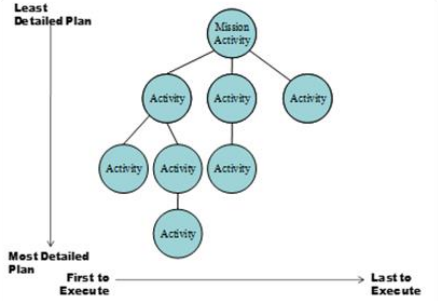


Draper's Mission-Level Autonomy Software Capabilities

- Technology
  - Suite of **autonomy modules** built upon a ROS architecture
  - Capabilities include ***GPS denied Nav, 3D Obstacle Avoidance, Dynamic Mission planning/management, Target recognition/tracking, 3D Mapping,*** *and* ***ATAK human-system interfaces***
  - Emphasis on modularity and reusability
- Technology Insertion
  - Integration/demonstration on a number of platforms: Snapdragon, Theiss Hex, Ascent Spirit
  - Tigershark, BlackHornet Nano, Vantage Vesper

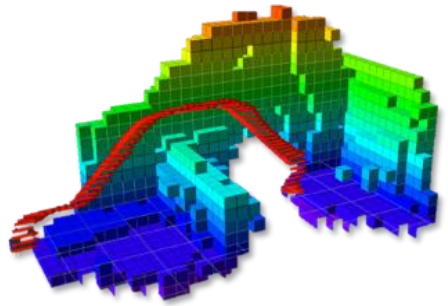
Mission Planning

Aims at decomposing high-level mission



Motion Planning

Aims at planning an obstacle-free path

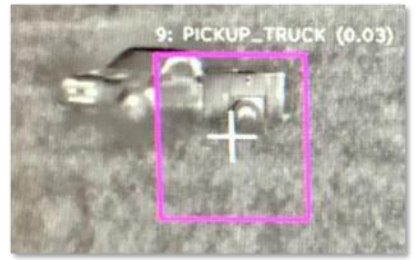


Dense Mapping

Aims at creating a dense tri-dimensional map of the explored environment

Automatic Tgt ID & Tracking

Aims at detecting, identifying and tracking tgt of interest



Explainability in AI

Aims at producing understandable AI solutions

GPS-denied Localization

Aims at estimating UAS location at frame rate

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Questions?

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