An Operator Function Taxonomy for Unmanned Aerial Vehicle Missions

Carl E. Nehme
Jacob W. Crandall
M. L. Cummings
Motivation

• UAVs being asked to perform more and more missions
  – Military
  – Commercial

• Makes it hard to keep up with GCS needs
  – Rapidly evolving systems
  – Dynamic human operator cognitive needs

• Need a taxonomy of UAV missions & associated operator functions
Why a Taxonomy?

UAVs are being used for multiple missions
- MQ-1 Predator can perform both reconnaissance and weapons delivery missions

Missions may not have the same interface/information requirements
- Heterogeneity of tasks and vehicles will require an operator to manage dissimilar tasks

UAV imagery during a search for survivors of Hurricane Katrina (credit: Safety Security Rescue Research Center)
Why a Taxonomy?

If we know operator functions of a “new” task, we can leverage research findings/designs from other tasks with similar operator functions

- So the taxonomy needs to specify common operator functions across different missions
- The common functions lead to a common set of information requirements
UAV Mission Taxonomy

• Three tiers
  – Mission types more specific with tree depth

• Taxonomy generic
  – Military
  – Commercial

• Extendable

• Missions closer together have similar characteristics
UAV Mission Taxonomy

Level 1: General Mission Types

- Intelligence/Reconnaissance
  - Mapping
  - BDA
  - Target Acquisition
  - Target Designation
    - Dynamic Target
    - Static Target
### Functional/Information Requirements

<table>
<thead>
<tr>
<th>Mission Phases</th>
<th>Phase Goals</th>
<th>Functional/Information Requirements</th>
</tr>
</thead>
</table>
| Planning       | - Scheduling of health and status reports | - Threat area information  
|                |             | - Planning path of area to be mapped  
|                |             | - No fly zone information  
|                |             | - Scheduling mechanism  
|                |             | - Decision support for path planning (including loitering)  
| Management     | - Tracking progress of UAVs and of health and status reports  
|                |             | - Image (map) analysis  
|                |             | - Health and status indicators  
|                |             | - Image analysis tools (zoom, panning, filtering)  
| Replanning     | - Resource allocation | - Asset coverage re-plan decision support |
Interoperability

- Missions with similar functional/information requirements have higher interoperability
  - We might be able to use the same interface

Example 1:

BDA = Mapping

More interoperable
Interoperability

- Missions with similar functional/information requirements have higher interoperability
  - We might be able to use the same interface

Example 2:

Target Acquisition ≠ Mapping

Less interoperable

Credit: www.cardiofx.com
### Operator Functions

- Operator functions specify the responsibility of the human operator in the UAS.
- They do **not** specify how the human operator will implement these functions.

#### BDA

<table>
<thead>
<tr>
<th>Mission Phases</th>
<th>Phase Goals</th>
<th>Functional/Information Requirements</th>
</tr>
</thead>
</table>
| Planning       | - Assessing targets and routes  
- Scheduling of order of assessments if more than one  
- Scheduling of health and status reports | - Threat area information  
- No fly zone information  
- Scheduling mechanism  
- Decision support for path planning (including loitering) |
| Management     | - Tracking progress of UAVs and of health and status reports  
- Analyzing BDA results | - Health and status indicators  
- Image analysis tools (zoom, panning, filtering) |
| Replanning     | - Resource allocation | - Asset coverage re-plan decision support |

- **Operator Functions**
  - Monitoring health and status of UAV  
  - Analyzing images  
  - Monitoring network communications  
  - Resource allocation & scheduling  
  - Path planning supervision  
  - Optimal position supervision  
  - Notifying relevant stakeholders
• Research on missions with similar operator functions can be leveraged

Example 1:

Target Acquisition

Listening

≈

More Carry-over
Carry-over

- Research on missions with similar operator functions can be leveraged.

Example 2:

Payload Delivery ≠ Mapping

Less Carry-over

Credit: http://www.1000pictures.com
Missions with common functional/ information requirement also have many operator functions in common

- Both derived from the same phase goals
# Table of Operator Functions

<table>
<thead>
<tr>
<th></th>
<th>Intelligence/Reconnaissance</th>
<th>Drones</th>
<th>Transport</th>
<th>Surveillance</th>
<th>Comm</th>
<th>Extra-ction</th>
<th>Insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mapping</td>
<td>BDA</td>
<td>Target acquisition</td>
<td>Target designation</td>
<td>Decoy</td>
<td>Target</td>
<td>Cargo</td>
</tr>
<tr>
<td>Monitoring payload status</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring network communications</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring health &amp; status of the UAV</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Monitoring for sensor activity</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negotiating with other stakeholders</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notifying relevant stakeholders</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal position supervision</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Path planning supervision</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Analyzing images</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyzing other sensor data</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Target Identification</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource allocation and scheduling</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking target</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most Common Operator Functions

- Monitoring health and status of UAV
  - In every mission
  - Should not subsume operator attention
  - Humans not very good at it (max 30 mins)
  - Robust decision support should be developed that leverages automation strengths
Most Common Operator Functions

• Notifying relevant stakeholders
  – Essential that UAV operators can communicate with others
Most Common Operator Functions

• Optimal position supervision
  – Both in the vertical and the horizontal
    • Also need to consider both current and projected position
  – Need robust automation
    • Interactive decision support tools
Most Common Operator Functions

- **Path planning supervision**
  - Due to limited cognitive resources, need automated path planners
  - But users need to be able to interact with them
    - Artificial intelligence path planning algorithms can be “brittle”
Most Common Operator Functions

• **Resource allocation and scheduling**
  – Computationally complex
  – Humans may not perform these tasks well
  – Need automated schedulers humans can interact with
Summary

• We have introduced a taxonomy of UAV missions

• Across missions, the taxonomy includes:
  – Information/functional requirements
  – Operator Functions

• Can potentially be used to
  – Leverage designs & research from one domain to another
  – Identify interoperability between UAV missions