L-3 Unmanned Systems

Autonomous Ground Moving

Target Tracking:
An Integrated Approach

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This presentation contains general capabilities information and information within the public domain. This presentation does not contain controlled technical data as defined within the International Traffic in Arms (ITAR) Part 120.10

25 October 2011
Agenda

- L-3 Unmanned Systems Overview
- Autonomous Surveillance of Multiple Moving Targets in Urban Terrain
- Applications in 2011
Unmanned Systems Division

- Guidance, Navigation and Control Systems
- Embedded Software Systems
- Unmanned Aircraft Systems Design and Manufacturing
- Autonomous Systems Advanced Development Engineering
- UAS Family (Cutlass SEUAS, Viking Series Tactical / Expeditionary UAS, Mobius Optionally Piloted Aircraft), UAS Flight Controls (flightTEK), UAS GCS and C2 Systems (missionTEK, linkTEK)
Autonomous Surveillance of Multiple Moving Targets in Urban Terrain

- Paper based on work done for DARPA initiative
- Focused primarily on vehicle control problem
  - Target identification and cueing not addressed
  - Integrated sensor and flight controls to maintain persistent track after track is initiated by user
  - Patent Pending
- Architecture proposed for multi-vehicle collaborative control
  - Communications protocols
  - Track state definitions for handoff
  - Autonomous mission planners determine handoff time/locations
Problem Statement

- Urban canopy enables numerous small enemy urban units to employ highly lethal hit-and-run tactics
- Need to provide persistent surveillance of high value targets traversing through hostile urban environments w/out adding additional cognitive burden to the urban warfighter
- Urban structures (buildings, bridges, etc.) occlude targets, making it difficult to maintain persistent track
- Target movements unpredictable – targets not constrained to roads, can change speed and turn quickly, and can hide behind (or inside) buildings, under bridges, etc.
Key Tenets to Problem Solution

- Small agile UAVs can respond dynamically to unpredictable / unanticipated target movements
  - Maintaining persistent surveillance of moving targets in urban environments is a *dynamic sensor line-of-sight management* problem

- Small agile UAV teams can collectively ensure persistent surveillance through coordinated target track handoffs
  - Target handoff is a target *tracking and discrimination* problem

- Small UAV teams can scan zones looking for and establishing track on moving targets according to a prioritized threat list (initializes tracking problem)
  - Scanning a wide zone is a *sensor field-of-view management* and *target identification* problem
Technology Components

- Autonomous moving target tracking using existing small UAV EO/IR sensors
  - Low cost, low resolution sensors
  - Pan-Tilt-Zoom quality controllers augmented with software stabilization techniques
- Autonomous target discrimination using existing UAV EO/IR sensors
- Autonomous mission planning optimizing sensor coverage for target search, accounting for urban features and UAV performance constraints
- Collaborative vehicle control providing collective zone scanning and target track handoffs
  - Automatic Target recognition
  - Integration via autonomous mission planners
- Integrated sensor/vehicle control providing dynamic (high frequency) sensor line-of-sight management
Integrated Sensor / Vehicle Control

- **Sensor Control**
  - Pan-tilt PWM servo-driven 2-axis (pitch, yaw) controller with gimbal position feedback for sensor plane orientation tracking
  - Sensor stabilized with flight software using an IMU feed-forward technique - provides stable image plane for target tracking
  - Image jitter removed via digital image stabilization
  - Target coordinates (position and velocity) computed in earth coordinates (ECEF and geodetic) using passive target state estimation Kalman Filter

- **Vehicle Control**
  - UAV body to sensor frame kinematics implemented in flight software for line-of-sight stabilization and control
  - Flight software computes target state estimate (position and velocity) from auto-tracker measured boresight errors
  - Flight software commands moving loiter at point guidance
    - Target located at center of loiter pattern
    - Software propagates loiter pattern through inertial space at heading and velocity of target (real-time trajectory synthesis)
Integrated Sensor / Vehicle Control
Functional Design

Autonomous Ground Moving Target Tracking Functional Diagram

Sensor / Tracker → Gimbal Controller → Pan-Tilt Gimbal → Track State Estimator → Guidance → Autopilot → Airframe

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Gimbal Controller

Track State Estimator

Guidance

Autopilot

Airframe

Inertial Pos, Inertial Vel

Navigation Filter

IMU

GPS

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Inertial Pos, Inertial Vel

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Inertial Pos, Inertial Vel

Inertial Pos, Inertial Vel
Integrated Sensor/Vehicle Control

Target Inertial Velocity = 30 Knots
System Development and Evaluations

- System evaluated in high-fidelity hardware-in-the-loop environment
  - Minimize risk to UAV assets
  - Comprehensively assesses proposed technologies – can simulate thousands of scenarios w/ real-world constraints in a timely manner
Demonstration Hardware

- Baseline Capability Scheduled for Live Flight Demonstration in June ’04 Using Following Components
  - Dakota UAV integrated with Variable Autonomy Control System
    - flightTEK™ airborne avionics package (hosts VACS™ airborne software modules)
    - missionTEK (VACS™-equipped multi-UAV ground control station)
    - linkTEK (UDP/IP multi-UAV datalink system)
  - OCTEC Adept-34 PCI Multi-Target Tracker
  - BAI Series 66 Mini-PTZ
Example HIL Simulation Results: Single UAV/Single Target Tracking

- Closed-Loop HIL Simulation
  - Provides setting to test and prototype advanced guidance algorithms for ground moving target tracking on the hardware in real time.

Ground Moving Target Tracking scenario at Desert Center, CA

GMTT.mov
Technology Gains

- Trackers
  - Miniaturization
  - 2004 = PCI, 2011 = Chip

- Turrets
  - Miniaturization
    - Allows application on smaller UAS
  - HD Video
  - Higher Precision

- Video Exploitation Systems
  - Video Scout
VideoScout – Remote Viewing

- Tactical Video Exploitation & Management
- Simple to use, Plug & Play System for Video
  - Recording
  - Exploiting
  - Managing
  - Archiving
  - Disseminating
- Addresses the needs of the Tactical & INTEL user, making video
  - Actionable
  - Interoperable
  - Reusable
- Video support through mission
  - Planning, Execution, Analysis
VideoScout Capabilities

- View Live Video
  - Picture-In-Picture (Real-time + DVR)
  - 90 Minute DVR Buffer
- Capture, View, Annotate, Archive
  - Analog, digital capture
  - MPEG-2, MPEG-4
- Create Video Clips
  - Extract a subset video
- Create Snapshots
  - Enhance/Process Images
- Search Archived Content
  - Compound Search
- Stream or Transmit Video
  - Real-time
  - Match bandwidth
- Formal Training Materials & Users Guide
## Cutlass Small Expendable UAV

### Dimensions
- Wingspan: 55.2 inches
- Height: 4.5 inches
- Length: 32.6 inches

### Weights
- Payload: 3 lbs
- Flight Weight: 12-15 lbs

### Performance
- Max Air Speed: 85 KEAS
- Cruise: 55-65 KEAS
- Op Endurance: 1 hour
- Controlled Range: 30 NM (RF)
- Glide Ratio: 12 : 1

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*Jun 09 Test*
Viking 400 – Expeditionary UAS

Viking 400 Key Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Endurance / Mission Sensors</td>
<td>11.4 hours carrying 75 lbs mission sensors</td>
</tr>
<tr>
<td></td>
<td>8.2 hours carrying 100 lbs mission sensors</td>
</tr>
<tr>
<td>Data Link Range</td>
<td>&gt;70 nm</td>
</tr>
<tr>
<td>Power Available for Sensors</td>
<td>&gt;1.5 KW</td>
</tr>
<tr>
<td>Max Gross Takeoff Weight</td>
<td>530 lbs</td>
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<tr>
<td>Propulsion</td>
<td>Zanzottera 498i, 38 HP</td>
</tr>
<tr>
<td>Wing Span</td>
<td>20.0 ft</td>
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<tr>
<td>Launch / Recovery</td>
<td>Autonomous Takeoff</td>
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<tr>
<td></td>
<td>Autonomous Landing</td>
</tr>
<tr>
<td>Mission Sensor Bay Volume</td>
<td>23” Long x 19” Tall x 16” Wide</td>
</tr>
<tr>
<td>Cruise / Dash Speeds</td>
<td>60 kts / 90 kts</td>
</tr>
</tbody>
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L-3 Awarded UAS U.S. Special Operations Command Expeditionary UAS Contract
Integrated Sensor/Vehicle Controls

- Enables Easy Collaboration
  - A mission planner/coordinator merely needs to hand-off target state between vehicles
  - No new guidance steering commands, waypoints, etc. needed
- Minimizes Operator Workload
  - Designate target and command track
  - Focus on video, not vehicle controls
  - Target flies the vehicle
- Leverages future technology gains with minimal architecture changes
  - Trackers
  - Video exploitation systems
  - Turrets/Cameras
Benefits to Urban Warfighters

- Significantly reduces vulnerability to enemy urban unit hit and run tactics by:
  - Delivering high quality threat situation awareness in real-time w/ minimal to no increase in soldier’s cognitive load
  - Provide real-time persistent surveillance of high priority threats

- Significantly increases urban warfighter’s ability to prepare high quality intelligence assessment of the urban battlefield