Unmanned Aircraft Systems (UAS) Design & Test

“How to test your drone”

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P-3C Orion Tactical Coordinator. Navy Drone Tester (DT/OT) for 7 years. 3DR Solo hobbyist.

MQ-8B Fire Scout Flight Test, added weapons & radar capability. First rotary-wing UAS ops with LCS-1/2 and USCG Legends Class.
Overview

- UAS 101
- Design
- Testing
UAS 101: What is a UAS? (or Drone)

1. **Air Vehicle (AV)**
   - Airframe, Propulsion, Payloads, Sensors, Guidance/Navigation, Controls, Comms

2. **Control Station (CS)**
   - Control & Comms

3. **Data Links (DL)**
   - Connectivity between CS/AV and AV and external units

4. **Launch & Recovery Equipment (LRE)**
   - Launch and Recovery Devices and Technologies (VTOL)

5. **Manpower**
   - Operators (Vehicle/Sensor), Intel, Maintainers (CS, AV, LRE)
UAS 101: Generic UAS Operations

- GPS
- Air Traffic Control
- COMMS
- UAV Common
  Automatic Recovery System (UCARS) (Ship)
- LOS
- BLOS
- PAYLOAD
- CS
- CS
- Manning 2
- Narrowband AV C2
- Wideband Imagery
- Narrowband AV Status
- LAUNCH & RECOVERY
- GPS Spot (Land)
- GPS
- or
- UAV CONTROL
- AV & MP
- PAYLOAD CONTROL
- Control System (CS)
- Launch & Recovery Equipment (LRE)
- Schweizer
UAS 101: Commercial 3DR Solo

- GPS
- Wifi
- AV Status Imagery
- LOS
- AV C2 Payload C2

Control Components:
- Manning 1
- AV & MP
- Payload Control
- Launch & Recovery
UAS 101: Drone-vertising

Good for **Dull, Dirty or Dangerous** missions.

And someone has to **test it**!
UAS 101: Drone/UAS Missions

DIRTY
- Inspection (Tower/Pipeline)
- Infrastructure Monitoring

High Threat
- Force Protection
- Persistent ISR

DANGEROUS
- Strike
- Damage Assessment
- Disaster Response
- Border Surveillance

Simple
- Aerial Imaging/Mapping
- Real Estate
- Mining
- Agriculture
- Traffic Monitoring

Low Threat
- Sports Events
- Telecommunications
- Cinematography
- Transport
- Cargo Resupply

Complex
- Sea-based ISR
- Mission
- Environment
- Sensors
- Crew Size
- Duration
- Coordination

DULL

HARD
UAS Design: What do I need to fly UAS?

• It depends…
  – Mission: type, duration, covert
  – Environment: threat, weather, rules, envelope
  – Platform Type: fixed-wing, rotary-wing, other
  – Payloads: types, control interfaces
  – Comms: radio (LOS), satellite (BLOS)
  – Autonomy: autopilot, sense-and-avoid
  – L&R methodology: VTOL, skyhook, launcher
  – Operators: number, training
UAS Design: System

- **Capability-based design (Mission Optimized)**
  - Available Trade Space (Air Vehicle Focus)

<table>
<thead>
<tr>
<th>Design Mission</th>
<th>Size (GTOW)</th>
<th>Employment</th>
<th>Type</th>
<th>SWaP + CECC</th>
<th>Cost &amp; Sched.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>capacity + speed + endure</td>
<td>stealth + cost + quantity + interop. + autonomy + caps + sensors</td>
<td>Rotary vs. Fixed Wing vs. Other</td>
<td>Size, Weight, Power, Comms, Environment, Computing, Cooling</td>
<td>Funding &amp; Urgency</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
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“Good, Fast, Cheap, pick any two.”
UAS Design: Control Station

- **Function**: Fly & Train (Live & Sim missions)
- **Size**: Drives crew size, expansion possibility
- **Weight**: Drives mobility, transportability
- **Power**: Backup power sources
- **Heating & cooling**: Environmental effects on crew and equipment
- **Noise**: Low enough for good crew comms
- **Comms**: Intercommunication, radios, phone, internet, hands-free
- **Integration**: Interoperate with host C2, host mission
- **Visibility**: Window/camera for situational awareness of AV and area

Room-sized Control Station (multi-operator) in building
### UAS Design: Info Needed to Fly

<table>
<thead>
<tr>
<th>Manned Aviation Standard</th>
<th>Drone/UAS Standard?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airspeed</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Attitude</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Altimeter</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Turn &amp; Slip</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Heading</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td>Vertical Speed</td>
<td><img src="image_url" alt="Image" /></td>
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<tr>
<td>+ Comms + Charts</td>
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</tr>
<tr>
<td>+ Know Rules + Training</td>
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Manual info integration & interpretation of displays

Integrated & simplified displays
UAS Design: Control & Display

**Act:** Actionable info, controls for current phase of operations.

**Know:** Decision-level info, not raw data/code.

**Show:** Info value changes based on system functions, phase and state.

**Flow:** Logical arrangement using standard conventions.

**Go:** Match function. Precise or rapid inputs and required feedback.

Intuitive, clear, simple, unambiguous
Adapt: Don’t mirror manned aircraft controls and displays.


Glow: Bright/dim controls for wide range of operating conditions.

Match: Match definition (pixel-density) of input source payload.

Share: Workload and information sharing.
UAS Test: What do I need to test UAS?

- It depends…
  - What questions need answers? Key requirements?
  - What data are needed to make those decisions?
  - Instrumentation required? Real-time or post-processed?
  - Formal Test Process

In God We Trust. All Others Bring Data.
UAS Test: 7 UAS Problem Areas

How to Test:
- Operators/Maintainers (Fleet Trained)
- Fleet Documentation/Procedures
- Whole System Test (Cyber)
- Mission Focused
- Joint Environment

Manpower Neutral

Easy Operations

Easy Integration

Easy Training

Cheap

Easily Joint

Balloon Mentality
UAS Test: Lessons

- **Normal Formal Structured Test**
  - Test Plans, Test Hazard Analysis, Test Points, Detailed Method of Test (DMOT) and Knock-it off, GO/NOGO Criteria

- **Test Coordination**
  - Resources, Priorities, Status, Schedules, DT/OT Issues

**UAS Specific Test Procedures:**

- **Safety - Understand System States & Logic**
  - System behavior in certain conditions *(Rule sets)*
  - Logic and behavior transitions along state changes *(Risk)*

- **Telemetry (TM) Data Characterization**
  - Safety of Test (SOT), Safety of Flight (SOF), Analysis Critical

- **Available airspace**
  - Adequate for mission, airspace sharing arrangements (concurrent/multiple AV operations)
UAS Specific Test Procedures:

• Chase requirements
  – Loose form 4-5 rotor arcs. Flight logic can cause unexpected abrupt turns. Direction of turn not indicated or predictable.

• COA process
  – For flights outside warning/restricted areas. Long lead times are required. Chase usually required.
UAS Test: Lessons (Design for Test)

- **Software Function Segregation**
  - Reduces required lab and flight regression
  - Safety of Flight (SOF) vs. Payload

- **Modified Flight Test Methods**
  - *Test-only scripts and commands*: To induce certain anomalies, conditions or control inputs
  - *Test build-up procedures*: control margins vs. pilot rating
  - *Instrumentation/Logs*: video screen capture, keystroke logging equipment, network monitoring and troubleshooting tools, frequency monitoring

- **Configuration Management & Verification**
  - Entire system HW/SW configuration Summary

- **Power and Communications Architecture**
  - Individual component on/off switches speeds test process.
  - Visual status lights to indicate what UAS is thinking
UAS Test: Lessons In Flying Solo

Know the rules
- Below 400 ft, Line of Sight
- 5 miles from airports
- Not in D.C.

Know the system
- Read the manual
- Ground test –
- Emergency - motor power off
- Learn advanced flight techniques before trying them

Manage risk
- Ask “What is the worst that could happen?”
- Ask “What if…”

Test Execution
- Risk Assessment - None
- Airspace – Small front yard, not large open area
- Training: Watched tutorial videos, did not read full manual
- System understanding: System holds relative GPS position, unless GPS drop-lock occurs

Results
- 4th flight, lost GPS – crashed.
  - Cost: 4 propellers, burned out a motor. (2 weeks/$100)
- Advanced Modes – crashed.
  - Cost: 2 propellers. ($14)

Help me!
TEST: “We’ll get there when we get there…”

PM: “Are we there yet?”

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14th Annual AUVSI
Student UAS Competition
June 15-19, 2016 Webster Field, MD

Autonomous UAS Design, Build & Fly
Student Competition

By The Numbers (2015)
• 7 countries
• 46 teams
• 25 U.S. colleges
• 16 international colleges
• 5 high schools

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