February 20, 2020

Upper E Traffic Management (ETM) Tabletop 2 Summary

NASA Ames Research Center, December 12, 2019

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1 Introduction

In April 2019, the National Aeronautics and Space Administration (NASA) hosted an Upper E Traffic Management (ETM) Tabletop/Guided Discussion session with Federal Aviation Administration (FAA), industry, and government stakeholder Space Act Partners in attendance to gain an understanding of planned operations above Flight Level (FL) 600 and begin discussions around a concept of operations for ETM, including common principles and assumptions about the operating environment.

A second tabletop exercise with FAA, industry, and government stakeholders was hosted at NASA Ames Research Center on December 12-13, 2019 to explore ETM concept development considerations associated with air traffic control (ATC)/ETM interactions.

On December 12th, Day One of the Tabletop, the FAA and NASA facilitated the discussions, focusing on operations transitioning to/from ETM environment, operations that occur both above and below FL600, contingency operations, and other topics that impact air traffic control operations. Subject matter experts with operational expertise from industry (operators and stakeholders), Department of Defense (DoD), NASA, and the FAA participated in the discussions (see Appendix A for a list of attendees).

On December 13th, Day Two of the Tabletop, the industry stakeholders facilitated the discussions around ETM cooperative management above FL600- a community-based traffic management concept where the Operators are responsible for the coordination, execution, and management of operations.

The objectives of Tabletop #2 were as follows:

- Identify operational issues/considerations and data impacts associated with:
  - Assess current and future operational characteristics/tempo
  - Transition to/from ETM
  - Operations straddling ETM/Class A boundary (operating above and below FL600)
  - Off-nominal/Contingency operations
  - Inform development of cooperative management concept

Scenarios were presented to facilitate discussion between participants using structured questions to explore operational details. An overview of the scenarios is provided in the Tabletop #2 Scenario Overview table.

Table 1. Tabletop #2 Scenario Overview.

Scenario #	Scenario	Scenario Events
1	Planning, Takeoff, Ascent (location for takeoff-remote field within Air Route Traffic Control Centers [ARTCC] only ops or field within terminal control)	• Planning/Clearance • Takeoff • Ascent to operating altitude
2	Descent (location for landing-remote field within ARTCC only ops or field within terminal control)	• Planning • Descent from operating altitude • Landing
3	Dual Class A/Upper E Operations	• Operations straddling FL600
4	Off-Nominal	• Uncontrolled descent into lower altitudes • Lost link

Participants were asked to discuss operator tasking, detailed procedures, operational impacts, and system/data impacts based on their operational perspectives. Structured questions for each operation type were asked with regard to:

- Operating environments (takeoff/landing locations, airspace classes, traffic densities)
- Operational impacts/issues for each phase of flight and operation type
- Communication, Navigation, and Surveillance (CNS)/equipage
- Required ATC services
- Procedures
- Information/data requirements

This report summarizes the FAA/NASA-facilitated discussions that took place on Day One. Although ETM cooperative management was not on the Day One agenda, there was some discussion on this topic, highlights of which are summarized in Section 4. Actions resulting from the Tabletop are presented in the Section 6. Slides from the Tabletop are available for review in Appendix B.

2 Upper Class E Vehicle Types, Operators, and Operational Profile Descriptions

Industry participants represented the population of current and/or projected upper Class E operations and vehicle types, including an manned fixed wing supersonic aircraft, an unmanned fixed wing - high speed vehicle, several high altitude long endurance unmanned fixed wing vehicles, an unmanned balloon, and an airship. These vehicle types and operating characteristics are summarized in this section.

2.1 Manned Fixed Wing Supersonics

Aerion

The Aerion AS2 is leveraging emerging low boom capabilities to enter the market of supersonic passenger travel around 2026. Aerion initially expects to operate out of smaller, executive airports on an as-needed basis. The vast majority of aircraft owners will be individuals and FlexJet. The aircraft will be built in southeastern U.S., with close access to unrestricted airspace for testing. Aerion aircraft will operate similar to a conventional aircraft but with a faster ascent rate (and potentially steeper climb). Operations will range from FL410 to above FL600, with vehicles capable of reaching supersonic speeds in the mid-FL300 range. Aerion's goal is to operate at high altitudes for as long as possible to maximize fuel efficiency. Aerion is prepared to comply with all FAA regulations applicable to their operation, including CNS requirements. Direct pilot-controller communications will be established through Controller Pilot Data Link Communications and traditional push-to-talk capabilities. ADS-B will be used for surveillance. Navigation will be enabled through Global Positioning System (GPS) navigational capabilities.

2.2 Unmanned Fixed Wing – High Speed

Northrup Grumman

Northrop Grumman's Global Hawk operates similar to large manned aircraft; however, it is controlled by a remote pilot at an operations center. Global Hawks are government aircraft used to support military operations, conducting research and surveillance missions, so they typically operate out of restricted airspace. They take 30 minutes to reach operating altitude above FL500 at speeds of up to 360 knots ground speed. Instrument Flight Rules (IFR) flight plans and clearances are obtained for transit through controlled airspace. Ascent/descent is typically performed via a spiral climb (to promote airspace efficiency). The aircraft can maneuver as needed via manual adjustment by the remote pilot-in-command (RPIC). Takeoffs and landings are limited to government-controlled airfields.

2.3 High Altitude Long Endurance (HALE) Unmanned Fixed Wing

Airbus

The Airbus Zephyr high altitude unmanned fixed wing vehicle currently provides broadband communications and collects research data in Australia. The Zephyr executes conventional takeoffs and landings in a remote area via a slow cylindrical ascent and descent pattern (approximately eight hour duration, 100-150 feet/minute) to operational levels above FL550. The Zephyr is vulnerable to environmental impacts, has limited maneuverability, and can maintain altitude if necessary, depending on conditions. IFR flight plans are not required in Australia, but notification prior to ascent and descent is provided via Notices to Airmen (NOTAMs), and ATC authorization is obtained in accordance with applicable Letters of Agreement (LOAs). Surveillance consists of transponders and automatic dependent surveillance - broadcast (ADS-B). Communications with ATC are established through a ground control center landline. Navigation is primarily GPS-based.

Aurora

The Aurora Odysseus intends to provide climate researchers with long-term, high-resolution observation capabilities. Aurora currently does not have an operational vehicle, but intends to launch one several weeks-long mission once per week within the next two years. Much like other aircraft in its class, the Odysseus is slow-moving, taking four to six hours to reach operational altitude. It will execute a pattern climb (e.g., spiral) to accommodate ATC needs. It travels 16 to 20 knots true airspeed, but speed is wind dependent. Launch is anticipated to take place in controlled airspace. ATC notification and NOTAMs will be required prior to launch. Communication with ATC will occur throughout the operation. Chase aircraft will be used up to an altitude of FL180, with ATC providing separation services through Class A airspace. Surveillance will consist of transponders and ADS-B, with ground control center voice communications with ATC. Navigation will be GPS-based.

AeroVironment

The AeroVironment Hawk30will perform as telecommunications base, delivering connectivity to remote areas above a fixed location. Although AeroVironment prefers a cruise climb, it typically executes a cylindrical ascent/descent (mission and wind dependent) up to operational altitudes of about FL600. Climb and descent rate is approximately 100 feet/minute, taking roughly eight hours to ascend to operational altitude and reach the ground on descent. Currently, IFR flight plans are not filed - operations are conducted under a Certificate of Authorization (COA). A mix of waypoints and coordinates are used to navigate. Equipped much like other aircraft of its class, the Hawk30 uses ADS-B for surveillance, establishes voice communications with ATC via control center, and uses GPS for navigation.

2.4 Balloon

Loon

The unmanned long endurance Loon balloons deliver connectivity to people in unserved and underserved communities around the world. Up to a dozen Loon balloons launch per week with months-long flight durations. They currently operate under LOAs and waivers, coordinating with ATC as appropriate. Ascending to operational altitudes above FL500 roughly in one hour, the free balloon follows the wind pattern, reaching ground speeds of up to 100 knots. Ascent cannot be stopped. Maneuverability at operating altitude is achieved by adjusting altitude to catch prevailing winds. Loon coordinates ascent and descent with ATC, descending within radar coverage whenever possible. Vehicles descend into remote areas using parachutes to guide the vehicles to planned landing sites. ADS-B is used for surveillance. Communication with ATC occurs directly through an operations center that supplies position reports. GPS is used for navigation.

2.5 Airship

Sceye

The Sceye TV 17 airship is a lighter-than-air, helium-filled, remote-controlled airship that enables communications and research capabilities through long duration, high altitude flight. These operations are currently in a planning state—none are operating at this time. It will launch and land in dedicated locations as a free balloon. A source of limited power will provide maneuverability at operating altitude (FL640-FL650). Sceye anticipates operating under IFR flight plans. They have the ability to provide highly accurate predicted tracks based on observed environmental factors. ADS-B is anticipated to be used for surveillance while very high frequency (VHF) will establish RPIC/ATC communication. Navigation will be enabled through GPS.

3 Tabletop Exercise

Operators provided details about their vehicle and operations via a questionnaire prior to the Tabletop. This data was incorporated into the Tabletop #2 data collection materials to maximize time during the exercise. The Tabletop discussions were primarily structured by phase of flight—flight planning, takeoff/launch, descent, straddling operations, and contingency operations. Operators were asked to share information individually for vehicle and operations-based portions of the exercise, while other conversations were group ATC/operator discussions designed to elicit thoughts on potential airspace management techniques for specific scenarios (i.e., Class E Entry Point Change and Operations Straddling FL600 scenarios).

3.1 Operational Tempo

Operators provided information about their anticipated operational tempo, both near and far term, so that the Tabletop participants could gain perspective on the number of predicted operations and impact to the National Airspace System (NAS).

3.1.1. Manned Fixed Wing Supersonics

Aerion

Aerion is not currently operating; their goal is to be operational by 2026. Aerion will operate in the fixed wing supersonic category, serving as a business jet. Their goal is to sell 500 aircraft over the next few years, with 10 aircraft airborne globally at any given time (three to four operating within the NAS at a given time). Aerion's operations will provide on-demand service unlike scheduled airline operations. Not all flights will be supersonic operations. Short-range flights will be subsonic, flying at approximately FL400.

3.1.2. Unmanned Fixed Wing – High Speed

Lockheed (U-2)

Lockheed's U-2 performs routine military flights out of restricted airspace in the western half of the United States (U.S.). Lockheed is also developing an airship with an envisioned fleet of 100 aircraft. They expect to maintain a consistent airborne fleet size, each performing six-month loitering operations, with the frequency of launches dependent on the refresh rate.

Northrop Grumman

Today, Global Hawk operations occur five to six days a week, operating mostly within FL510-FL590. Some Global Hawks operate off the east and west coasts of the U.S. but most operate overseas. They expect a stable operation tempo although the North Atlantic Treaty Organization (NATO) is expected to obtain the aircraft with the goal of international flight.

3.1.3. HALE Unmanned Fixed Wing

Airbus

Airbus currently has one unmanned HALE fixed wing aircraft operating that stays airborne for multiple weeks, but they are expecting to eventually operate multiple aircraft at a time.

Aurora

Aurora expects to begin operating within one to two years, with launches approximately once per week. The aircraft, a solar unmanned HALE fixed wing, is designed for weeks-long flights, with single air vehicle flights every few weeks. Aurora will start with infrequent test flight/data collection operations. Once operational, they expect once-a-week flights on average (takeoffs and landings). The objective is to transition to commercial operations.

AeroVironment

AeroVironment has a current operational tempo of about one flight per month (up to 12 per year). Beginning in 2020, the rate of operations is expected to double yearly. The goal is regular flight with hundreds of aircraft, and hundreds of operations, within a given year.

3.1.4. Balloon

Loon

Loon currently logs about 400,000 flight hours each year—about 100,000 are accrued in United States oceanic airspace annually. Seventy-five percent of these operations occur between FL500 and FL600 and are comprised of clusters of 50-plus balloons. Loon is currently launching about a dozen balloons per week, with the goal of ramping up to several million flight hours with hundreds of vehicles.

3.2 Pre-flight and Takeoff/Launch

Pre-flight and take-off/launch discussions focused on coordination, flight planning practices, and procedures specific to each vehicle type. Each operator detailed information specific to their operation. FAA participants offered agency/ATC perspectives on the subjects.

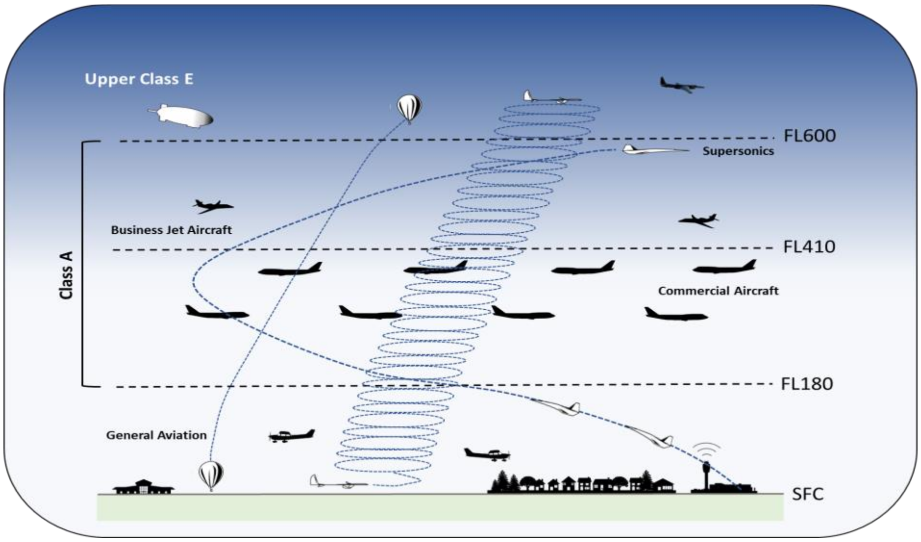

Figure 1. Take-off/launch and transit to Upper Class E airspace.

3.2.1. Pre-flight and Flight Planning

Preflight and flight planning discussions revolved around flight planning, ATC notification, and authorization requirements. Balloon operators are the only participants not required to file flight plans; all operators notify ATC of intent and receive ATC authorization to fly.

All Tabletop participants agreed that changes to FAA flight planning could offer opportunities to better support flight planning for upper Class E operations. Flight plan considerations included:

- The provision of a set of routes and contact information to ATC is the primary function of the current flight plan—it is possible that more information could better support ATC needs.
- A number of operator flight plans are/will be composed of both waypoints and latitude/longitude (lat/long) coordinates. This combination has potential impacts on ATC (e.g., lat/long conversions) and ATC systems (e.g., could exceed flight plan characters or route limits).
- Current flight planning support systems do not support long duration missions. Flight plans that exceed 24 hours time out. Flight plans will typically work for vehicles transiting to/from Upper E, but not long endurance flights operating at altitude. There are work-arounds, such as re-filing and flight plan stitching, but the potential for errors and system robustness needs consideration.

- Unmanned Aircraft Systems (UAS) contingency plans must be available to ATC in some form. Flight plans are a potential avenue for sharing contingency routes because they are readily accessible to ATC.
- Many vehicle trajectories are susceptible to uncertainty and require frequent updating and modification. Flexibility is a key consideration for flight planning procedures and requirements.

3.2.2. Takeoff/Launch

During takeoff/launch discussions, industry participants were asked to provide information related to their individual takeoff/ launch procedures. Responses varied by aircraft type/operation and maturity of operations.

Many operations are, or expect to be, managed through LOAs with ATC facilities, COAs/waivers, segregated airspace/airspace restrictions, use of low volume airports/airspace, and special use airspace.

Unmanned aircraft have difficulty getting to FL180 due to the inability to meet FAA regulations (e.g., sense and avoid). Regulatory gaps must be filled to accommodate UAS, as these changes can aid in normalizing operations and accommodating unique departures. The FAA has identified regulatory gaps and plans are underway to fill them, but these changes take time. Ground-based detect and avoid (GBDAA) can aide in meeting these operator requirements. Workarounds and mitigations are in place (e.g., chase planes) and are safe, but they are not standardized or normalized. If LOAs are in place with local facilities, they can greatly facilitate transit (ascent and descent) for both ATC and operators.

Weather conditions at takeoff are key considerations for HALE fixed wings, balloons, and airships, as these vehicles are susceptible to winds, ice, and other environmental factors. These susceptibilities impact vehicle takeoff times, vehicle trajectories, and other operational factors, so flexibility is imperative for efficient operations. An ETM operator/ATC digital exchange capability would enable fluid communications, facilitating more flexible and efficient operations.

The performance characteristics and operational limitations of some vehicles that operate in upper Class E airspace have the potential to create impacts to air traffic below FL450. For example, new supersonic fixed wing operations may require a corridor for takeoff and initial climb out while HALE fixed wing aircraft will likely execute very slow spiral climbs to reach altitude.

3.3 Ascent to Operating Altitude

Discussions on the ascent phase of flight explored procedures, ATC service and coordination expectations, and operational issues specific to each vehicle type. Each operator detailed their ascent procedures separately, providing information specific to their vehicle. Vehicle performance and equipage tables were available for reference throughout the discussion. These are located in Slides 35-40 in Appendix B.

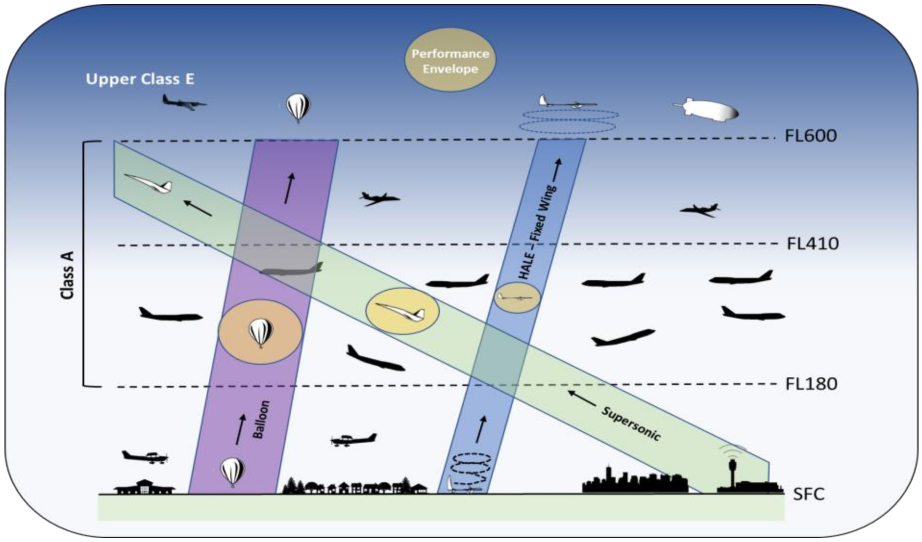

Figure 2. Ascent to operating altitude.

3.3.1. Ascent to Operating Altitude – Airspace Management and Procedures

Ascent procedures and characteristics can vary widely based on aircraft and operation types. Payload capacity can limit vehicle ability to comply with regulations/equipage requirements. Aircraft propulsion, airframe design, and, in certain cases, operating altitude can limit vehicle ability to comply with ATC instructions.

Supersonic fixed wing aircraft operators emphasized the need for a rapid climb to altitudes above FL180 due to high fuel consumption at lower altitudes. Supersonic aircraft need very large airspace volumes to adjust their flight path (as large as 100 miles vertical and 10,000 feet horizontal).

For HALE fixed wing aircraft, the rate of ascent is very slow and lateral maneuverability can be very limited during climb. Vehicle performance is significantly different than traditional aircraft. Generally, launch and climb to altitude requires a calm atmosphere. These aircraft are also very sensitive to weather and wake turbulence generated by other aircraft.

High moisture content and updrafts/downdrafts within thunderstorms can cause failures for balloon and airship operators. They climb relatively quickly and can maneuver laterally using winds but cannot stop, climb, or descend. Balloon operators can predict climb path with a high rate of certainty.

ATC will need to understand the range of performance characteristics and operational differences (e.g., some HALEs may fly backward at times).

3.3.1.1. Manned Fixed Wing – Supersonics

Aerion

Aerion will provide 25-passenger service out of business/executive airports (as opposed to primary commercial airports). Aerion's aircraft operates similar to a conventional manned aircraft but may execute steeper climbs at higher speeds due to fuel efficiency, lapse rates, and noise levels. Aerion's objective is to take off and accelerate as quickly as possible to reduce fuel burn. The aircraft can reach FL410 in approximately 10 minutes and is capable of reaching supersonic speeds at about FL350, although it is operationally inefficient to do so. Supersonic operations typically occur once at operating altitude. There are circumstances where they might cruise as low as FL370, but that would be atypical (e.g., the aircraft is stuck in a strong headwind and does not want to go around). Exact procedures are notional at this time.

The aircraft has the ability to comply with ATC instructions, with the same maneuverability as a subsonic airplane. However, maneuverability becomes more limited at higher speeds, especially when supersonic. When operating at supersonic speeds, the aircraft will take longer to turn.

The airplane weighs approximately 60 tons with wake on the order of a Boeing 737. It is no more vulnerable to meteorological factors than a conventional manned aircraft of similar size.

Aerion expects ATC services to be consistent with the airspace in which it is operating.

3.3.1.2. Unmanned Fixed Wing – High Speed

Northrup Grumman

Global Hawk data and information provided (Slide 36 – Appendix B) reflect one set of procedures for one location; there are no blanket statistics to provide. Procedures vary at different locations. The procedures in place are primarily due to FAA needs and regulatory structure. If NAS constraints were not in place, Global Hawk may choose to operate differently.

Global Hawk is a UAS that typically operates out of restricted airspace and executes a spiral climb through controlled airspace into restricted airspace (upper Class E); both airspace and ascent patterns are mitigations, not preferences. Horizontal departure is preferred, spiral departure is typically executed to meet ATC/NAS needs. The Global Hawk can comply with air traffic instructions. It does not have a wake turbulence classification (due to the nature of these operations no unmanned aircraft has received a wake categorization to date).

Global Hawks navigate via lat/longs while ATC uses waypoints, this combination can create issues because the NAS/ATC operates via waypoints and a common navigation language is important to ATC. Controllers cannot convert and interpret lat/long data quickly and easily.

3.3.1.3. HALE Unmanned Fixed Wing

Airbus

The Airbus Zephyr is a UAS with plans for long endurance missions (capable of more than 100-day flights) with infrequent ascents/descents. It is not likely to operate out of airports. To date, it has operated in exclusionary airspace in Australia and the U.S. (flight tests). It launches in a calm atmosphere and is vulnerable to wake and meteorological issues. It has a very slow rate of ascent, taking up to eight hours to reach altitude. It has some ability to maneuver, but vehicle performance has limitations - for example, lateral movement is limited and slow. Vehicle performance is very different to traditional aircraft - the vehicle may fly backwards at times due to winds. Decision making is considerably different from other aircraft, planning has to be done far in advance.

Payload is critical to the mission, which limits its ability to meet equipage requirements (e.g., airborne collision avoidance system, detect and avoid [DAA]). It is equipped with ADS-B and the operator has ground communication with ATC. There is no DAA system on the vehicle—they currently coordinate with Loon to avoid conflicts while at operating altitude.

Aurora

The Aurora Odysseus is a UAS that will take off and transit to altitude via a pattern climb (likely spiral). A chase aircraft is expected to provide separation up to FL180; ATC services will provide separation through Class A.

Transit operations will be relatively infrequent due to long endurance missions. Aurora's airspeed range on climb is 16-20 knots (note: Appendix B, Slide 38 data incorrect). The vehicle's performance is impacted by winds, such that airspeed will be less than wind speed in mid-altitudes, and the vehicle can fly backwards at times. The vehicle's ability to fly a heading is also limited based on winds. If directed to turn a heading, the vehicle could go in the opposite direction (control is most limited in the jet stream). The aircraft is able to hold altitudes for reasonable amounts of time, but long holds (up to an hour) can affect energy, impacting the vehicle's ability to reach altitude.

The transit portions of the flight will be most problematic due to the inability to meet applicable FAA regulations. Aurora will likely try to seek waivers to operate (e.g., use NOTAM, chase planes). They recognize integration of HALE fixed wing aircraft impacts on NAS operations due to the need for large segments of segregated airspace and their unusual performance characteristics, but the low tempo of transit operations means minimal disruption, at least initially, while total HALE volume is low.

Aurora intends to equip with ADS-B.

AeroVironment

AeroVironment's Hawk30 is a UAS that typically launches from sites with tranquil atmospheric conditions (e.g., sites free of clouds, ice, turbulence). Non-ideal meteorological conditions will delay launch. It typically executes a cylindrical ascent/descent, but cruise climb is operationally ideal. A corridor would be an ideal way to manage transit (perhaps a dynamic, moving block of airspace that promotes equity).

The vehicle can respond to air traffic instructions. It can level off, climb, and ascend upon request, but executes the changes slowly.

Environmental conditions greatly impact the Hawk30. The vehicle is massively affected by lift or sink, as these disruptions impact energy state. It is also vulnerable to icing, turbulence, and wake. Significant vertical and lateral buffer is required, although the amount will differ between aircraft pairs.

The vehicle is equipped with ADS-B.

The vehicle is currently operating in restricted airspace. The goal is to explore alternatives and learn as much as possible.

3.3.1.4. Balloon

Loon

Loon is an unmanned balloon that launches from remote locations. It has a steady ascent rate that cannot be stopped. The balloon can use winds to maneuver horizontally, but not necessarily on request. The path of the balloon can be very reliably predicted. Trajectories are constantly being recalculated throughout the operation and can be shared with ATC.

Loon balloons are somewhat resilient to wake and turbulence; they can withstand some pressure and wake, within limits. Heavy moisture content (e.g., storms, clouds) can cause failures. Updrafts and downdrafts within thunderstorms can cause significant failures.

3.3.1.5. Airship

Sceye

Sceye behaves as a balloon with a steady ascent rate to altitude (ascent cannot be stopped). The vehicle can drift quite drastically on ascent (drift 100 miles and go 100 knots) but it is very predictable. Once at altitude, it has powered cruise to its operational area.

Sceye is very resilient and flexible to turbulence, updraft, downdraft, and wake.

3.3.2. Ascent Scenario – Class E Entry Point Change

Tabletop facilitators presented a scenario in which an operator's planned entry point into the ETM environment has been deconflicted prior to launch. Due to an unforeseen issue, the ETM entry point changes (perhaps due to weather or ATC instruction change), and there is now a conflict. Both vehicles in conflict are limited in their ability to maneuver. The goal of the scenario was to discuss whose responsibility it would be to manage the conflict (ATC/ETM operators) and how it might be resolved.

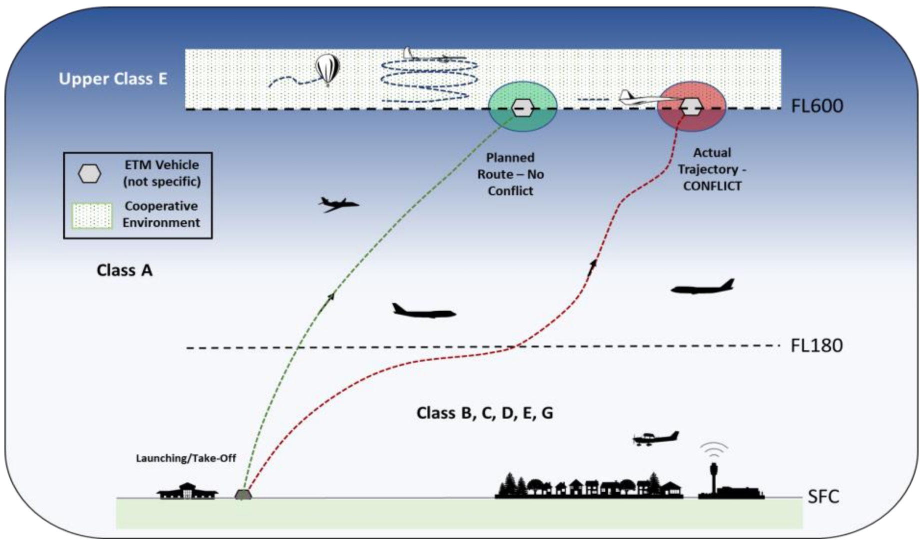

Figure 3. Class E entry point change.

The group agreed responsibility for conflict resolution at an ATC/ETM transition point would fall on ETM operators. Prevention of a conflict at transition into the ETM environment is the most important element of managing this situation because the lack of maneuverability of some vehicles could mean a collision is unavoidable. It is critical that vehicle maneuverability and trajectory projections are built into the cooperative right-of-way paradigm so that clear rules are in place. Should a conflict occur during transition to ETM, the more maneuverable vehicle would have to take action to deviate. For example, HALE fixed wing aircraft may be able to level off and maneuver, but balloon and airship operators will not have that same option.

Continuous re-planning, precise projections, and clear, convenient communication mechanisms among ETM participants and ATC are key to avoiding a scenario of this nature. It would be beneficial for operators to share atmospheric conditions and other detailed information in order to more precisely calculate trajectories and predict conflicts. The more insight operators have regarding limitations, maneuverability, and position projection, the safer and more efficient the airspace. When two vehicles are going to be in the same airspace, a possible cooperative requirement could be that they share key operational information (e.g., atmospheric information) using an agreed upon operator-to-operator paradigm for proximate aircraft.

3.4 Descent from Operating Altitude to Landing

Descent flight planning, airspace management and procedures, and landing were explored in the same manner as ascent. Each operator provided information specific to the vehicle. Performance and equipage tables for all vehicles were available for reference throughout the discussion to provide context (Slides 41-52 in Appendix B).

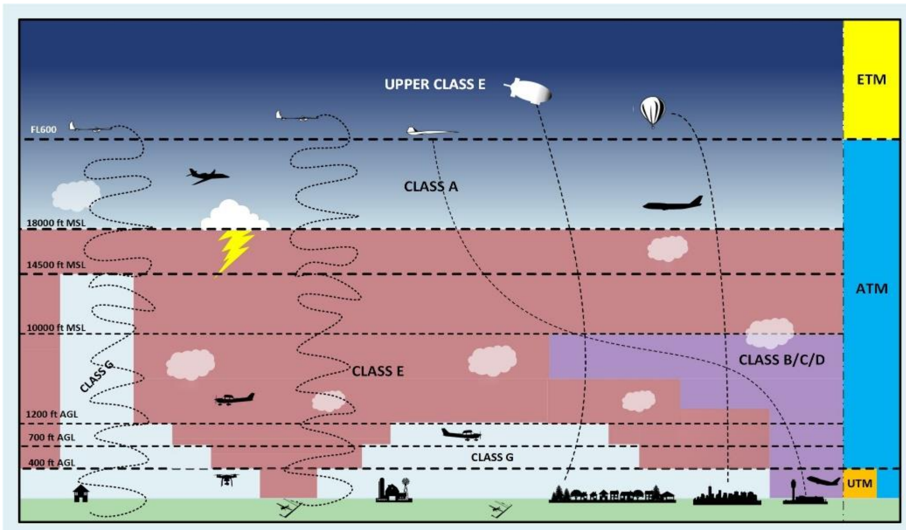

Figure 4. Descent from operating altitude to landing.

Descent from operating altitude is similar to ascent to altitude in all cases. Under the current rules, balloon operators are the only participants not required to get an ATC clearance prior to descent. All operators notify ATC of intent to descend. The ability to comply with ATC instructions is limited for certain aircraft, based on vehicle design and capabilities, among other things. The ability to predict the exact track of certain aircraft types as they transition will vary depending on the type of vehicle and the frequency of re-planning under changing conditions. For the purpose of ATC planning and instructions, the accuracy of the flight track on descent is critical.

Supersonic fixed wing aircraft will want to stay as high as possible for as long as possible to manage fuel and control speed during descent. HALE fixed wing aircraft need to manage available power for thrust during descent; power level depletion rates impact the operator’s ability to provide a 24-hour notice. Balloon and airship operators use descent planning tools and trajectory calculators to predict flight paths.

3.4.1. Manned Fixed Wing - Supersonics

Aerion

For Aerion, descent is similar to ascent. The timing of a subsonic to supersonic switch is situational. On descent, they must manage their airspeed and descent rate to avoid overspeed, this usually requires some space to achieve. The goal is to remain as high as possible for as long as possible and execute an idle descent. Coordination with ATC is important to meet both company and NAS needs.

3.4.2. Unmanned Fixed Wing – High Speed

Northrup Grumman

Descent procedures mirror ascent procedures.

3.4.3. HALE Unmanned Fixed Wing

Aurora

Aurora provides a 24-hour notice to ATC. IFR clearance is required for descent. There is a risk that descent planning could be impacted by low energy reserves, in which case, the 24-hour notice of descent may not be possible.

Vehicle performance on descent is better at higher altitudes. Bank angles at low altitudes are shallow; the vehicle has faster rates of turn at higher altitudes. Its bank angle is very limited at low speeds because of the long wingspan.

AeroVironment

If the vehicle is low on energy, the RPIC may need to request lower altitudes on an ATC clearance. Under nominal operations, the vehicle will perform similar to ascent, except that it will be a little bit slower than the climb. Battery power is a concern on descent, if the vehicle runs low, or out, of power it could trigger an off-nominal event.

3.4.4. Balloon

Loon

Prior to descent, Loon targets a landing area and simulates drift to control the descent to target. Loon coordinates the descent simulation path with ATC 24 hours in advance. Coordination with ATC occurs again, both two hours and one hour prior to descent. Loon then calls ATC five minutes prior to descent. ATC may request a delay.

On descent, drift is controlled by parachute. The balloon separates and becomes two targets below 10,000 feet to minimize impact as payload separates from envelope. Both targets are transponder equipped with ADS-B. Whenever possible, descent is executed within radar coverage.

3.4.5. Airship

Sceye

Sceye descends as a free balloon. It sends up its own radiosondes during flight to determine flight accuracy and uses a descent planning tool similar to other balloon programs. The resulting profile is very accurate. The projected ascent and descent tracks are shared with ATC.

Sceye is currently an unmanned free balloon but planning for Sceye One is underway. Sceye One will be equipped with a small motor for maneuvering while at altitude. On ascent and descent, Sceye One will act as a free balloon.

3.5 Operations Straddling FL600

Tabletop #1 indicated that ETM operators have a need to regularly operate both above and below FL600 (straddle upper Class E and upper Class A airspace). As a result, Tabletop #2 explored operator needs, potential requirements, and potential solutions for managing operations that drift between upper Class E and Class A airspace.

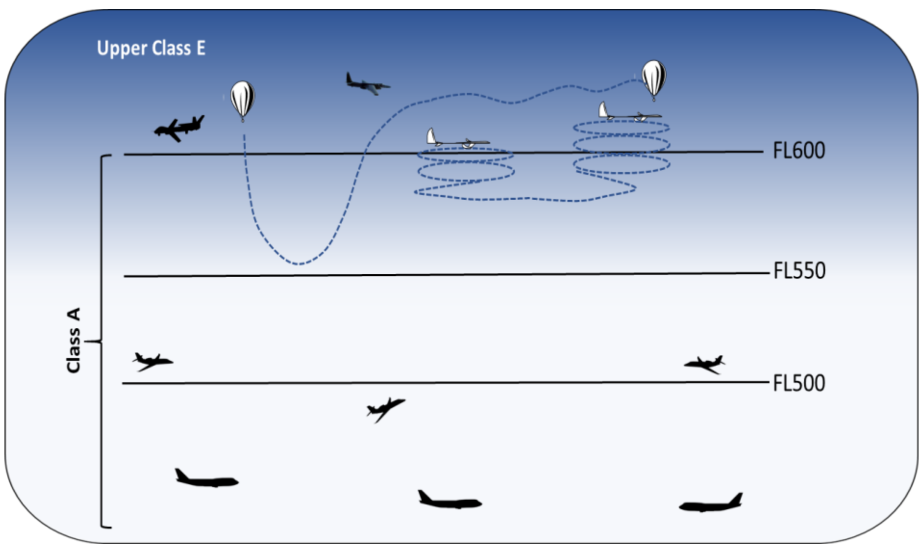

Figure 5. Operations straddling ETM and provided separation environments.

3.5.1. Flexible Floor of Cooperative Environment

All but one participating operator needs to descend into or operate in Class A airspace due to winds and/or to optimize power. FL500 is the lowest operational altitude required by participating operators, although Loon would ideally have as much flexibility to the floor as possible.

Operator needs by vehicle type:

- Supersonic: Aerion's supersonic operations will typically occur between FL500 and FL550, but they will have situational need to operate above FL600.

- Balloons: Loon respects the lowest operational floor permitted by ATC. They prefer as much flexibility to the floor as possible. Their maximum operating altitude is FL650.

- HALE fixed wings: Fixed wing operators plan to operate above FL600 during the day and descend into Class A at night. Descent altitude varies by season and location but the lowest altitude vehicles could tolerate would be FL500.

- Airship: Sceye plans to operate between FL640 and FL650. They may ascend at night (within 1000 feet).

Several options for managing flights that straddle upper Class E and Class A airspace were discussed:

- Airspace Re-classification: Lowering the Class A floor (where conventional traffic is light) to allow ETM cooperative operations below FL600 would accommodate straddling flights. However, it would take FAA regulators five to seven years to make a change when there is not a clear, suitable floor that benefits both ETM- and ATC-managed traffic. A more flexible, less time-consuming solution is desirable.

- ATC Altitude Reservations: ETM operators could coordinate with ATC to obtain block altitudes in Class A airspace on an as needed basis. There are several advantages to this solution: (1) this is done today, so there is a system in place to support this strategy; (2) it reduces controller workload by eliminating the need for controllers to coordinate with one or multiple operator(s) floating in and out of Class A; and (3) establishing a volume of airspace for ETM operations in Class A is sensible due to the nature of high altitude operations and the performance characteristics of the vehicles (e.g., loitering/grid patterns, limited maneuverability, and vulnerabilities requiring considerable buffer). Intensive management of upper Class A operations is not required today. Managing more block altitudes in the future would require additional ATC resources.

  Airspace equity issues could also emerge if operators are competing for large blocks of airspace.

- Flexible Floor of Cooperative Environment: Lowering the cooperative floor where operationally feasible (without reclassifying the airspace) would be an ideal way to provide ETM operators the flexibility they are seeking, while also relieving ATC of the responsibility to manage these operations. A concept of operations that supports the needs of both cooperative- and ATC-managed operations, along with a regulatory structure, would need to be developed.

  At issue is whether the airspace would be exclusive to cooperative operations or whether flights receiving provided separation services would remain under ATC control in the airspace. Participants shared concerns about having two different control systems for one airspace.

3.5.2. Considerations

- ATC-managed descents to Class A must consider a balance between timing and certainty. The longer the ATC notification requirement, the less certain an operator can be of their descent plan (e.g., time, altitude). ETM operators require flexibility due to business models and dependence on environmental factors. ATC needs time to prepare and plan (e.g., move traffic, if necessary), but they also have concerns about making unnecessary adjustments.

- ATC altitude restrictions must be respected by operators regardless of vehicle performance and reliances.

- Whatever the vision for future ETM operations, ATC needs to have knowledge of, and access to, ETM flights/flight data. Two potentially different control systems comingling in the same airspace adds risk for operational issues. The system must also consider the lack of, or gaps in, ATC capabilities (e.g., flight plans time out on these long duration flights).

- Rules for fair access to airspace are imperative—the airspace management method must be fair and equitable for cooperative- and ATC-managed aircraft.

- Accurate, timely information is key to NAS efficiency and safety. ATC tools are not built to manage strategic deconfliction/operations, so supporting capabilities and information management need consideration if the FAA is going to support deconfliction processes.

3.6 Contingency Management

Uncontrolled descent and lost link contingency management was explored from an operational perspective. Individual operators were asked to discuss management techniques and vehicle considerations specific to each event. ATC was asked to comment, from their perspective, on manageability of, and issues associated with, proposed responses.

3.6.1. Uncontrolled Descent

An uncontrolled descent scenario was presented to elicit operator response protocols and drive out operational considerations. Each operator detailed their response to uncontrolled descent. ATC noted operational factors and difficulties associated with managing an uncontrolled descent.

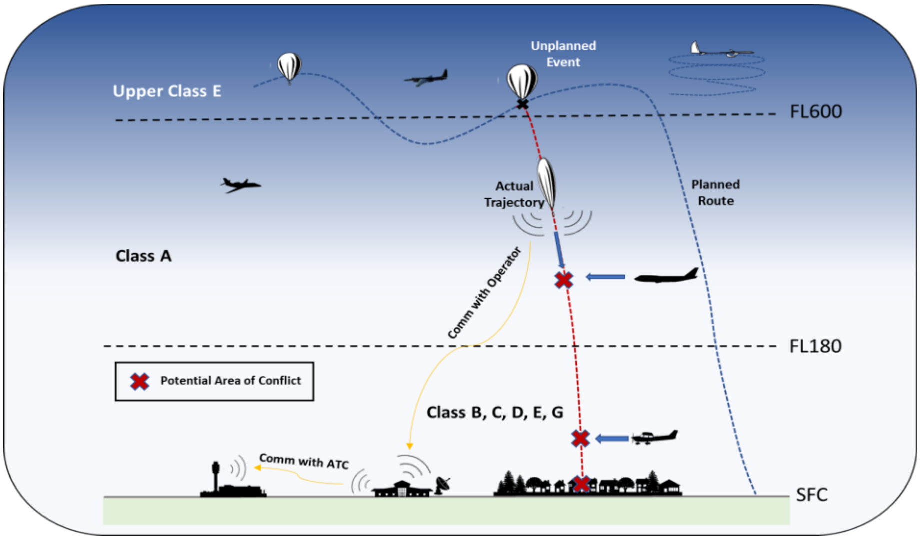

Figure 6. Uncontrolled descent.

3.6.1.1. Manned Fixed Wing - Supersonics

Aerion

In the event of an uncontrolled descent, Aerion would squawk 7700 and follow manned aircraft emergency protocols.

3.6.1.2. Unmanned Fixed Wing – High Speed

Northrup Grumman

The RPIC would attempt to regain control of the aircraft and if the Command and Control (C2) link was available, the squawk code would be adjusted to 7700. Standardized procedures are in place for uncontrolled descent. These procedures would be followed to mitigate potential damage.

3.6.1.3. HALE Unmanned Fixed Wing

Aurora

Aurora has a quick reference handbook outlining procedures for a number of contingencies. A human engineer would be in the loop to manage the process. If the vehicle is not behaving as expected, Aurora's ground station has automated alert and alarm functionality that would alert the RPIC. ATC could be notified via aircraft communications or telephone. In the future, Aurora intends to automate contingency management, including squawk code changes and contact with ATC.

AeroVironment

AeroVironment personnel would calculate a fall point based on current location, altitude, and forecasted winds. This fall point would be communicated to test personnel today, but it could be piped to other agencies and stakeholders as well (e.g., fire department). Flight crews have procedures for contingencies memorized. In this case, mission control would be notified, followed by ATC and emergency response personnel. The appropriate code would also be squawked. The long-term plan is to automate procedures and develop more sophisticated responses, including squawking a special code in the case of an event.

Airbus

Zephyr would react to uncontrolled descent in a similar manner to Aurora and AeroVironment.

3.6.1.4. Balloon

Loon

The Loon control center would get an alert in the event of an uncontrolled descent. They would use available ATC phone numbers to notify ATC and squawk the appropriate code. They have not automated a change of squawk code because "emergency" code does not have a universal standard, but they are considering alternatives. Emergency response personnel would not be required if a balloon was experiencing an uncontrolled descent.

3.6.1.5. Airship

Sceye

In the event of an operation failure, such as a complete loss of power, Sceye would contact ATC. The projected trajectory of the ship would be profiled and shared with ATC. If aircraft communications are intact, the flight crew would adjust the squawk code. A mobile control center would monitor the flight path. The ship would still have considerable lift, the descent would not be rapid (approximately 750 feet per minute), and a huge impact would not be anticipated.

3.6.1.6. FAA

The most critical component to managing an uncontrolled descent is the timing of ATC notification—ATC must be notified of the event as soon as possible. Accurate trajectory information is also key (e.g., operator projections, surveillance data) so that ATC can sanitize the airspace along the projected path. Loss of aircraft surveillance would be very problematic in this situation (e.g., ADS-B/transponder loss) - redundancies and multiple links are important mitigations.

3.6.2. Lost Link

A lost link scenario was presented to elicit individual vehicle response protocols and drive out operational considerations. Each operator detailed their operational response to lost link. ATC noted operational considerations associated with managing a lost link event.

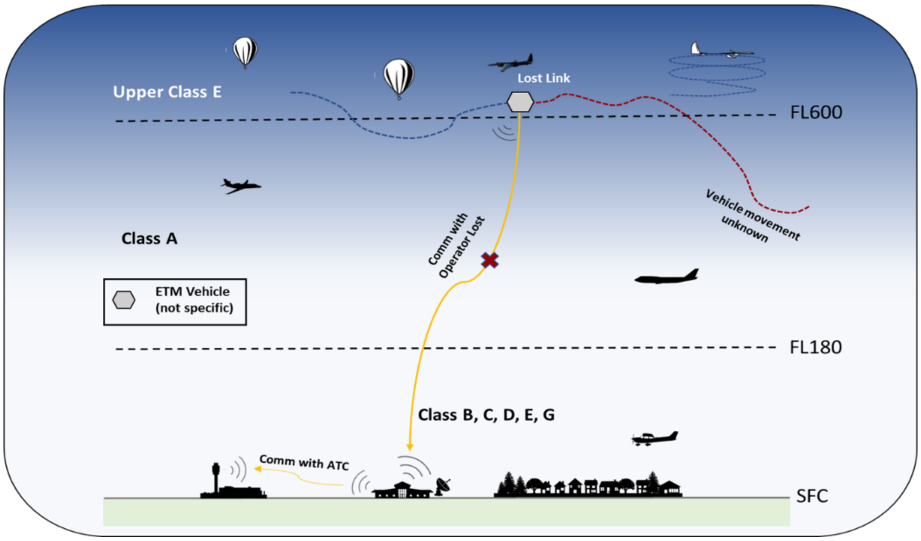

Figure 7. Lost link.

3.6.2.1. Manned Fixed Wing - Supersonics

Aerion

Aerion is a manned aircraft, so a lost link would constitute limited information to the aircraft. The aircraft would have to slow down, but it would still remain under the pilot's control and operate normally. A change of communications status would be communicated to ATC, if possible.

3.6.2.2. Unmanned Fixed Wing – High Speed

Northrup Grumman

Global Hawk has a sophisticated suite of lost link logic. Contingency routing and planning are carefully developed prior to flight. Pilot and flight crew contingency training is stringent. Contingency plans are available to ATC.

3.6.2.3. HALE Unmanned Fixed Wing

Aurora

The Odysseus has three communication and control links—two line-of-sight radios and one backup satellite link—so lost link is unlikely, but not impossible. Once a predetermined time elapses with no signal (a few minutes), lost link would be declared, the vehicle would change the squawk code to 7400, and execute a preprogrammed flight path to a landing location. The lost link procedure (flight path) is updated in the event of lost link.

AeroVironment

The Hawk30 response to lost link would be similar to Aurora, right down to C2 link configuration. The vehicle would squawk a lost link code, but the response would depend on the problem. The vehicle may not execute a landing, but it may descend and hold altitude until link is restored. Speed adjustments may be required due to the lack of data designed to maintain speed.

3.6.2.4. Balloon

Loon

After three hours has elapsed with no link, the transponder would squawk a discrete code, and the balloon would descend. The three-hour time delay is configurable and can be automatically set per onboard programming. If the transponder is off, it will come back on automatically after a period of time. Balloons are programmed not to descend in areas where it could be problematic. Loon works with ATC to ensure surveillance (ADS-B) is functional and provides them a projected flight path.

3.6.2.5. Airship

Sceye

Sceye programming allows ten minutes to reestablish communication prior to terminating flight and descending.

3.6.2.6. FAA

ATC must be notified of a lost link event as soon as practical. The vehicle response to the event must be known and predictable. If the ATC plan is available and reliable, it can manage lost link events.

Contingency management is not just aircraft centric—it is much more comprehensive. It needs to take NAS operations into account (e.g., traffic flows).

4 ETM Cooperative Environment

Although discussions on cooperative operations above FL600 were reserved for industry-led discussions on Day Two, potential interim solutions for strategic deconfliction did surface during on Day 1. In particular, two different alternatives were discussed:

- The FAA Air Traffic Control System Command Center (ATCSCC) Central Altitude Reservation Function (CARF) Unit does strategic deconfliction for space launches, military airdrops, and other operations. The CARF has the potential to provide an interim cooperative deconfliction function for upper Class E operations. The CARF Unit has top secret DoD clearance (e.g., top secret mission information, due regard operation details), which would allow for DoD/industry deconfliction without the concerns of compromising sensitive or classified information.

- FAA CARF and moving altitude reservations (ALTRV) could provide opportunities to strategically deconflict operations prior to implementation of full-scale ETM deconfliction capabilities.

5 Summary

- General discussion about vehicle performance characteristics, equipage, procedures, and operations will inform concept and requirements development, identify potential considerations, and inform research and simulation activities.
- The need for a structure to support ETM operations that regularly flows between upper Class E and Class A was confirmed. Potential solutions for supporting these operations were identified for consideration (e.g., dropping the cooperative floor).
- Contingency management for uncontrolled descent and lost link were explored from an operational perspective. This information will inform operational requirements and research and simulation activities.
- The FAA's CARF Unit may be able to assist with strategic deconfliction of high-altitude operations as an interim solution.

6 Actions

6.1 Industry Actions

- Industry will identify information requirements and/or considerations for FAA/ATC systems (e.g., flight planning needs, separation envelopes).
- Industry will continue to develop cooperative operations concepts, strategic deconfliction requirements, and vehicle performance envelopes.
- Industry will work with NASA to develop simulations and conduct research to further development efforts.
- Aerion will share airports/characteristics of airports with NASA, if possible.

6.2 NASA/FAA Actions

- The FAA will continue development of a Concept of Operations for upper Class E operations.
- NASA will work with industry to develop simulation and research platforms.

Acronyms

Acronym or Term	Description
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance-Broadcast
ALTRV	Altitude Reservation
ARTCC	Air Route Traffic Control Centers
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
CARF	Central Altitude Reservation Function
CNS	Communication Navigation Surveillance
COA	Certificate of Authorization
DAA	Detect and Avoid
DoD	Department of Defense
ETM	Upper E Traffic Management
FAA	Federal Aviation Administration
FL	Flight Level
GPS	Global Positioning System
HALE	High Altitude Long Endurance
IFR	Instrument Flight Rules
Lat/Longs	Latitude/Longitude
LOAs	Letters of Agreement
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NOTAM	Notice to Airmen
RPIC	Remote Pilot in Command
UAS	Unmanned Aircraft System

Appendix A – List of Attendees

The following participants attended the Tabletop, meeting either in person or by teleconference.

Organization	First	Last	Email
Loon	Léonard	Bouygues	leonardb@loon.com
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Appendix B - ETM Tabletop Meeting Slides

Upper E
Traffic Management (ETM)

Tabletop Exercise 2

December 12, 2019

NASA Ames Research Center
Moffett Field, CA

1

Participants

NASA
Ames Research Center

Defense & Security
Dept. of Defense (DOD)

FAA
NextGen (ANG)
Aviation Safety (AVS)
Air Traffic Organization (ATO)
National Air Traffic Controllers Association (NATCA)
UAS Integration Office (AUS)

Industry

LOON
AERION SUPERSONIC
SCEYE
AIRBUS
AeroVironment
LOCKHEED MARTIN
NORTHROP GRUMMAN
leidos
BOEING
Aurora FLIGHT SCIENCES

2

Agenda

NASA Ames Research Center
Building N-232, Conference Rm 103
December 12, 2019

8:30 AM – 8:45 AM	Check-In	All
8:45 AM – 9:00 AM	Participant Introductions	All
9:00 AM – 9:30 AM	Tabletop 1 Recap Tabletop 2 Introduction ETM Concept	FAA/NASA
9:30 AM – 10:15 AM	Pre-Flight and Take-Off/Launch	All
	BREAK	
10:30 AM – 11:45 AM	Ascent to Operating Altitude	All
	LUNCH	
1:00 PM – 1:45 PM	Descent to Landing	All
1:45 PM – 3:00 PM	Operations Straddling FL600	All
	BREAK	
3:15 PM – 4:15 PM	Contingency Management	All
4:15 PM – 5:00 PM	Discussion Recap & Next Steps	All

3

Welcome!

4

Tabletop 1 Recap

5

Highlights of Discussion

- Industry participants described their different vehicle types and operational profiles
- Discussed current ATC handling practices for transition to and from upper E (FL600) at a high level
- High level scenarios covered:
  - Transition into ETM
  - Strategic Deconfliction between Operations (Pre-Flight)
  - Deconfliction between Pre-Flight and Active Operations
  - Planned Overlapping Areas of Supersonic & HALE Operations
  - Tactical Deconfliction
  - Off-Nominal Event

6

Highlights of Discussion

Agreed upon conceptual areas of development include:

- The ETM floor is FL600; more flexibility to the floor will be considered if/when practical.
- Operators will cooperatively manage the airspace according to a common set of industry-developed rules that foster equity of access.
- Industry-developed rules/guidelines for the cooperative environment could be established, and enforced, by an industry consortium.
  - Safety risk or regulation violations (e.g., separation standard or risk envelope violations) are investigated and enforced by the ANSP/FAA.
  - Non-conformance/violation of consortium-based rules (e.g., equity and access violation or other rules not pertaining to safety) could be managed through the consortium.

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Highlights of Discussion

- Industry will coordinate and strategically de-conflict operations (according to an established set of business rules), possibly using a common, decentralized, internet connected API.
- Separation criteria/performance envelopes for transition will be researched by industry and provided to the regulator for verification and approval.
- Risk envelopes will provide means of separation in the cooperative environment (as opposed to separation minima); industry will determine their envelopes and present them to the FAA for review and approval.
- In the event of an emergency, there is an assumption of priority; priority rules for the cooperative environment will be agreed upon and established by industry.
- As far as practical, there will be a common set of standardized terminology and procedures for off-nominal events.

8

Highlights of Discussion

- Industry (potentially in collaboration with NASA) will propose rules, solutions, and/or recommendations for:
  - ETM cooperative sharing architecture (to include common, decentralized API for cooperative data sharing)
  - Equity and access rule development and enforcement guidelines
  - Rules of the road (e.g., right of way rules)
  - Performance envelopes
  - Emergency/Priority operations

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Tabletop 2 Introduction

Objectives
Exercise Overview
Planned Outcomes

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Tabletop Exercise *Objectives*

- Identify operational issues/considerations and data impacts associated with:
  - Transition to/from ETM
  - Operations straddling ETM/Class A boundary (operating above and below FL600)
  - Off-nominal/Contingency operations
- Inform development of cooperative management concept
- Assess current and future operational characteristics/ tempo

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Tabletop Exercise *Overview*

- Format
  - Set of Participatory Exercises
    - Scenarios relating to Operator interactions with ATC and other vehicles during transition to/from operating altitudes
    - Facilitated discussion between participants with structured questions to explore operational details with respect to each type of vehicle/Operator
  - Audience Participation
    - Participants discuss Operator tasking, detailed procedures, operational impacts, and system/data impacts
    - Participants provide expertise and input from the perspective of their operational type/role
- Capturing Participant Inputs
  - Supporting personnel will record input, major decisions, actions, and overall discussion.
  - A review of the discussions will be presented at the end of the day

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Tabletop Exercise *Planned Outcomes*

- Identify strategic and tactical operational issues and/or considerations that may result from ATC and ETM operator interactions
- Understand impacts of transitioning ETM operations to ATM systems
- Identify high-level ATM information requirements for ETM operations
- Inform ETM:
  - Concept development
  - Information/data requirements
  - Modeling and simulation platform development
  - Equipage and system requirements

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ETM Concept

Operational Environment
Principles
Operations Phases

14

Current Operational Environment

- Historically, Class E above FL600 has been an unconstrained operational environment
- Today, Upper E include military (e.g., reconnaissance), experimental/research (e.g., hypersonic), and civilian (e.g., high-altitude balloons, space transit) operations
- ATM provides separation services to aircraft transiting through Class A to/from upper Class E, and to aircraft in upper Class E as necessary

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Future Operational Environment

- New types of operations
  - Hypersonic flight, reintroduction of supersonic passenger flights, and very slow (or on-station) long endurance flights
- ATM scalability
  - Current manner of ATM service delivery cannot cost-effectively scale to meet the needs of the envisioned ETM environment
  - Current ATM services may not be desired in the ETM environment
- Solutions are needed that
  - Scale beyond current NAS infrastructure and manpower resources
  - Promote shared situation awareness among Operators
  - Support the management of operations where no ANSP separation services are desired, appropriate, or available
  - Solutions may include **Cooperative Separation** and **Provided Separation**

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Principles

- The ETM environment is notionally defined as Upper Class E airspace above FL600.
- ETM Operators include - but are not limited to – commercial, public/government, and research entities operating both manned and unmanned vehicles.
- FAA retains regulatory authority over the airspace.
- The ETM supporting architecture and associated services are scalable to meet the needs of market forces.
- The ETM concept will be developed with consideration to international application.

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Principles

- Policies and regulatory framework must be adapted to support operations in the ETM environment.
- Methods of separation in ETM/Upper Class E airspace include:
  - Cooperative Separation - community-based traffic management, where the Operators are responsible for the coordination, execution, and management of operations, with rules of the road established by FAA
  - Provided Separation - provision of separation services by ATC (e.g., radar and non-radar separation)

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Principles

- With **cooperative separation:**
  - Industry will coordinate and de-conflict operations (according to an established set of business rules) using a common platform.
  - These systems utilize industry's ability to supply services under the FAA's regulatory authority where these services do not exist.
- Cooperative separation utilizes a separate, collaborative set of separation services from those provided by ATC.
- Operators within cooperative separation environments are responsible for maintaining separation from one another.
- Safe separation and demand capacity balancing are enabled through harmonized ETM airspace user interactions, established procedures, and compatible technology.

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Principles

- For cooperatively managed operations, the FAA makes real-time airspace constraint data available to Operators, who are responsible for managing their own operations safely within these constraints without receiving ATC services.
- During transit to/from the ETM environment, Operators are responsible for complying with applicable regulations governing operations within the ATC service environment. ATC will not make special accommodations beyond techniques/procedures used today to support transit operations.
- The FAA has on-demand access to data on cooperative operations as needed.
- Standardized terminology and procedures are established for off-nominal events.

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Principles

- IFR services may be provided by ATC through radar or non-radar services.
- Some operations conducted by State entities include flight without separation provided by ATC (e.g., due regard, VFR).
- When operating in ETM/Upper Class E airspace:
    - Unmanned vehicles are required to participate in cooperative separation.
    - Civil/commercial manned vehicles are required to participate in cooperative separation, at a minimum. Level of engagement with provided separation is to be determined.
    - Public manned vehicles (e.g., Department of Defense) are NOT required to participate in cooperative separation (to maintain operational anonymity), but are encouraged to participate, at a minimum, to access information on other operations, and fully participate (e.g., provide data on their own operations) when mission-able.

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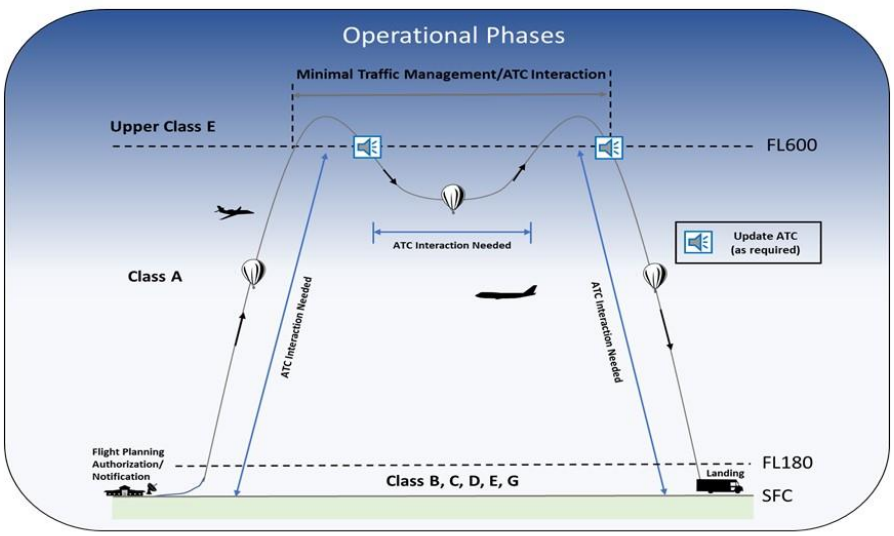
Operational Phases- *Current*



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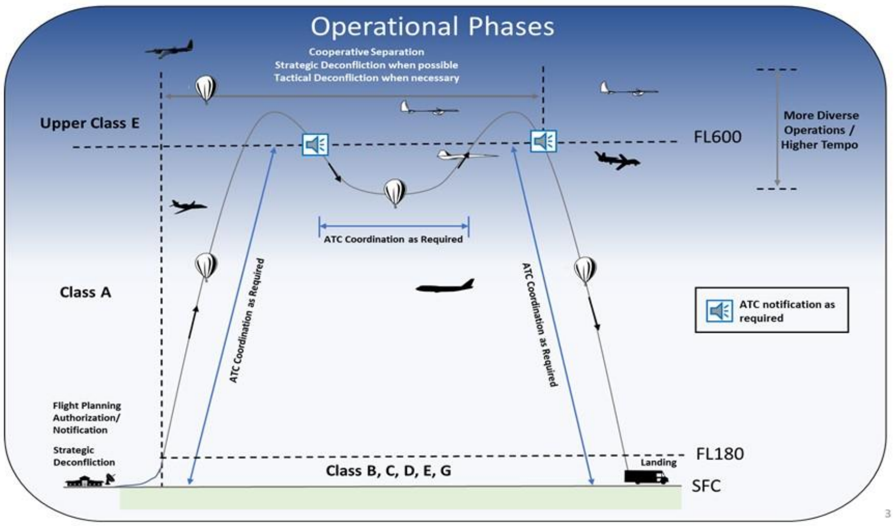
Operational Phases – *Notional*



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Tabletop Exercise

Operation Tempo
Pre-Flight and Take-Off/Launch
Ascent by Operator/Vehicle Type
Descent and Landing by Operator/Vehicle Type
Operations Straddling FL600
Contingency Management

24

Overview

Scenario #	Scenario	Topics
1	**Planning, Take-off, Ascent** (location for takeoff-remote field within ARTCC only ops or field within terminal control)	• Planning/Clearance • Take-off • Ascent to operating altitude
2	**Descent and landing** (location for landing-remote field within ARTCC only ops or field within terminal control)	• Planning • Descent from operating altitude • Landing
3	**Dual Class A/Upper E Operations**	• Operations straddling FL600
4	**Off-Nominal**	• Uncontrolled descent into lower altitudes • Potential events on ascent/descent (e.g., lost link)

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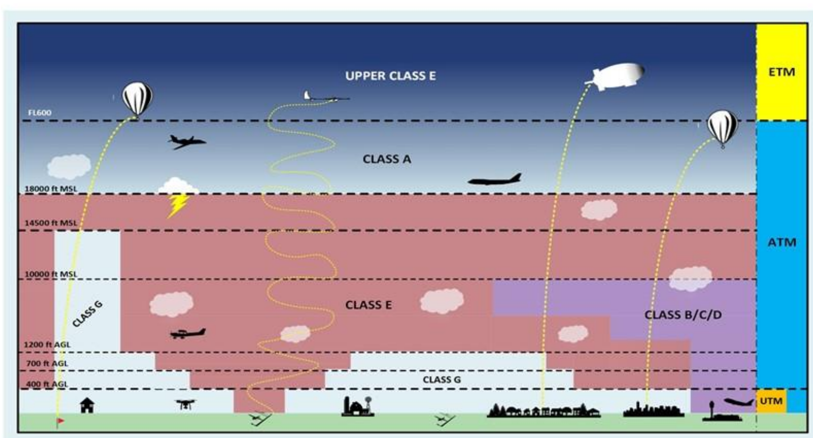
Tabletop Exercise



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Operational Tempo

Operators

- If operating today:
  - What is your current operation tempo?
  - Is your intention to expand tempo over time?
- If not operating today, what is your intended operation tempo?

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Pre-Flight and Take-Off/Launch

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Pre-flight

ATC Flight Planning, Notification, Authorization

	Manned Fixed Wing (Super/Subsonics)	Unmanned Fixed Wing- High Speed	HALE Unmanned Fixed Wing	Balloon (HALE or Short Endurance)	HALE Airship
Flight Plan	IFR Flight Plan Filed at least 24 to 6 hours in advance (per 7110.65 9-2-15a)	IFR Flight Plan filed 1 to 2 hours in advance. Covers route between airport and special use area	File as required based on national regulation	Not adequate due to complexity	IFR Flight Plan 24 hours prior
Notification Required	N/A	Yes, to the nearest ATC facility	NOTAMs requested 24 hours prior to launch	Yes, adapted from 14 CFR Part 101.37 Nearest ATC facility 6-24 hours prior to operation	Yes, as required per 14 CFR Part 101.37
Authorization Required	After filing flight plan, operator receives a full route clearance and a squawk code	ATC Clearance is provided or amended real-time (same as manned aircraft)	Yes, in accordance with Letter of Agreement with ANSP	Waiver authorization as required per 14 CFR Part 101.33 No written/formal authorization required	Yes, as required per 14 CFR Part 101.37

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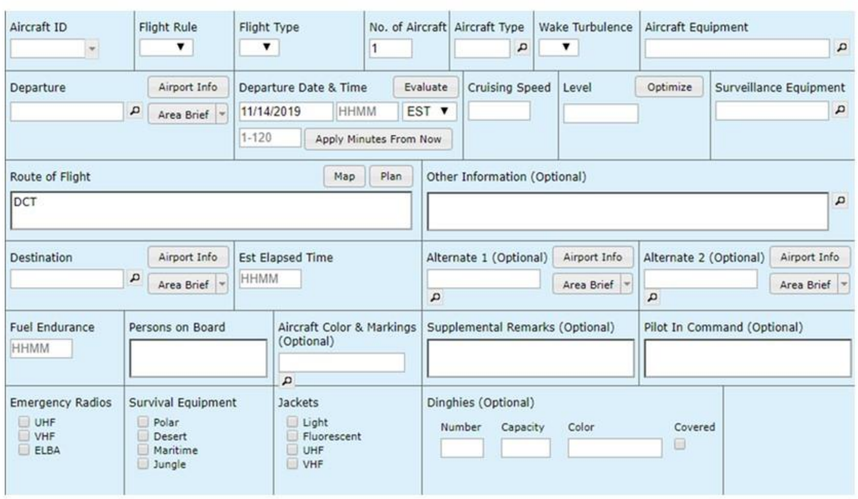
Flight Planning



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Notification/Authorization

What do you information do you provide/expect to provide beyond what is required when notifying or obtaining relevant authorizations?

Examples of Relevant Requirements:

- Notification
  - 14 CFR Part 101.37 – Balloon Notice Requirements
    - 101.37(a) – Prelaunch Notice (standard notice requirement)
    - 101.37(b) – Prelaunch Notice (short notice allowance)
    - 101.37(c) – Cancellation Notice
    - 101.37(d) – Launch Notice
- Authorization
  - 14 CFR Part 101.33(a) – Balloon Operations requiring ATC Authorization
  - 14 CFR Part 91.173 – ATC Clearance Requirement for IFR Operation in Controlled Airspace

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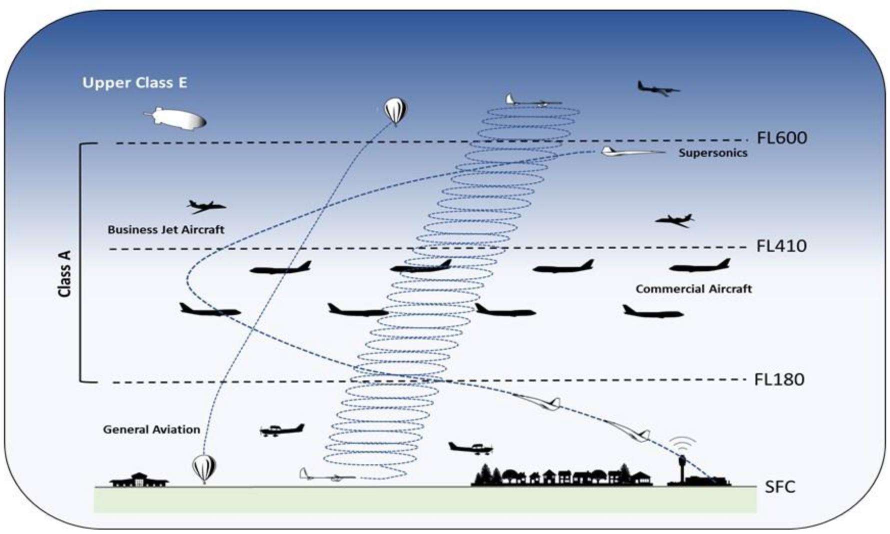
Take Off/Launch



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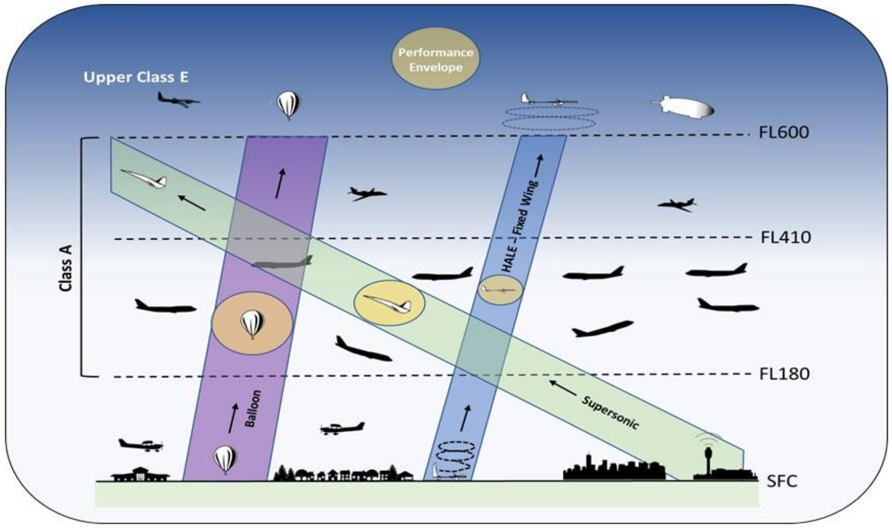
Transit To/From Operating Altitude



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Ascent

Ascent to Operating Altitude
Airspace Management and Procedures

Aerion AS2 (Super/Subsonic)

Ascent	Manned Fixed Wing
Ascent Pattern	
Speed	270-280 accelerating to 380 knots
Rate of Ascent	6200 FT/min initially
Time to reach altitude	Approximately 10 minutes
Ability to move laterally and horizontally	Yes
Ability to maintain position (hold altitude)	Able to level off at any portion of the flight

Equipage	Manned Fixed Wing
Surveillance	Planned Secondary Surveillance Radar (SSR) and ADS-B
Communications	Controller Pilot Data Link Communication (CPDLC) and traditional Push-to-Talk (PPT)
Navigation	Global Navigation Satellite System (GNSS), GPS, Inertial Reference System (IRS)

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude
Airspace Management and Procedures

Northrop Grumman Global Hawk

Ascent	Unmanned Fixed Wing – High Speed
Ascent Pattern	Flight plan orbit pattern in SUA from 12,000ft to FL400
Speed	130 kts ground speed after takeoff up to 360 kts ground speed at FL500
Rate of Ascent	4000 FT/min after takeoff, approximately 300 FT/min above FL500
Time to reach altitude	Approximately 30 minutes up to FL500
Ability to move laterally and horizontally	Maneuvers like large aircraft and turn rate is programmed with no ability to execute steep/expedited turns
Ability to maintain position (hold altitude)	Able to maintain altitude

Equipage	Unmanned Fixed Wing - High Speed
Surveillance	Transponder Mode-C
Communications	Pilot in radio communication with ATC
Navigation	GPS

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude
Airspace Management and Procedures

Airbus Zephyr

Ascent	HALE Unmanned Fixed Wing
Ascent Pattern	Cylindrical, slow climb via waypoints in designated airspace in vicinity of launch location
Speed	Approximately 12kts Estimated Airspeed and 12-40kts TAS
Rate of Ascent	100-150 FT/min
Time to reach altitude	About 8 hours to FL550
Ability to move laterally and horizontally	Able to execute turns and navigate as required subject to wind and weather considerations. Backwards drift may occur in certain conditions due to slow airspeed
Ability to maintain position (hold altitude)	Hold of +/-200FT is possible for prolonged period subject to insolation (solar ray exposure) considerations

Equipage	HALE Unmanned Fixed Wing
Surveillance	SSR, ADS-B, organic telemetry, other GNSS-independent method
Communications	Radio comm or landline to ATC backed up with email
Navigation	Global Navigation Satellite System (GNSS)

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude
Airspace Management and Procedures

Aurora Odysseus

Ascent	HALE Unmanned Fixed Wing
Ascent Pattern	Nominally cylindrical but mission and wind dependent
Speed	Approximately 12kts Estimated Airspeed and 12-40kts TAS
Rate of Ascent	200-300 FT/min
Time to reach altitude	Approximately 4 to 6 hours
Ability to move laterally and horizontally	Approximately 2 deg/s turn rate, 200 FT/min ascent
Ability to maintain position (hold altitude)	Hold of +/-500FT

Equipage	HALE Unmanned Fixed Wing
Surveillance	Mode-S transponder that supports ADS-B In/Out
Communications	VHF radio on aircraft with voice relay to pilot-in-command on ground
Navigation	GPS

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude
Airspace Management and Procedures

AeroVironment

Ascent	HALE Unmanned Fixed Wing
Ascent Pattern	Cylindrical but mission and wind dependent
Speed	Approximately 20-25kts estimated true airspeed and 20-60kts TAS
Rate of Ascent	200-300 FT/min
Time to reach altitude	Approximately 8 hours
Ability to move laterally and horizontally	
Ability to maintain position (hold altitude)	No ability

Equipage	HALE Unmanned Fixed Wing
Surveillance	Mode-S and ADS-B
Communications	NAS Voice Switch to ATC
Navigation	GPS, INS

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude
Airspace Management and Procedures

Loon

Ascent	Balloon
Ascent Pattern	Depends on wind, drift during ascent ranges from 0-100+ nautical miles
Speed	Depends on wind, can reach up to 100 knots
Rate of Ascent	Ranges 600-1000 FT/min depending on configuration
Time to reach altitude	Stabilization altitude reached at FL550 after 1hr
Ability to move laterally and horizontally	No ability to maneuver
Ability to maintain position (hold altitude)	No ability. After ascent vehicle can change a maintain altitude within +/- 200ft

Equipage	Balloon
Surveillance	Transponder Modes A/C/S and ADS-B In/Out
Communications	Mission Control Comm; Multiple links with ATC
Navigation	Multiple redundant GPS chips, backup triangulation through Iridium satellite

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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Ascent to Operating Altitude

Airspace Management and Procedures

Sceye TV 17

Ascent	HALE Airship
Ascent Pattern	Free balloon ascent based on wind pattern
Speed	Approximately 8 kts
Rate of Ascent	Approximately 750 FT/min
Time to reach altitude	Approximately 1hr20mins
Ability to move laterally and horizontally	No ability
Ability to maintain position (hold altitude)	No ability

Equipage	HALE Airship
Surveillance	ADS-B
Communications	VHF
Navigation	GPS

SCEYE®

- Ascent procedures
  - ATC services/coordination
- Operating altitude procedures
  - ATC services/coordination
- Operational Issues
  - FAA identified
  - Industry identified

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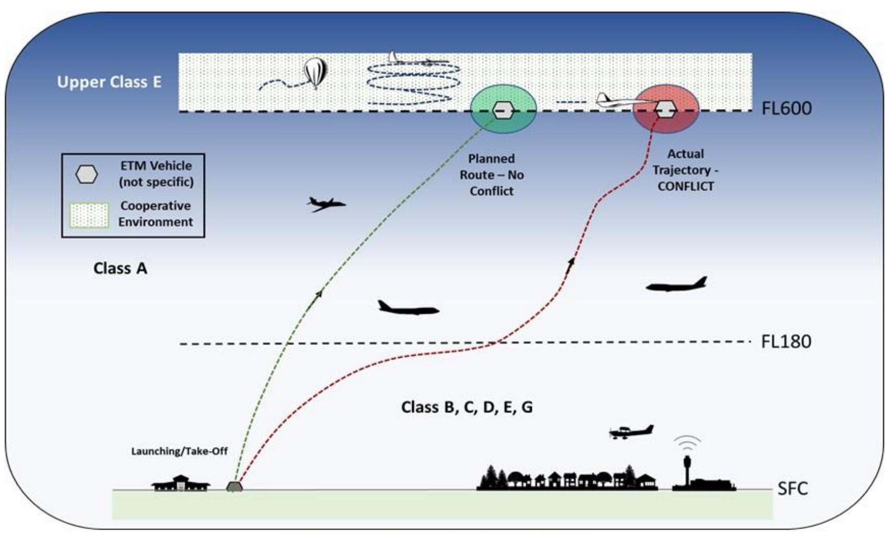
Ascent - Scenario

Management Concept for Class E Entry Point Change



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Descent

Descent from Operating Altitude to Landing

Flight Planning

- Planning procedures
  - ATC flight plan (existing or new)
  - ATC Coordination

Authorization, Notification, & Clearance Requirements

	Manned Fixed Wing	Unmanned Fixed Wing – High Speed	HALE- Unmanned Fixed Wing	Balloon	HALE Airship
Notification Required	Compulsory reporting or if a cross restriction is given by operator	As required (just like manned aircraft)	NOTAMs requested 24 hours prior to planned descent with intent to land	Yes, nearest ATC facility 1 hour prior to beginning descent and forecast of FL600 penetration (101.39)	Notify ATC prior to descent
IFR Clearance Required	Yes, to prior to any descent	Yes, prior to descent	Yes, stepped descent clearance once in controlled airspace	N/A	Yes, prior to descent

Descent
Airspace Management and Procedures

Aerion AS2 (Super/Subsonic)

Descent	Manned Fixed Wing
Descent Pattern	Varies based on flight plan and/or ATC instruction
Speed	Varies
Rate of Descent	Varies
Time to land	Varies based on ATC instruction
Ability to move laterally and horizontally	Yes
Ability to maintain position (hold altitude)	Able to level off at any portion of descent
Landing	Aerodrome

Equipage	Manned Fixed WIng
Surveillance	Planned Secondary Surveillance Radar (SSR) and ADS-B
Communications	Controller Pilot Data Link Communication (CPDLC) and traditional Push-to-Talk (PPT)
Navigation	Controller Pilot Data Link Communication (CPDLC) and traditional Push-to-Talk (PPT)

- Separation
- ATC services
- Descent Procedures
- Operational Issues
  - FAA identified
  - Industry identified

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Descent
Airspace Management and Procedures

Northrop Grumman Global Hawk

Descent	Unmanned Fixed Wing – High Speed
Descent Pattern	Pilot can maneuver as required for descent
Speed	360 to 130 kts ground speed
Rate of Descent	Up to 4000 FT/min
Time to land	30 minutes
Ability to move laterally and horizontally	Maneuvers like large aircraft and turn rate is programmed with no ability to execute steep/expedited turns
Ability to maintain position (hold altitude)	Able to halt descent
Landing	Government controlled airport and requires runway of 8000 x 150ft or greater

Equipage	Unmanned Fixed Wing – High Speed
Surveillance	Transponder Mode-C
Communications	Pilot in radio communication with ATC
Navigation	GPS

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
  - FAA identified
  - Impacts if ATC requires delayed descent due to traffic/sector management?
  - Industry identified

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Descent
Airspace Management and Procedures

Airbus Zephyr

Descent	HALE Unmanned Fixed Wing
Descent Pattern	Cylindrical, slow descent via waypoints in designated airspace in vicinity of landing location
Speed	Approximately 12 kts estimated true airspeed and 40 to kts TAS
Rate of Descent	Approximately 100FT/min
Time to land	Approximately 10-12 hours
Ability to move laterally and horizontally	Able to execute turns and navigate as required subject to wind and weather considerations. Backwards drift may occur in certain conditions due to slow airspeed
Ability to maintain position (hold altitude)	Hold of +/-200FT is possible for prolonged period subject landing timing considerations
Landing	Remote area or conventional landing into clear area (could be a runway)

Equipage	HALE Unmanned Fixed Wing
Surveillance	SSR, ADS-B, organic telemetry, other GNSS-independent method
Communications	Radio comm or landline to ATC backed up with email
Navigation	Global Navigation Satellite System (GNSS)

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
    - FAA identified
    - Impacts if ATC requires delayed descent due to traffic/sector management?
    - Industry identified

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Descent
Airspace Management and Procedures

Aurora Odysseus

Descent	HALE Unmanned Fixed Wing
Descent Pattern	Nominally cylindrical but mission and wind dependent
Speed	8 to 10 meters/second, 16 to 21 kts estimated airspeed
Rate of Descent	Approximately 100FT/min
Time to land	Approximately 10-11 hours
Ability to move laterally and horizontally	Approximately 2 deg/s turn rate, 100 ft/min descent
Ability to maintain position (hold altitude)	Hold of +/-500FT is possible for hours
Landing	Paved runway, conventional landing procedures (shallow descent angle)

Equipage	HALE Unmanned Fixed Wing
Surveillance	Mode-S transponder that supports ADS-B In/Out
Communications	VHF radio on aircraft with voice relay to pilot-in-command on ground
Navigation	GPS

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
    - FAA identified
    - Impacts if ATC requires delayed descent due to traffic/sector management?
    - Industry identified

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Descent
Airspace Management and Procedures

AeroVironment

Descent	HALE Unmanned Fixed Wing
Descent Pattern	Cylindrical but mission and wind dependent
Speed	20 to 25 kts estimated airspeed and 20 to 60 kts TAS
Rate of Descent	Approximately 100FT/min
Time to land	
Ability to move laterally and horizontally	
Ability to maintain position (hold altitude)	
Landing	

Equipage	HALE Unmanned Fixed Wing
Surveillance	Mode-S transponder and ADS-B
Communications	NAS Voice Switch to ATC
Navigation	GPS/INS (Inertial Navigation System)

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
  - FAA identified
  - Impacts if ATC requires delayed descent due to traffic/sector management?
  - Industry identified

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Descent
Airspace Management and Procedures

Loon

Descent	Balloon
Descent Pattern	Follows wind and may be non-linear. Drift varies 0-100+ NM
Speed	Varies based on prevailing winds
Rate of Descent	1500FT/min – 4000 FT/min. Approximately 1000FT/min after parachute deployed at 10000FT
Time to land	Can be 25min-3hrs but typically 1hr-1hr 20min
Ability to move laterally and horizontally	No lateral control
Ability to maintain position (hold altitude)	No ability but parachute can slow descent
Landing	Unpopulated remote area with ease of access

Equipage	Balloon
Surveillance	Transponder Modes A/C/S and ADS-B In/Out
Communications	Mission Control Comm; Multiple links with ATC
Navigation	Multiple redundant GPS chips, backup triangulation through Iridium satellite

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
  - FAA identified
  - Impacts if ATC requires delayed descent due to traffic/sector management?
  - Industry identified

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Descent
Airspace Management and Procedures

Sceye TV 17

Descent	HALE Airship
Descent Pattern	Free balloon descent based on wind pattern
Speed	Approximately 8 kts
Rate of Descent	Approximately 750 FT/min
Time to land	Approximately 1hr20mins
Ability to move laterally and horizontally	No ability
Ability to maintain position (hold altitude)	No ability
Landing	Landing in to remote area

Equipage	HALE Airship
Surveillance	ADS-B
Communications	VHF
Navigation	GPS

SCEYE®

- Separation by airspace class
- ATC services
- Descent Procedures
- Operational Issues
  - FAA identified
  - Impacts if ATC requires delayed descent due to traffic/sector management?
  - Industry identified

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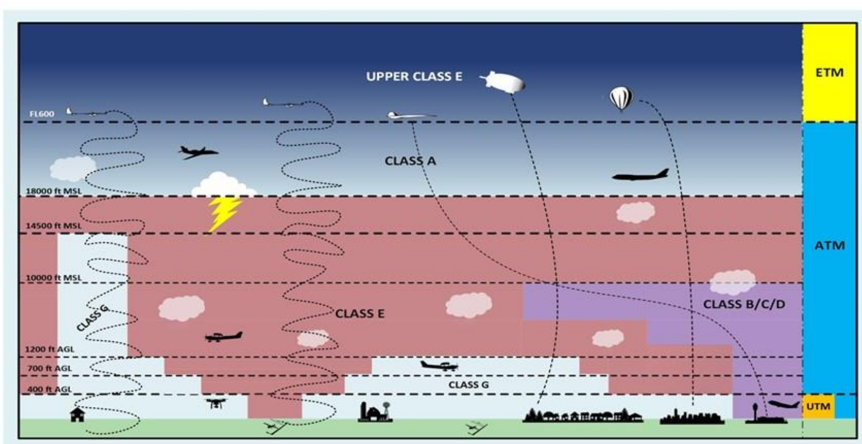
Landing



- Location (e.g., controlled/uncontrolled airport, field, etc.)
- ATC Interactions
  - Flight plan closeout (e.g., ATC facility cancels flight plan)
- Stakeholder coordination

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Operations Straddling FL600

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Operations Straddling FL600

Overview

During Tabletop 1, multiple stakeholders indicated that their vehicles will straddle FL600 during operations, due to various operational needs.

- Supersonic Transport
  - Will initiate supersonic cruise above FL500. As fuel is consumed, altitude increases, which may include some portion of flight above FL600.
- HALE Balloons
  - May ascend/descend between ~FL500 and FL700(+) to take advantage of different prevailing winds (primary method of controlling geographical position).
- HALE Fixed-Wing
  - Will ascend during the day using solar energy (charging batteries) - primarily above FL600. Will descend during night (battery only); the vehicle may drop below FL600.
- HALE Airship
  - Assuming they have equipment to control their lateral trajectory (e.g., motor/propeller and a rudder), are there reasons for these vehicle types to regularly operate below FL600?

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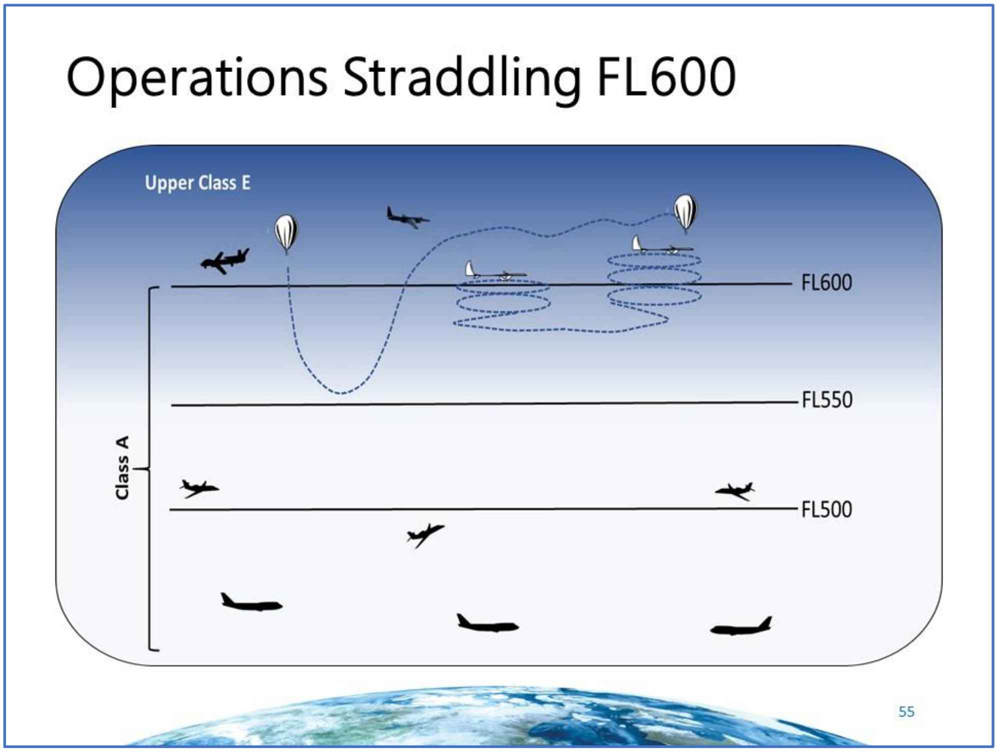
Operations Straddling FL600
Upper Class E
FL600
FL550
Class A
FL500
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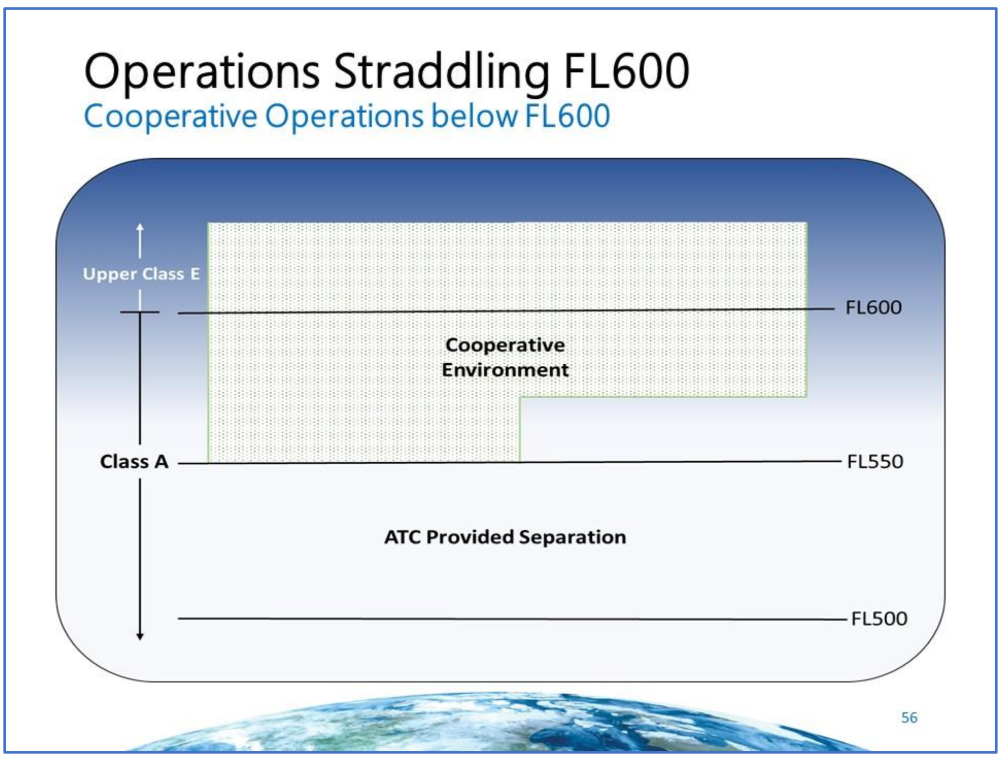
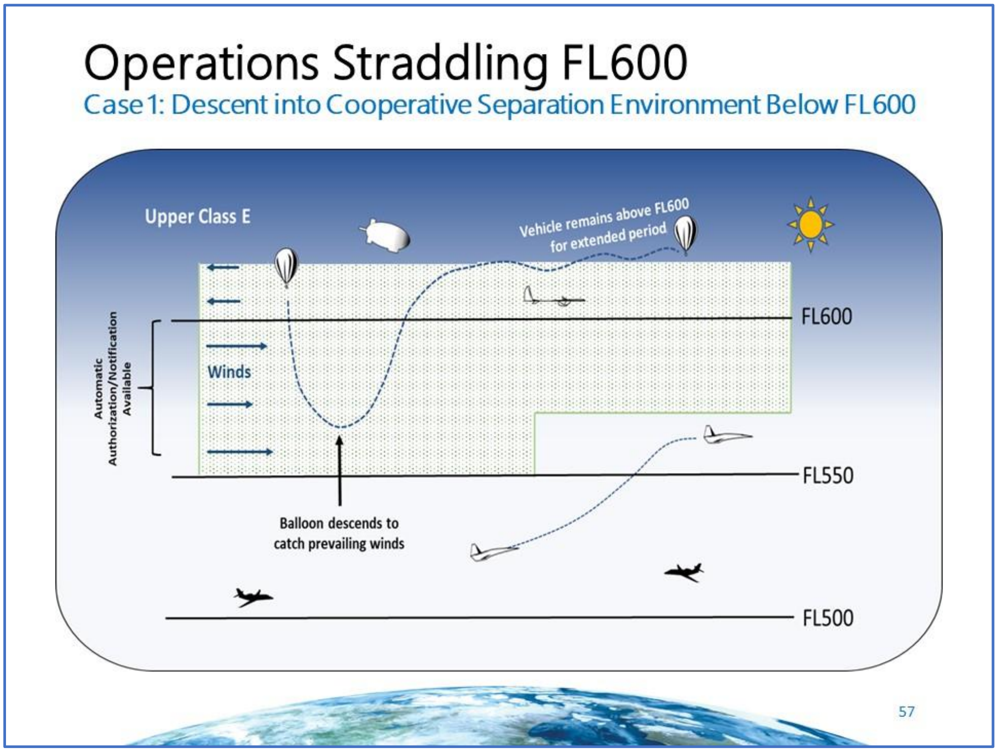
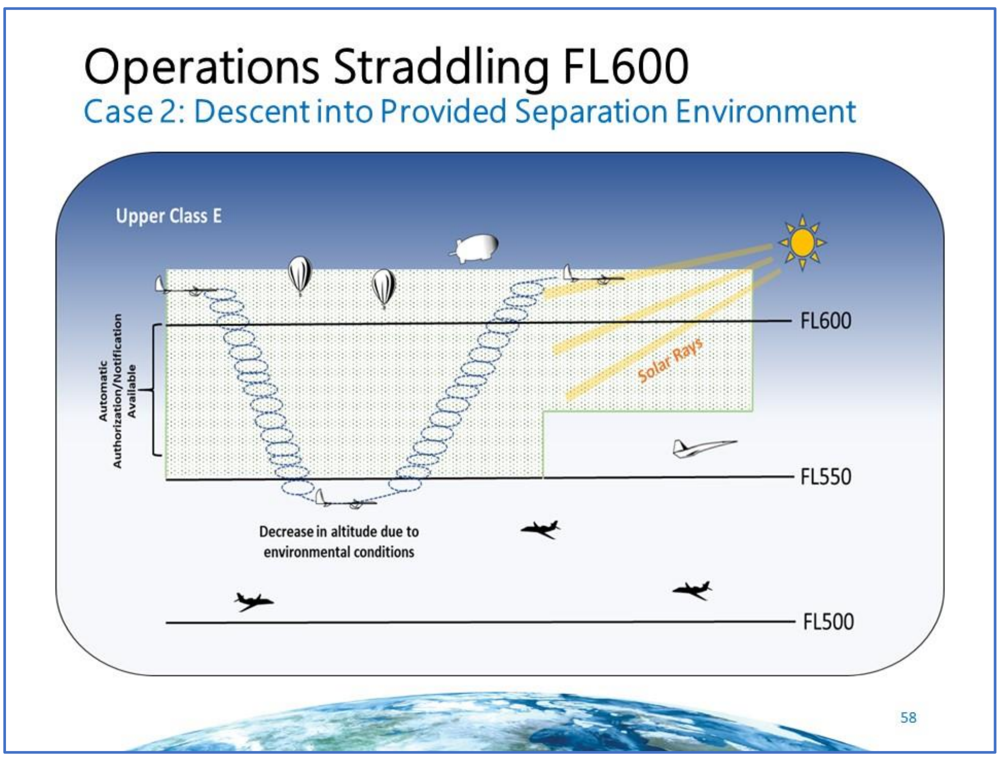

Operations Straddling FL600
Cooperative Operations below FL600
Upper Class E
FL600
Cooperative
Environment
Class A
FL550
ATC Provided Separation
FL500
56


Operations Straddling FL600
Case 1: Descent into Cooperative Separation Environment Below FL600
Upper Class E
Vehicle remains above FL600 for extended period
Automatic Authorization/Notification Available
Winds
FL600
FL550
Balloon descends to catch prevailing winds
FL500
57


Operations Straddling FL600
Case 2: Descent into Provided Separation Environment
Upper Class E
Automatic Authorization/Notification Available
FL600
Solar Rays
FL550
Decrease in altitude due to environmental conditions
FL500
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Contingency Management

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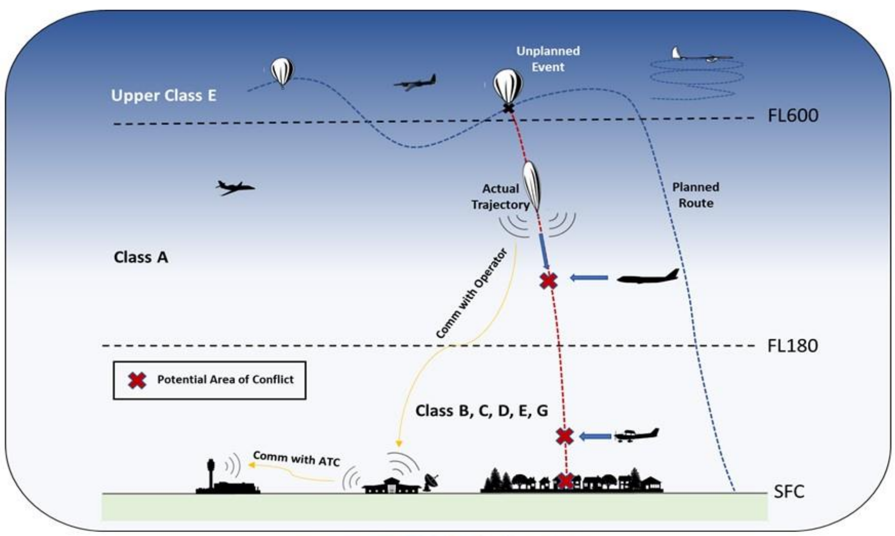
Contingency Management
Uncontrolled Descent



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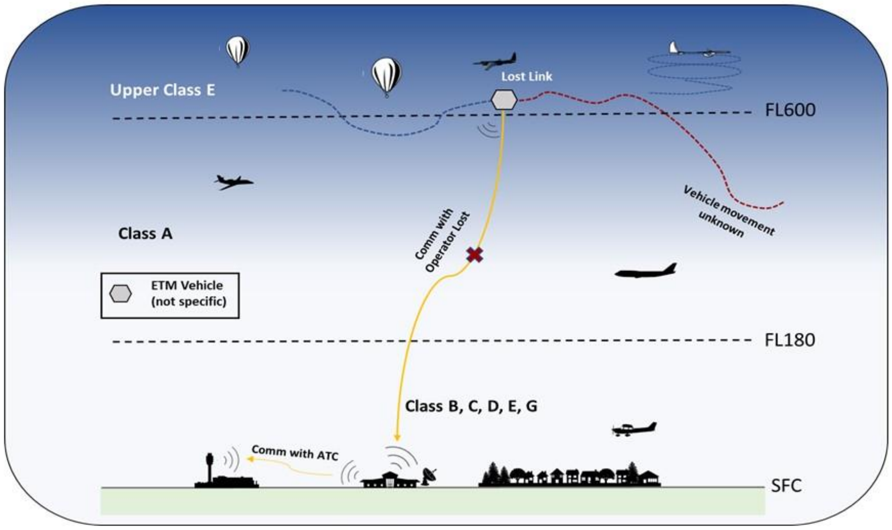
Contingency Management

Lost Link



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Next Steps

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Moving forward…

- Proceed with development of Concept of Operations to mature and refine the concept through use cases, roles and responsibilities allocation, and high-level operational and technical requirements
- Perform engineering analyses to highlight opportunities and challenges in the current infrastructure, technology, policies, and rules with regard to their applicability to support future operations
- Build simulation environment and conduct simulations to derive and validate requirements

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Lexicon

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Lexicon (1)

Term	Definition
Cooperative Separation	Separation based on shared trajectory intent/expanded data exchanges between operators, stakeholders and service providers, and is supported by the appropriate rules, regulations and policies for the planned operations.
Provided Separation	The provision of separation services by an ANSP.
Due Regard	A phase of flight wherein an aircraft commander of a State-operated aircraft assumes responsibility to separate his/her aircraft from all other aircraft.
High Altitude Long Endurance (HALE) Operation	Unmanned aircraft flight conducted at slow speeds and capable of lasting considerable periods of time (days, weeks, months) without recourse to landing.
Supersonic Operation	Aircraft flight speeds above Mach 1 (speed of sound). Includes both manned and unmanned operations.
Hypersonic Operation	Aircraft flight at significantly high Mach speeds, typically defined as above Mach 5. Typically performed as unmanned operations.

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Lexicon (2)

Term	Definition
Intent Information	Information exchanged for the purposes of strategic planning and cooperative separation between stakeholders for the purpose of managing the airspace. Examples of such information may include trajectories (of defined fidelity), volumes, etc.
Conflict	A point in time in which the predicted separation of two aircraft is less than the defined separation minima.
Strategic Deconfliction	Deconfliction between trajectories via advanced planning and information exchange, including intent.
Tactical Deconfliction	Timely response to avoid a conflict after strategic deconfliction has failed, or was not executed.
Constraint	Anything that interferes with the normal flow of air traffic. Constraints can be natural (e.g., weather), circumstantial (e.g., runway construction), or intentional (e.g., TFR).
Unmanned Traffic Management (UTM)	A traffic management environment in which UAS operators cooperatively separate from one another, enabled by the open exchange of relevant intent information for the purposes of strategic and tactical deconfliction.

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Lexicon (3)

Term	Definition
Oceanic	Oceanic operating environment refers to the offshore, international airspace for which the US is the designated service provider. It is characterized by large volumes of airspace and less legacy infrastructure than domestic US airspace. Separation procedures are based on surveillance, in most cases, predicated on position reporting by individual aircraft.
Maneuverability	The ability of an aircraft to adjust its trajectory.
Altitude Reservation (ALTRV)	Airspace with defined dimensions within controlled airspace that is reserved for use by a civil or military agency during a specific time period. It may be stationary or moving in relation to the aircraft operating within and can be used for any purpose but is mostly used for mass movement of aircraft.
Clearance	Authorization by ATC to proceed under specific conditions into controlled airspace for the purpose of providing separation and avoiding collision between known aircraft.
ATC Notification	Provision of information to ATC personnel to satisfy applicable regulatory/operating requirements.

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Lexicon (4)

Term	Definition
Military Operations Specialist (MOS)	Specialist within an ARTCC that handles coordination for military requests for special military operations
Squawk code	A discrete transponder code assigned by air traffic controllers to identify an aircraft uniquely in a flight information region (FIR) allowing for easy identification of aircraft on radar.
Secondary Surveillance Radar (SSR)	A radar system used by air traffic control that detects and measures the position of aircraft and also request additional information from aircraft such as identity and altitude.
ADS-B	Surveillance technology that allows for an aircraft to determine its position by satellite navigation and periodically broadcasts I, allowing it to be tracked.
Traffic Flow Management (TFM)	Regulation of air traffic based on capacity and demand that ensures efficient utilization of the NAS

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