SURVEY OF SENSOR PAYLOADS for UAVs

NATO SET Meeting
Advanced Sensor Payloads for UAVs
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Lisbon, Portugal

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**Survey of Sensor Payloads for UAVs**

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**ABSTRACT**

**SUBJECT TERMS**

**SECURITY CLASSIFICATION OF:**
- a. REPORT: unclassified
- b. ABSTRACT: unclassified
- c. THIS PAGE: unclassified

**LIMITATION OF ABSTRACT**
UU

**NUMBER OF PAGES**
26
SURVEY of UAV SENSOR PAYLOADs

• BACKGROUND on SURVEY
• EO/IR SENSORS
  – FLIR
  – IRST
  – Multi / Hyperspectral Infrared
• LASER SENSORS
  – LIDAR (soft targets)
    • Pollution Monitoring
    • Chem / Bio Sensors
  – LADAR (hard targets)
    • Obstacle Avoidance
    • Terrain Mapping
• RADAR SENSORS (MTI / SAR)
  – Surveillance & Reconnaissance
  – Targeting & Fire Control
• ELECTRONIC WARFARE SENSORS
  – Precision ESM Sensors
  – Missile Warning Receivers
• TARGET LOCATION ERROR (TLE)
• AUTOMATIC TARGET RECOGNITION / BDA
• SUMMARY
Background on Survey

• Original surveys performed for Navy UAV Programs and summarized in CY2000 reports
• Types of information in each report
  – UAV sensor payloads (< 200 pounds)
  – Small UAV sensor payloads (<40 pounds)
• Presentation represents excerpts from reports
• Updated with new sensor payload information
TABLE 4. Hypothetical MWIR 512 x 512-Element Staring FPA Sensor Design Parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture diameter (cm)</td>
<td>15.24</td>
</tr>
<tr>
<td>Focal length (cm)</td>
<td>62.4</td>
</tr>
<tr>
<td>F/number</td>
<td>4.09</td>
</tr>
<tr>
<td>NFOV (mrad)</td>
<td>16.4</td>
</tr>
<tr>
<td>IFOV (mrad)</td>
<td>0.032</td>
</tr>
<tr>
<td>Noise equivalent temperature difference (NETD) (°C)</td>
<td>0.013</td>
</tr>
<tr>
<td>Detector integration time (ms)</td>
<td>16.5</td>
</tr>
<tr>
<td>Frame rate (Hz)</td>
<td>30</td>
</tr>
<tr>
<td>Noise bandwidth (Hz)</td>
<td>30.3</td>
</tr>
<tr>
<td>Nyquist frequency limit (cycles/mrad)</td>
<td>15.6</td>
</tr>
<tr>
<td>Magnification (with 12-in. display)</td>
<td>30</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Discrimination level</th>
<th>Example</th>
<th>Jitter = 10 μrad</th>
<th>Jitter = 20 μrad</th>
<th>Jitter = 30 μrad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>Vehicle</td>
<td>18.6</td>
<td>15.7</td>
<td>13.1</td>
</tr>
<tr>
<td>Type recognition</td>
<td>Tracked vehicle</td>
<td>16.2</td>
<td>13.6</td>
<td>11.3</td>
</tr>
<tr>
<td>Recognition</td>
<td>Tank</td>
<td>12.8</td>
<td>10.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Friend or foe</td>
<td>Hostile tank</td>
<td>9.1</td>
<td>7.5</td>
<td>6.1</td>
</tr>
<tr>
<td>ID</td>
<td>Tank type</td>
<td>7.0</td>
<td>5.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Authentication</td>
<td>Decoy Discrim.</td>
<td>5.7</td>
<td>4.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Positive ID</td>
<td>Allegiance</td>
<td>4.8</td>
<td>4.0</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Fast Boat in Middle East
MWIR ID(N95)*

- ID(N95) – 95% of the Operators viewing the MWIR image will correctly identify (highest level of discrimination) this maritime target
# UAV IRST MISSION & HARDWARE

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Weight</th>
<th>Volume</th>
<th>Power</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyesafe Laser Rangefinder (ELRF)</td>
<td>260.6 lbs</td>
<td>7.2 cu. ft.</td>
<td>1774 watts</td>
<td>FOR 90° EL x 165°AZF O V 3° x 3° (NFOV) 28° x 28° (WFOV) IFOV .10 mR (NFOV) 1.0 mR (WFOV)</td>
</tr>
<tr>
<td>Turret (with ELRF)</td>
<td>69 (121)</td>
<td>1.6</td>
<td>580</td>
<td></td>
</tr>
<tr>
<td>Controller</td>
<td>53</td>
<td>1.5</td>
<td>214</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>65</td>
<td>3.7</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>GPS/INS</td>
<td>21.6</td>
<td>.4</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Turret</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS/INS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **Weight:** Total weight of the system.
- **Volume:** Total volume of the system.
- **Power:** Total power consumption.
- **Performance:** Field of regard (FOR) and field of view (FOV) for both NFOV and WFOV, along withIFOV (Instantaneous Field of View) for each mode.
UAV IRST FIRST FLIGHT
FEB. 2, 2000

- INSTALLED ON CONVAIR 580 BASED IN Greenville, Texas
- BO2D TARGET AIRCRAFT
- COOPERATIVE PATTERNS
  - OVALS
  - FORMATION
- ELECTRO-MECHANICAL CHECKOUT @ 5000 ft.
- DEMONSTRATED
  - VIDEO TRACKER
    • WFOV
    • NFOV
  - DATA RECORDING
Multispectral/Hyperspectral Imaging

- Detection/identification of clear and partly concealed targets over large regions of the battlefield
  - Improved Battlefield/Situation Awareness
  - Onboard sensor data screening, reduced bandwidth
  - Rapid sensor-to-shooter cycle
  - Counter-CC&D

- Technical Issues:
  - Spectral Band Choice
  - Spectral Analyzer Development
  - Algorithm Development
  - System Integration
  - Performance Demonstration

AISA AIRBORNE SENSOR
Chem / Bio Agent Detection with LIDAR

LIDAR

• Sensing of Atmospheric Aerosols
  – Pollution Monitoring
  – Chemical Agent Detection
  – Biological Agent Detection

• Airborne “Biological Agent Sensor”
  – Aerosol Spatial Distributions
  – Precise wind speed of aerosol cloud
  – Bio-material detection by fluorescent scattering
  – Flown on Queen Air in CY 2000
  – < 40 lb payload for UAV

• Differential Absorption LIDAR (DIAL)
  – Carbon Dioxide Laser for Long Wavelengths
  – Compact systems in development
DIAL Chemical/Biological Agent Detection

E1 = E2

Laser

Detector Telescope receiver

E1 > E2

Hydrocarbon cloud

Dust & aerosols

(a) Water vapor absorption spectrum

(b) Typical DIAL signals as a function of range
LADAR Obstacle Avoidance HELLAS (EADS)
Flight 13 - (19 Mar 03)

Flight Video

Hellas LADAR

EYESAFE LADAR @ 1.54 MICRON
Applications of 3-D Imaging LADAR

Terrain Mapping

FOA laser generated model

Scanning laser radar

Topo needs only 1/1000 of Pulse energy cf underwater appl.

Swedish archipelago

Airborne laser radar (Top Eye Saab, 10 cm avst.noggr.)

Ex. of laser scanning of buildings

Intensitetsbild
Højdbild

<table>
<thead>
<tr>
<th>Radar system</th>
<th>Operating frequency (GHz)</th>
<th><strong>LARGE</strong> (UAV System)</th>
<th><strong>MEDIUM</strong> (UAV System)</th>
<th><strong>SMALL</strong> (UAV System)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8.4 to 9.0</td>
<td>15.2 to 18.2</td>
<td>Exact freq. TBD</td>
</tr>
<tr>
<td>Stripmap Mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (km)</td>
<td>200</td>
<td>7 to 30</td>
<td>4.4 to 10.8</td>
<td></td>
</tr>
<tr>
<td>Resolution (m)</td>
<td>1.0</td>
<td>0.3 to 3.0</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Ground swath (pixels)</td>
<td>TBD</td>
<td>2600</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>View size (m)</td>
<td>TBD</td>
<td>934</td>
<td>~800</td>
<td></td>
</tr>
<tr>
<td>Squint angle (deg)</td>
<td>±45</td>
<td>± (45 to 135)</td>
<td>±45</td>
<td></td>
</tr>
<tr>
<td>Spotlight Mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (km)</td>
<td>200</td>
<td>4 to 25</td>
<td>4.4 to 10.9</td>
<td></td>
</tr>
<tr>
<td>Resolution (m)</td>
<td>0.3</td>
<td>0.1 to 3</td>
<td>0.3 to 1</td>
<td></td>
</tr>
<tr>
<td>Swath width (pixels)</td>
<td>TBD</td>
<td>2x(640x480)</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Depression angle (deg)</td>
<td>TBD</td>
<td>TBD</td>
<td>-10 to -60</td>
<td></td>
</tr>
<tr>
<td>Squint angle (deg)</td>
<td>±45</td>
<td>± (45 to 135)</td>
<td>±45</td>
<td></td>
</tr>
<tr>
<td>Peak side lobes (dB)</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td></td>
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<tr>
<td>Dynamic range (dB)</td>
<td>TBD</td>
<td>&gt;85</td>
<td>&gt;75</td>
<td></td>
</tr>
<tr>
<td>Absolute RCS calibration, 3σ (dB)</td>
<td>TBD</td>
<td>TBD</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>635</td>
<td>120</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>Circular error probability (CEP) (m)</td>
<td>&lt; 4</td>
<td>&lt; 4</td>
<td>&lt; 25</td>
<td></td>
</tr>
<tr>
<td>Size (ft³)</td>
<td>15</td>
<td>3</td>
<td>~2</td>
<td></td>
</tr>
</tbody>
</table>
Lynx SAR (AN/APY-8) – Ku-band Radar

- Developed by Sandia National Laboratories and General Atomics for UAV applications
- In Production at General Atomics
  - Installed on King Air, Predator, IGNAT, Black Hawk
- High-performance, multi-mode radar
  - SAR spotlight resolution – 0.3 m to 3 m
  - Strip-map resolution – 0.3 m to 3m
  - GMTI mode
- Extended-range operation
  - 33 km for .3m resolution in weather
  - 54 km for .3m resolution in clear air
- Low weight and power
  - 115-lb total weight
  - <100-lb version developed
  - <1.2-kW prime power
**UAV Synthetic Aperture Radar (SAR)**

**MISSION:** Provide Surveillance, Targeting and Battle Damage Assessment Capability that Penetrates Weather, Haze and Obscurants.

### Example Current ATD (TUAVR)
- Size: 1.2 cu. ft.
- Weight: 65 lbs.
- Range: 7-10 Km. most cond.
- Resolution: 1.0 m, strip mode
  - 0.3 m, spot mode
- CEP: 25 m
- Flight Test: 4th quart. FY00

### Demonstration Goals by 2005*
- Size: < 0.5 cu. ft.
- Weight: < 20 lbs.
- Range: 3 - 7 Km. in weather
  - 7 - 10 Km. most conditions
- Resolution: 0.3 - 1.0 m., strip mode
  - 0.3 m., spot mode
- CEP: < 10 m

### Maturing Critical Technologies
- Monolithic Microwave Integrated Circuits (MMIC’s)
- Advanced Microwave Antenna Designs
- Multi-Resolution Signal Processing
- Computer Processing / Packaging
- Advanced Precision Navigation

### Expected Advanced Capabilities by 2005*
- Reduced CEP
- Improved Ground Moving Target Capabilities (GMTI)
- Interferometric SAR
  - 3D Imaging
  - Battle Damage Assessment
  - Target Identification
- Absolute Geo-Location
- Improved Imaging Techniques

*current programs

*current development areas
**CONCEPT DESCRIPTION**

- Real time specific emitter/platform ID & precise geo-location
- Sensor fusion of RF and EO/IR signal processing for Comm/ESM/MWS into one MMP
- Lightweight EO/IR MWS sensor
- Lightweight, short duration towed IR flares/RF decoys
- Real time sensor cueing for shooter, GCS, RCS

**REQUIREMENTS/NEEDS**

- Specific threat RF emitter identification & location
- Compact, low power, lightweight
- Integrated RF Comm/ESM/ECM/MWS mission payload
- Long range combat ID
- Lightweight, compact RF/IR towed decoys
- Comm intercept/relay
- Lightweight, compact EO/IR MWS sensor

**BENEFITS**

- Passive emitter targeting/sensor-to-shooter cueing
- Minimize fratricide
- Characterize battlespace/deconfliction
- Increase reaction time
- OTH Comm relay for SAR/FAC
- Improved situational awareness
- Platform survivability
ESM for UAVs

- Autonomous UAV Operation
- Cue to Emitter Bearing/Location
- Real Time Emitter/Platform ID
- <35 Lbs. including Antenna
Target Location Error

• **Target Location Error (TLE) model for EO/IR sensors**
  – Relative to platform coordinates
  – Absolute in GPS coordinates

• **2 Options for modeling TLE**
  – Sensor direct observations of target
  – Target position relative to observation of mensurated point in scene

• **Inputs to Model**
  – EO system parameters
  – Aircraft Altitude and Slant range

• **Outputs are plots of relative and absolute target location error with respect to range and altitude**
TLE Model Results

ABSOLUTE AND RELATIVE CROSSRANGE ERROR

GROUND RANGE (m)

ALTITUDE (m)

5000
3500
2000
5000
3500
2000

ABSOLUTE

RELATIVE
CONCEPT DESCRIPTION

- Target prioritization and weapon selection and tasking: less than 10 sec. from receipt of relevant information
- Minimize target location error
- Targeting and navigation in the absence of GPS
- All source sensor and data fusion

REQUIREMENTS/NEEDS

- Replace intensive manual updating
- Enable near real time sensor archive update
- Imagery linkage for situational awareness
- Improved timelines for mission planning
- Common view of the battlespace
- Enable reach-back capability

BENEFITS

- IR Video ~ 2 m/pixel Resolution (416.2 m²); Color Aerial Photo ~ 5 m/pixel Res. (314.1 km²)
- 2 USGS DEM 7.5° Quadrangles ~30 m elevation post spacing
- Sub-section of North Ranges China Lake, CA

Sensor Image - Map Overlay
### ATR and ABDA for VTUAV

#### CONCEPT DESCRIPTION:

- ATR and ABDA decision aid
- Integrate SAR, LADAR, and IIR into coordinated network-centric target information source for ATR and ABDA
- Employ SAR for long-range wide-area GMTI, detection, recognition, and ABDA
- Employ IIR for limited FOV detection and recognition

#### Requirements/Needs:

- Real-Time Detection, Identification, and Battle Damage Assessment of Moving and Stationary Mobile Targets
- Under the Following Conditions:
  - Heavy Urban and Rural Clutter
  - In-Hide Behind Trees, Terrain, Buildings
  - All-Weather

#### Benefits:

- Improved weapon efficiency and effectiveness
- Improved op-tempo
- Reduce image analyst time to detect and declare targets < 1 min
- Reduced time to weaponeer to collateral damage constraints <1 min
- Reduced time to ascertain strike damage < 1-5 min
Current General ATR Capabilities
(Applicable to all Sensors/Seekers)

Stationary Mobile Targets In-The-Clear with no Obscuration

<table>
<thead>
<tr>
<th>POT</th>
<th>Detection</th>
<th>Recognition</th>
<th>ID</th>
</tr>
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<tbody>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
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<td>400</td>
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<td>600</td>
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<tr>
<td>800</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
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</tr>
</tbody>
</table>

Meaning of Demonstrated
- Demonstrated in 6.3
- 80% Correct Identification Rate
- Acceptable FAR

- Detection => Vehicle
- Recognition => Tank
- Identification => T-72 Tank
- POT => Pixels-on-Target
UAV SENSOR PAYLOAD STUDY

SUMMARY OF CAPABILITIES

- **EO/IR TECHNOLOGY**
  - EO/IR/TV
  - MULTI/HYPERSONSPECTRAL IR
- **LIDAR TECHNOLOGY**
  - POLLUTION MONITORING
  - CHEM/BIO AGENT DETECTION AND TRACKING
- **EYESAFE 3-D LADAR TECHNOLOGY**
  - OBSTACLE AVOIDANCE & TERRAIN MAPPING
  - TARGETING & FIRE CONTROL
- **SAR TECHNOLOGY**
  - ALL WEATHER RECONNAISSANCE & SURVEILLANCE
  - SUFFICIENT RESOLUTION FOR DETECTION & RECOGNITION
- **EW TECHNOLOGY**
  - INTEGRATED WITH OTHER RF/IR SYSTEMS
  - SMALL MISSILE WARNING RECEIVERS
- **TARGET LOCATION ERROR (TLE)**
  - PRECISION NAVIGATORS versus SCENE MATCHING CORRELATION
  - PREDICTIONS FOR EO/IR SENSORS
- **ATR/ABDA TECHNOLOGY**
  - TARGETS IN OPEN BY 2005 (LADAR, SAR)
  - TARGETS IN HEAVY CLUTTER BY 2010 (FOPEN, UHRR SAR, IFSAR)
Survey of Sensor Payloads for UAVs

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