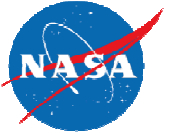


Strategies for Small UAS: An Airspace Underlay Experiment

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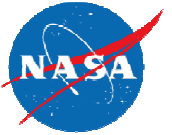
11th AIAA Aviation Technology, Integration, and Operations Conference
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Presentation Outline

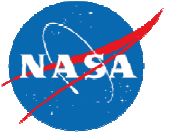
- Motivation
- Concepts to Enable
- Experience to Leverage
- Airspace
- Opening the Door to the NAS
- Potential Paths for Underlay Success
- Conclusion

Motivation



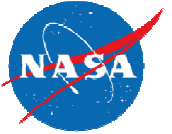
- Many small UAS (<50lbs) exist and are being introduced
- Current database of small UAS (SUAS) performance leads to a much worse mishap rate than commercial and general aviation aircraft
- Where will UAS be able to fly without certificate of authorization (COA)?
- Do the experiences we have afford a new way of National Airspace System (NAS) access?
- How can trust in SUAS systems be built to allow more NAS access?
- Recent Afghanistan MC130 and RQ-7 mishap points to many issues needing resolution...
- The underlay experiment concept: According to existing regulations, fly SUAS *underneath* uncontrolled Class E and G airspace, in order to build an experience database that makes progressive FAA approval in more desired airspace possible and extends to more complex missions (potentially airspace with manned aircraft)

Small UAS Concepts to Enable



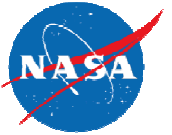
- Public Use:
 - Lifeguard surveillance
 - Rip-current location/monitoring
 - Searching for a troubled swimmer from on high
 - Police surveillance/tracking
 - Surveillance: expanding the database for locating and avoiding trouble
 - Tracking targets
 - Disaster support
 - Surveillance; search and rescue
 - Critical supply delivery
 - Forest fire mapping
 - Dirty/dangerous jobs – into the unknown
- Commercial Use
 - Farm Monitoring
 - Realtor Assistant
 - Neighborhood package delivery
 - On demand services never before dreamed of
- Private Use
 - Prescription delivery
 - Convenience delivery
- Etc

Experiences to Leverage

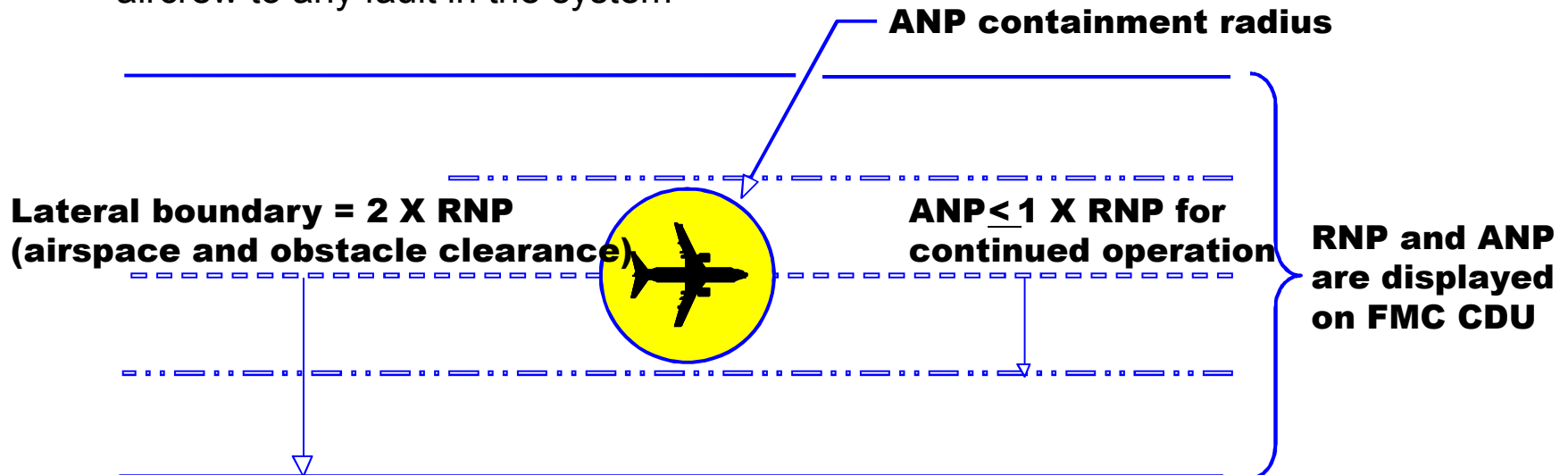


- Performance Based Navigation...Alaska Airlines Required Navigation Performance (RNP)
- Air Force Procedural Separation and Orchestration of Aircraft
- Operation Heli-STAR
- Alaska Capstone Program
- Small Aircraft Transportation System Higher Volume Operations (SATS HVO)

Performance Based Navigation (PBN)



- PBN is a cornerstone of NextGen...Three operator requirements:
 1. Equip the aircraft...ascertain the aircraft's position in space through GPS and other navigation receivers, Inertial Reference System and barometric altitude sensing equipment
 2. Develop the procedures...Avionics that can create a navigation trajectory, (on RNP certified aircraft this is provided by the Flight Management System (FMS) which can store thousands of trajectories)
 3. Meet operational/training requirements...Aircrew must be able to operate the automation to be able to fly RNP procedures while using autopilot/auto-throttle and display systems that depict the aircraft progression along the procedure and alert the aircrew to any fault in the system



Alaska Airlines Required Navigation Performance



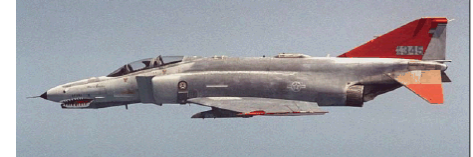
- Example of Advanced Automation in place in the NAS
- Advanced Avionics (e.g., redundant FMS/INS/GPS with EGPWS)
- Procedure flown in service, in visual conditions to collect navigation performance data...built the case for IMC approval of the procedure
- RNP enabling elements:
 - Accuracy (calculated position, including errors)
 - Integrity (containment protection)
 - Availability (GPS and onboard systems)
- Alaska Airlines' Typical RNP values:
 - .3nm – hand flight authorized (same value as public GPS approaches)
 - .2, .15, etc. – auto-coupled only
 - .11 – 737 NG (e.g., SFO and DCA)
 - .10 – 737 NG with Nav Performance Scales on PFD
- Actual Navigation Performance (ANP) calculated, displayed to pilot, and input to autopilot – ANP must be better than the Required Navigation Performance of the flight procedure
- If ANP value increases beyond RNP, then the higher RNP value may be used

Air Force Weapon System Evaluation Program

- Purpose: weapon performance data gathering and ground/aircrew training
- Planning/Briefing
 - Design the mission to objectives (airspace/aircraft/missile to be used?)
 - Full-scale or sub-scale drone with any extras?
 - Weather
- Execution
 - Range Sweep with E-9A, Airspace Surveillance and Control, Chase Aircraft
 - Weapon Kinematic Trajectories
 - Drone Recovery Procedures
- Contingencies
 - Loss of Comm or Data Link
 - Ordinance problems
 - Damaged Drone
 - Other? Chain of command managed...
- Lessons for SUAS: Tests are routine and safe, so can SUAS airspace testing!



MQM 107
sub-scale drone



QF-4
full-scale drone



4-ship F-15 Launch of AIM 7s

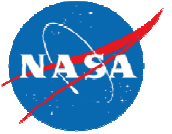


E-9A with
Sea Surveillance Radar



Control Room 8

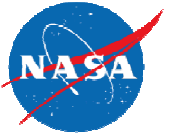
Military UAS Operations



- Airspace Management: Procedural Separation of UAS from other UAS or Manned Aircraft is conducted through the daily Air Tasking Order
 - Daily airspace deconfliction plan sets up segregated airspace from manned aircraft
 - Dynamic changes managed in real time by air battle managers
 - Large UAS have comm-relay and JTIDS link capability that allows UAS pilot/operator to follow datalink or voice command and control or ATC instructions
 - Small UAS do not integrate with manned aircraft operations and are segregated
- Runways afford common points of use for medium and large UAS, but not small ones which most have off-runway landing zones
- Even as good as military operations are, they have more risk than a typical civilian is willing to accept... so what can the SUAS community learn from the MC130 and RQ-7 mishap?



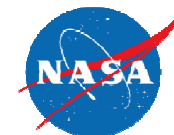
Operation Heli-STAR...1996 Atlanta Olympics



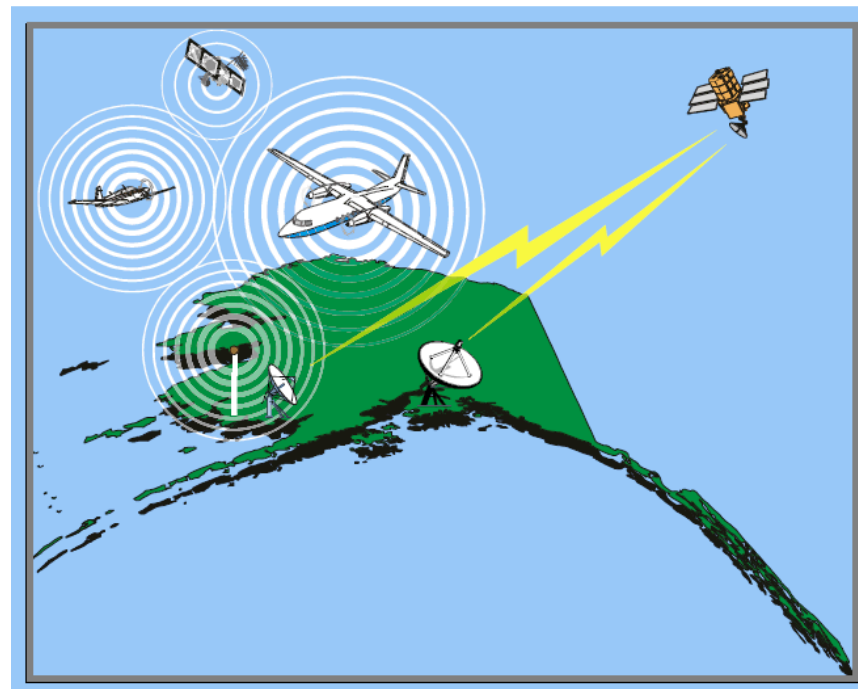
- Helicopter Short Haul Transportation and Aviation Research
- Public-Private partnership (\$10M), FAA led, NASA, state and industry supported
- Used cockpit traffic and weather displays, highways in the sky (above existing highways), and controller pilot datalink communications (CPDLC)
- Heli-STAR had three major thrusts:
 1. The establishment and operation of a helicopter-based cargo and emergency response transportation system
 2. The management of low-altitude air traffic in the airspace near the Olympic venues
 3. The collection and analysis of research and development data associated with items 1 and 2



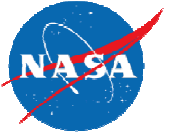
Alaska Capstone Program: 1999 to Present



- Championed by George Donohue, FAA Associate Administrator of Research and Acquisitions
- Govt funded as a transformative aviation technology system by Vice President Gore and congressional leadership
- Alaska chosen for test bed – improve General Aviation safety accident rate 4X that in lower 48
- FAA rapidly implemented airborne system: certified, purchased and installed avionics (GPS, ADS-B, moving map, terrain, traffic and weather displays)
- FAA rapidly implemented ground control system: Ground-Based-Terminal network installed and ADS-B location reporting implemented and authorized for use by controllers on radar screens for 5nm IFR separation



Small Aircraft Transportation System: 2005



Arrival from En route

- By IFR flight plan, managed by ATC
- Pilots request landing sequence from AMM prior to SCA entry

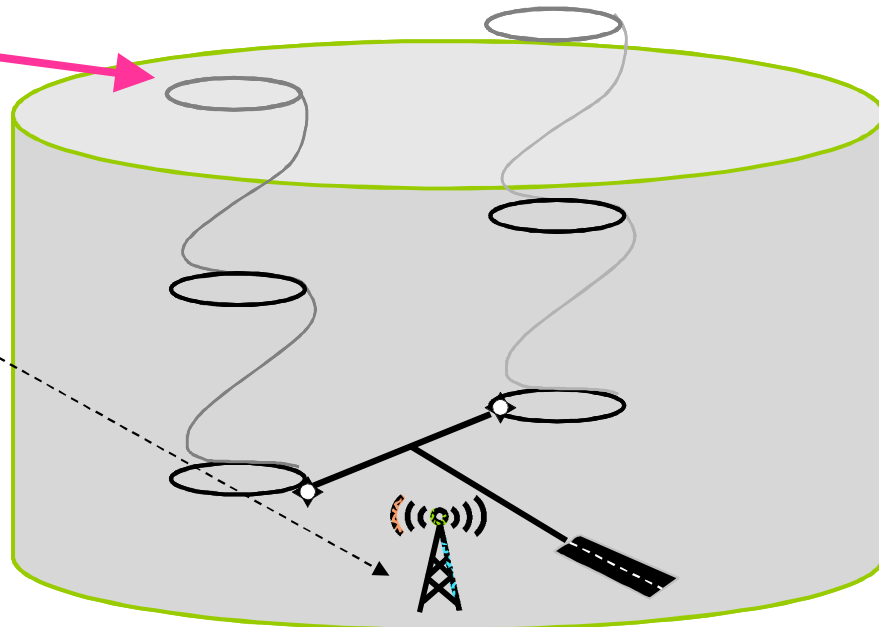
Self Controlled Area (SCA)

- Established during IMC by ATC
- Pilots responsible for self-separation
- Pilots fly simple, orderly, IFR procedures (initially a GPS-T)
- Traffic alerts give second safety tier



Airport Management Module (AMM)

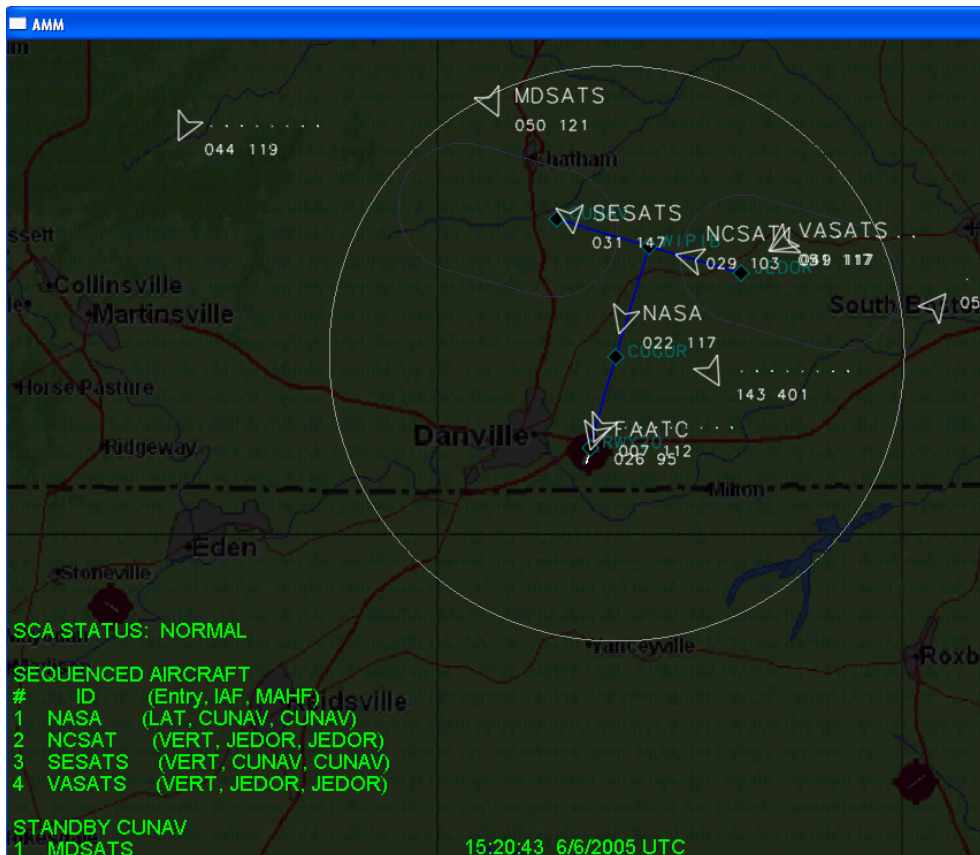
- Provides SCA status and arrival sequence
- Simple “Bucket counter”...Does not provide separation or clearances



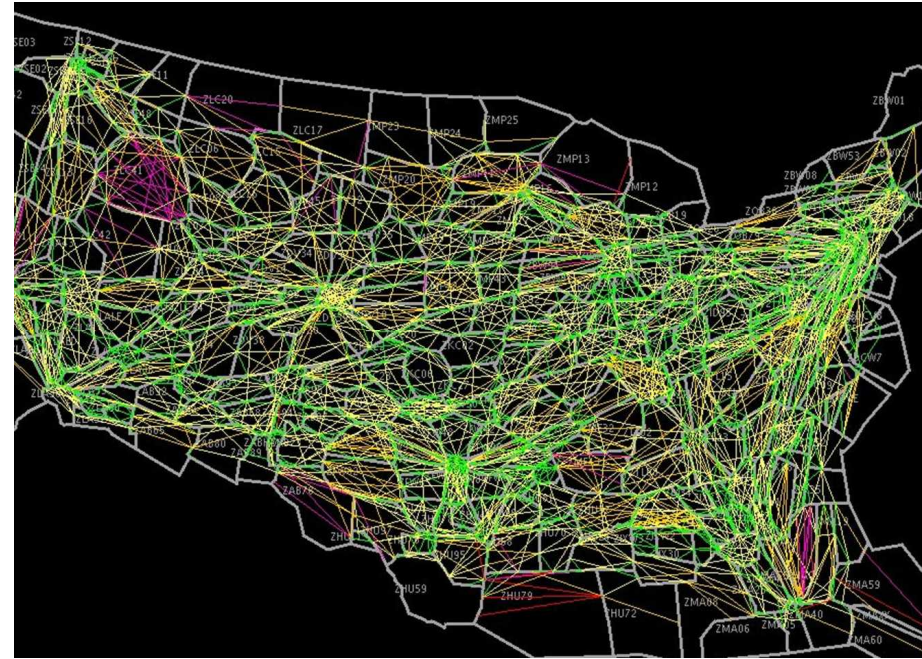
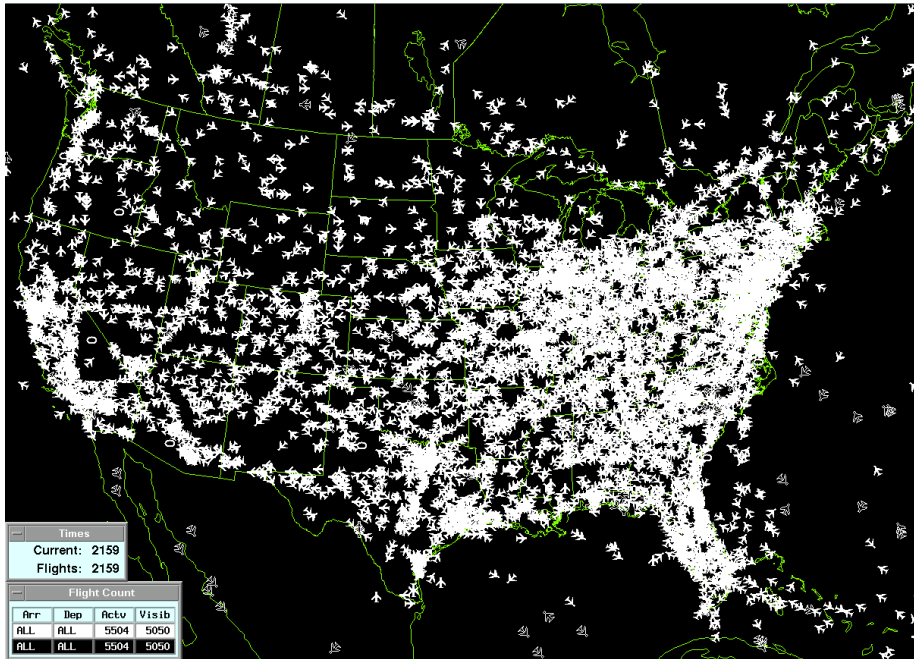
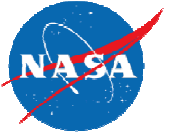
SATS HVO...Three Tiers of Conflict Prevention



1. Design the HVO Procedures to assure separation (verified by formal analysis)
2. Aid the Pilots with Procedure Support to guide them through HVO Procedures
3. Provide Independent Conflict Detection and Alerting System as the final tier



Airspace: The NAS is crowded...



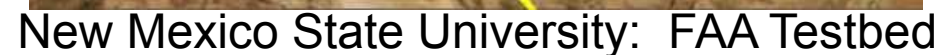
But:

- The NAS does still have a lot of availability that can be used by SUAS
- Uncontrolled airspace in Class E and G surface to 17,999 feet – General Aviation aircraft are not required to have positive control by FAA
- However, uncontrolled GA aircraft do have registered owners and certificated pilots so are still a known commodity and can be procedurally avoided – don't set up a SUAS underlay experiment near them!
- A Sense & Avoid capability would be necessary to avoid colliding with general aviation aircraft with no transponder or radio

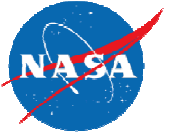


- Crop Monitoring
- Package Delivery
- ISR

- 15,000 sq mile range
- Developing File and Fly UAS requirements for vehicle certification, sense and avoid, vehicle separation standards

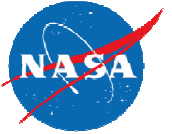


State of the Art Access to the NAS...



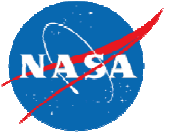
- State of the Art: NAS access cautiously permitted for small UAS
- **14 CFR Part 91 Policy Statement**: *The current FAA policy for UAS operations is that no person may operate a UAS in the National Airspace System without specific authority. For UAS operating as public aircraft the authority is the COA, for UAS operating as civil aircraft the authority is special airworthiness certificates, and for model aircraft the authority is AC 91-57.*
- Public operator – Special Use Airspace by COA, pilot in command is responsible for separation and obstacle avoidance
- Civil operator – experimental category, can be for R&D, not for business
- Recreational use of the NAS (aircraft modelers): within line of sight, below 400 feet and away from airports except by permission, not for business
- **A new FAA rule is coming in 2013 about small UAS...**

Opening the Door to the NAS...Building Trust



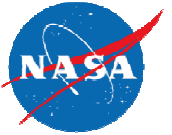
- Opening the door by building trust: Can public, civil experimental, or model aircraft operators *prove* we can trust SUAS?
- Airspace Experiments that will build trust (such experiments can be research, but not for business)
- Increase perceived value: Expand societal capability by including UAS automation (e.g., collect weather data and improve weather modeling)
- Reduce societal risk: Emulate SUAS doing jobs people do poorly (prone to human error)
- Reduce the mundane tasks: Emulate SUAS doing repetitious jobs that can be standardized
- Increase societal familiarity with these systems: Make SUAS operations routine, low-risk and high payoff
- Mitigate by design: Can SUAS be as safe as (a bird, a GA aircraft, etc.)?

Opening the NAS Door...SUAS Capability



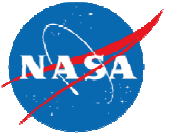
- SUAS requirements that could extend robustness and performance to more complex UAS and airspace
 1. Redundancy levels need to be defined for avionics/communications navigation and surveillance (CNS) and flight critical systems
 2. System errors need definition and risk mitigation
 3. Graceful failure modes (conflict prevention system, navigation, datalink, flight systems)
 4. Safe off-nominal vehicle performance (e.g., engine out results in “safe” vehicle descent rates to automated crash landing)
- Ground station standardization: need requirements (robustness, reliability, availability, etc)
 - Build the trust...

Potential Paths to an Underlay Success...



- Testing/data collection in service – Airport runway/lighting inspections conducted by military for Military Airfield, potentially by FAA air traffic tower controllers Civil Airport
- Scheduled Airspace Use of a low use airspace? (By COA, UAS can occupy low-use airspace when no others do)
- Underlay Experiment Considerations
 1. Select a candidate mission
 2. Develop “nominal” flight procedures that can be replicated as a template for multiple locations (ensure vehicle separation from obstacles, people, and other vehicles)
 3. Single vehicle with an advanced navigation system, including lost navigation source error progression – resulting in known nav precision and a procedure to support it
 4. Datalink (for navigation, and broadcast of position state info, health, intent)
 5. Augment with ground automation (sequencer, sense and avoid)
 6. Multi-vehicle procedures developed and validated
 7. Develop “off-nominal” flight procedures (Lost link reacquisition profile; ditching procedure)
 8. Collect flight data under nominal conditions that extend into more complex conditions (e.g., begin within line of sight before going beyond line of sight; VMC before IMC)
 9. Chase aircraft can be used to maintain visual

Conclusions



- It seems feasible to set up underlay airspace (<400ft by COA) that can facilitate progress to higher altitude COAs
- Public use data or civil research or even model aircraft research can help prove to society we can trust these systems
- The University of North Dakota and New Mexico State University have standing COAs that could be helpful and partnering is encouraged
- Much experience exists that should be applied to multi-aircraft flight procedures, vehicle avionics, and ground stations that would facilitate separation assurance and build an airspace access roadmap for SUAS
- Once society trusts these systems, then a champion will speed the SUAS airspace access process

