



# Unmanned Aircraft Systems (UAS) Design & Test

*“How to test your drone”*

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# Twitter-duction



**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.**



**P-3C Orion**



**3DR Solo**



**MQ-8B Fire Scout**

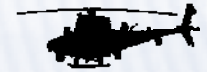


# UAS 101: What is a UAS? (or Drone)



## ① Air Vehicle (AV)

Airframe, Propulsion, Payloads, Sensors, Guidance/Navigation, Controls, Comms



AV

## ② Control Station (CS)

Control & Comms



CS

## ③ Data Links (DL)

Connectivity between CS/AV and AV and external units



LOS  
BLOS

## ④ Launch & Recovery Equipment (LRE)

Launch and Recovery Devices and Technologies (VTOL)



LRE

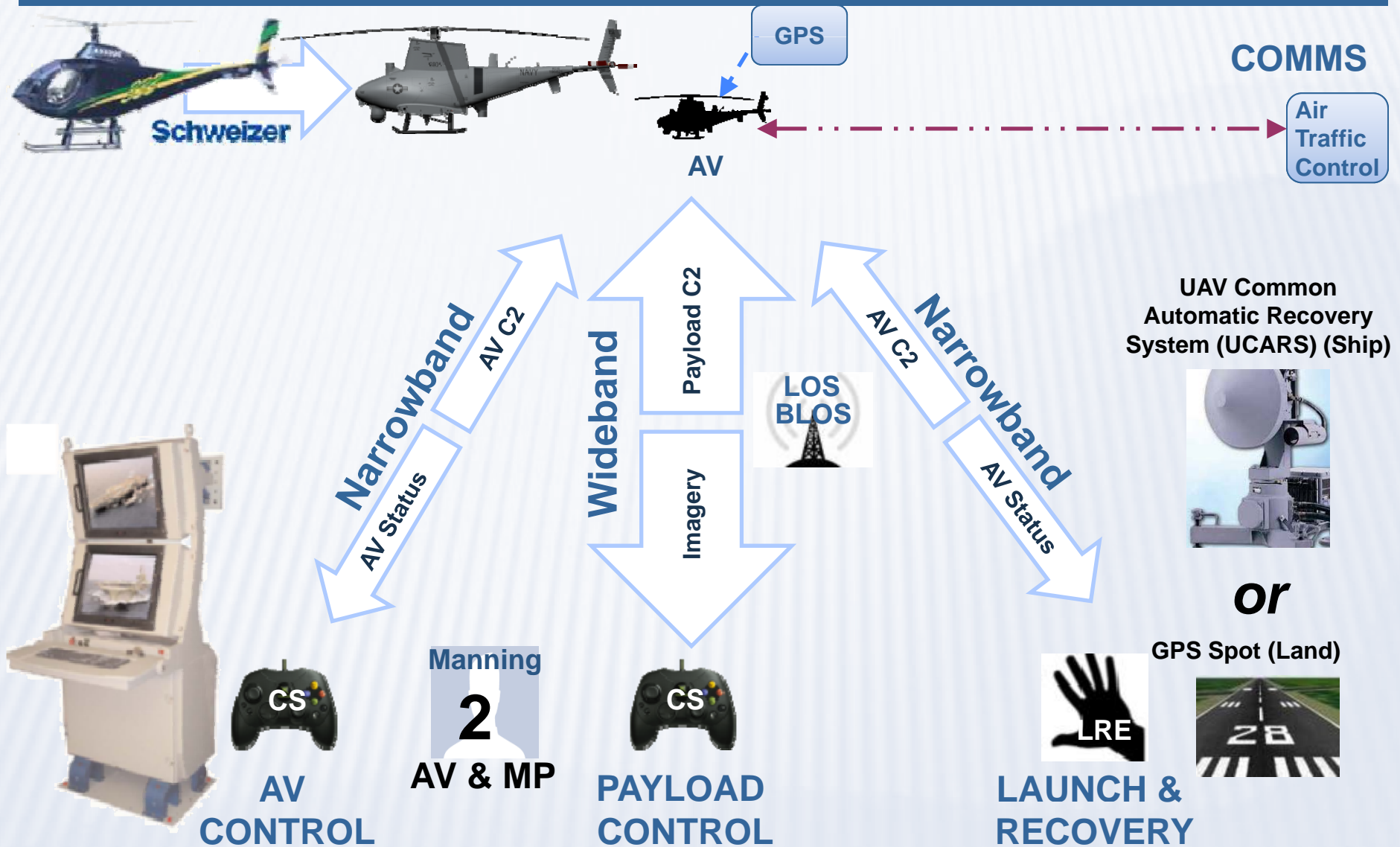
## ⑤ Manpower

Operators (Vehicle/Sensor), Intel, Maintainers (CS, AV, LRE)

Manning



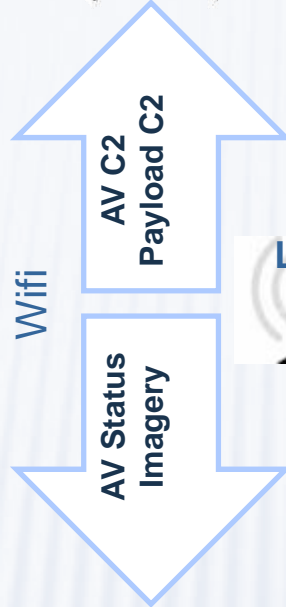
# UAS 101: Generic UAS Operations



# UAS 101: Commercial 3DR Solo



GPS



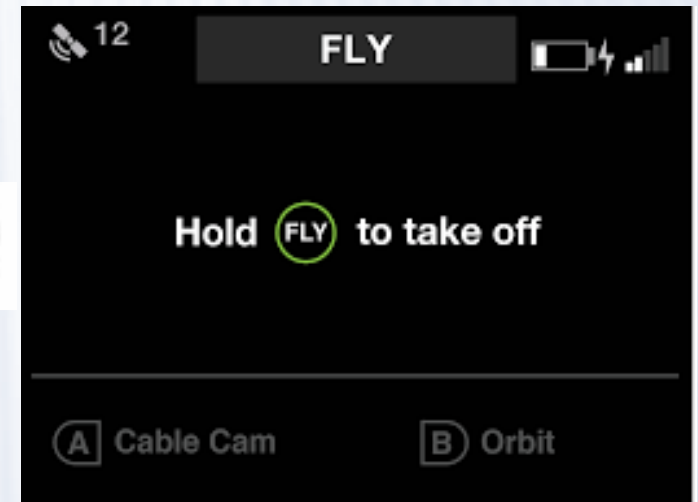
Wifi

AV C2  
Payload C2

AV Status  
Imagery



LOS



AV  
CONTROL

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

Defense  
Commercial

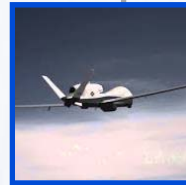
**DIRTY**



Inspection (Tower/Pipeline)  
Infrastructure Monitoring

*High Threat*

Force Protection  
Persistent ISR



Damage Assessment  
Disaster Response  
Border Surveillance

**DANGEROUS**



Strike



*Simple*

Aerial Imaging/Mapping  
Real Estate  
Mining  
Agriculture  
Traffic Monitoring



Sports Events  
Telecommunications  
Cinematography  
Transport

Cargo Resupply



Sea-based ISR



Refueling (AAR)

*Complex*

Mission  
Environment  
Sensors  
Crew Size  
Duration  
Coordination

**DULL**

*Low Threat*

**HARD**



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

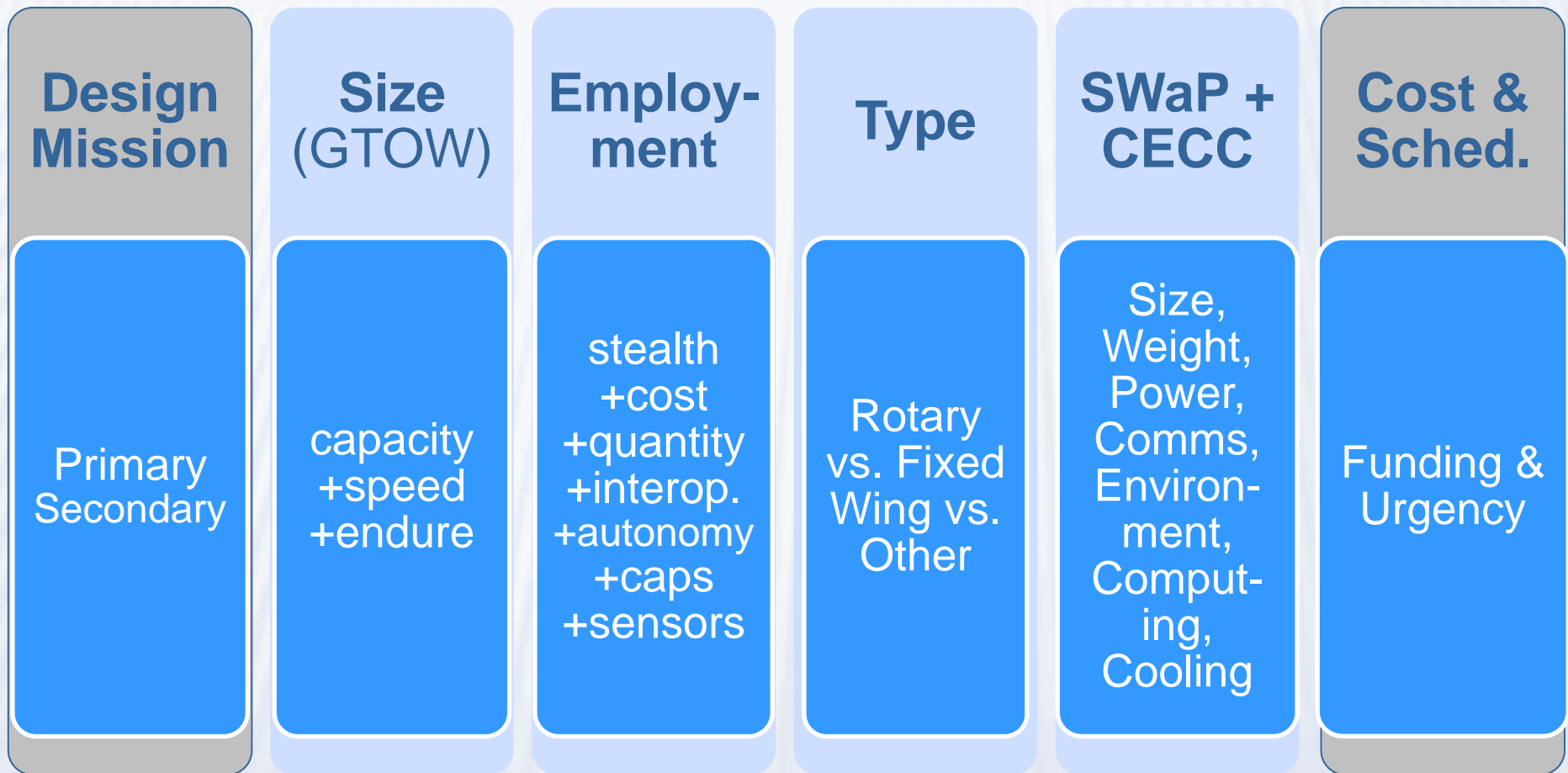
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- **It depends...**
  - **Mission:** type, duration, covert
  - **Environment:** threat, weather, rules, envelope
  - **Platform Type:** fixed-wing, rotary-wing, other
  - **Payloads:** types, control interfaces
  - **Comms:** radio (LOS), satellite (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)



“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



## Manned Aviation Standard



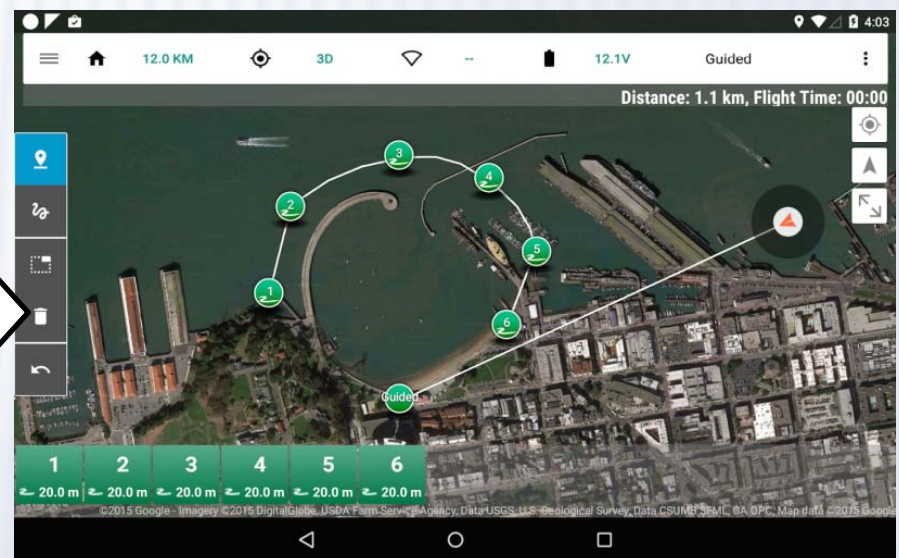
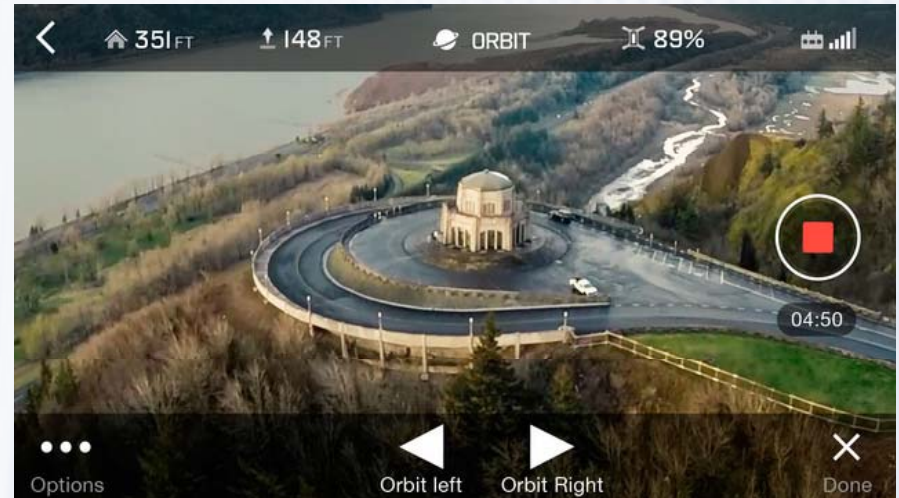
+ Comms + Charts  
+ Know Rules + Training



Manual info  
integration &  
interpretation  
of displays

Integrated &  
simplified  
displays

## Drone/UAS Standard?



# 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.

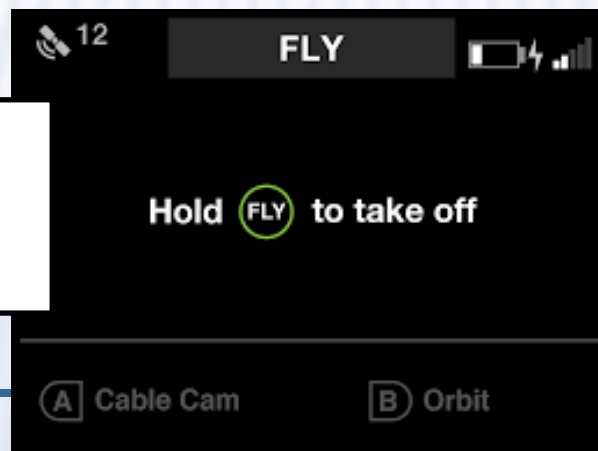


**Flow:** Logical arrangement using standard conventions.



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

Intuitive, clear,  
simple,  
unambiguous



# UAS Design: Control & Display



**Adapt:** *Don't mirror manned aircraft controls and displays.*

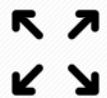


**Grow:** *Future growth: payloads, functions and missions.*

**Cluttered,  
Overlapping,  
Extraneous Info**



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



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



**Share:** *Workload and information sharing.*



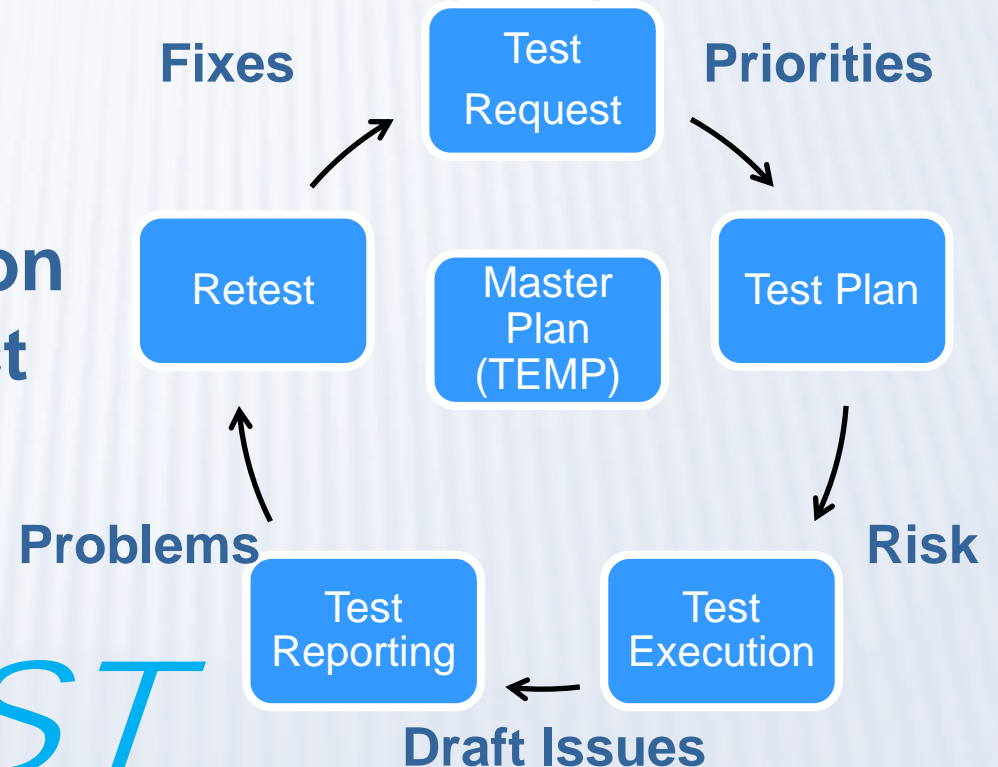
# UAS Test: What do I need to test UAS?

- **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.**

**Mission  
Impact**



**KNOW**  
BEFORE YOU **TEST**

# UAS Test: 7 UAS Problem Areas





# 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 Test: Lessons

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## 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)

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- **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

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## 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!



# Questions?

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PM: "Are we there yet?"

TEST: "We'll get there when we get there..."



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## 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

