AUTONOMY DEVELOPMENT PROCESS

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AVLS Autonomy Team

Bell V-247

Autonomy Under Development

- Precision Landing
- Waypoint Navigation (flight planning)
- 6-DOF Landings (on Boats)
- Unimproved Landings
- IFR / National Airspace
- Contingency Operations
- MUM-T
- DVE/ Night Operations
- GPS Denied
- See and Avoid (following up on NASA SIO)
- Formation Flying
- Aerial Refueling
- Sling Loads

Autonomy Functions Under Development

Operation	Nominal	Degraded/ Contingency	GPS Denied	Night/DVE/Wx
Precision Landing				
Waypoints				
Landing on Boats				
Unimproved Landings				
Search				
MUM-T				
See and Avoid				
Formation				
Aerial Refueling				
Sling Loads				

Landing on Boats

Process:

- **GPAS Ground Based Augmentation guidance +**
- **Optical Tracking +**
- **Lidar / Doppler Drift / Relative Navigation**

Research Gaps

- **All weather operations**
- **Contingency**

Strategies

- **“crawl-walk-run” approach**
  - Stationary landing
  - Stationary landing with 3d Information
  - Landing on trailer
  - Landing on moving trailer + envelop expansion
  - Landing on moving trailer with simulated wave data
  - Landing on boat

Off Field Landings

Process:

- **Vision (LIDAR, Radar, Video) based survey**
- **SWEEP – plan takeoff before you land, escape routes**
- **Direct observation technique – active guidance to touchdown**

Research Gaps

- **Edge Cases**
  - Water, bogs, snow, sand, etc
  - DVE – Degraded Visual Environments
  - Machine learning for classification of obstacles

Strategies

- **“crawl-walk-run” approach**
  - High Survey
  - Low Survey
  - Approach and Land

Autonomous Aerial Refueling

Process

- Formation Flying using DGPS
- Sensor-based tracking
- Transitions

Research Gaps

- Reliability, Repeatabilty, Reliability

Strategies

- Following NASA AAR efforts with F-18
- X-47
- British AAR experiments
- Partnering with experienced players

GPS Denied Navigation

Process:

- **Combination of seven navigation techniques**
- **Many date back to the '70's "pre-GPS"**
- **Includes SLAM, Terrain, visual odometry, fixtaking, SOO**

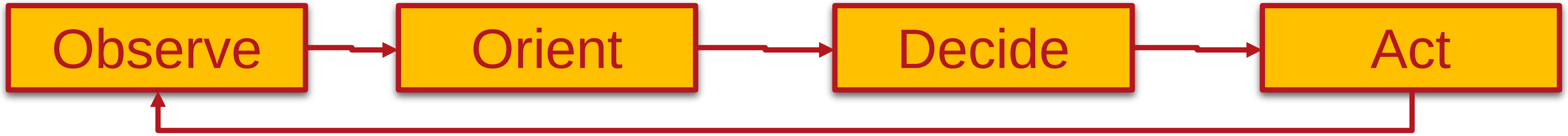
Research Gaps

- **Signals of Opportunity**
- **Daylight Star Tracker**
- **Over Water**

Strategies

- **Kalman Filter**
- **Adaptive Navigation Performance**
- **No "one size fits all" approach**

V-247 | OODA Loop



Sensors &
Sensor processing:
Radar
GPS, IMU
Ir, LIDAR, EW
IFF, ADS-B in
Link 16 SA
Engine, props, fuel
Airspeed, altitude, etc.

Place all data in a common reference frame
-Relative to the UAV
-Lat/long/altitude
-UTM
-Why is this data relevant to this UAV?

Given all data and relevant information, what needs to be done about it?
Determine course of action (COA) based on analysis of alternatives

Issue the necessary commands to the systems to execute the decision

Radar return 1.2 miles 32.123 deg
ADS-B report lat xx lon yy
GPS current position lat zz, long aa

Friendly Aircraft 1.2 miles away same altitude
Range decreasing bearing steady

Collision course
Avoidance maneuver necessary
Change altitude + 1000’

Send CWA notice to operator
Engine to climb power
Pitch up 5 degrees

Autonomy Development: WHY?

WHY?

- Risk Reduction for Unmanned Systems
  - Test on different Platforms
  - Simulator, SIL, 407, Truck, Dragon UAV, 412
- All future Bell autonomous and optionally pilot vehicles need it
- Comply with customer mandated FACE and MOSA requirements

Bell 407 Test Vehicle

Aircraft Agnostic Autonomy Pallet
Flight Director Display & Precision Landing

Crawl – Walk - Run

- Testing started with simulation to develop control loops
- Added sensors and systems in a stimulation environment
- Flight testing with manned open-loop helicopter (Bell 407)
- Flight testing with scale demonstrator (Dragon UAV)
- Flight testing with full size aircraft Fly By Wire a/c (Bell 412 or 429)
- Production Prototype