Airspace Automation Flight Tabletop Exercise
National Campaign Wisk Activity Team
And Partners

Aircraft Partner
Wisk Aero

Airspace Partners
ANRA
Avision
Collins Aerospace
OneSky
SkyGrid

C2CSP Partners
AURA
Collins Aerospace
Abstract

Interconnections of new systems are needed for airspace automation capabilities required in Urban Air Mobility (UAM). FAA Concept of Operations (CONOPS) V1.0 shows Provider of Services for UAM (PSU) at the center of the notional architecture; however, the functional role of the PSU in data exchange and the path to get there is unclear. In partnership with Wisk Aero, Avision, ANRA, Collins Aerospace, OneSky, SkyGrid, and AURA, the NASA National Campaign held discussions and tabletop exercises to test the functional allocations and work flows between an aircraft operator, airspace providers, Command and Control Communication Service Providers (C2CSP), and FAA air traffic in a real-world scenario. The exercise included preplanning and execution of a passenger mission with nominal, contingency, and conflict management scenarios for initial UAM operations. This working paper describes initial conditions for the flight tabletop exercise, exercise summaries, lessons learned, and recommendations for future work.
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<td>Brad Snelling and Nancy Baccheschi</td>
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1 Background

An initial set of tabletop discussions on the Minimum Viable Product (MVP) for airspace automation or Provider of Services for UAM (PSUs) was conducted May-June 2022 with Wisk, ANRA, Avision, Collins Aerospace, OneSky, and SkyGrid. The MVP for a PSU was thought of as the minimum level of capability and services required of a PSU for various maturity levels in AAM. These discussions used generalized PSU “User Stories” for discussions. The PSU User Stories focused on:

- Pre-flight Planning
- In-Flight Contingency
- In-Flight Conflict
- In-flight Non-Conformance

Many excellent topics were discussed, but there was a desire for more clarity on the operational concept in UAS Maturity Level (UML) 2B. UML-2B was defined as “later initial” operations, not the next step in AAM operations, but perhaps the next evolution beyond 2023/2024 early initial operations. The graphic in Figure 1 was used as a starting point for defining UML-2B. Continued discussions were formalized into the “Flight Tabletop Exercise”. The goal of each flight tabletop exercise was to provide just enough structure and initial conditions to discuss a realistic gate-to-gate AAM flight in a simplified UML-2B environment. This working paper provides the objectives, initial conditions, results, and recommendations after completing five 3-hour flight tabletop exercises. The Command and Control Services Provider (C2CSP) aspect was also included in the exercises with participation from AURA and Collins Aerospace as a combined PSU/C2CSP.

Figure 1 – Wisk UML-2B Construct
2 Objectives

A primary objective of the flight tabletop exercises was to test the functional allocations and work flows between an aircraft operator, airspace providers, C2CSPs, and FAA air traffic in a real-world scenario based on NC/Wisk “PSU User Stories” in UML-2B. While detailed components of the ATM-X airspace construct have been developed and are being tested in simulation environments, the goal of this exercise is to stretch the airspace automation concepts into a holistic operational scenario.

Characteristics of the exercise were determined as:
- Flight tabletop exercise will focus on the UML-2B stage
- Scenarios will be in the vicinity of Hollister Municipal Airport (KCVH) - Salinas Municipal Airport (KSNS)
- Scenarios will include the roles of PSUs, C2CSPs, ATC, vertiports, and aircraft operators
- Exercise will be managed with a timekeeper to ensure completion in the allotted time (2-3 hours)
- Specific people/roles will be assigned for PSU, C2CSP, ATC, Aircraft Operator, Operator Fleet Manager, and Vertiports
- All interactions, data exchanges and gaps will be logged as data
- Goal is for findings and recommendations to be captured in a final report and made available to the public domain

3 Initial Conditions

A set of initial conditions was developed to conduct the scenario based on discussion points from the previous tabletop discussions, Wisk CONOPS and experience on the activity team. These initial conditions are summarized below.

Aircraft: The aircraft capacity is 4 passengers in a lift+cruise configuration capable of instrument, remotely piloted operations. It has a takeoff/landing limit of 10 knots tailwind and 15 knots crosswind. This limit is artificially imposed for the exercise and not representative of the Wisk aircraft. The aircraft is assumed to be certified for RNP 0.1 approach/terminal/enroute operations. The aircraft’s Detect and Avoid (DAA) solution is a fused solution for tactical conflict management, complemented by the ground control station. The aircraft is equipped with a system allowing the remote PIC to use the aircraft’s VHF voice radio to receive and transmit from the aircraft.

Mission Requirement: The mission requirement is a passenger transport from ‘Wisk Terminal’ (WISK01) with 4 passengers to ‘Wisk Terminal’ (WISK02). Pax weight measured is 800lbs and Baggage weight measured is 80lbs. ETD is 1700Z. The notional WISK01 vertiport is collocated with Hollister Municipal Airport (KCVH), and the notional WISK02 vertiport is collocated with Salinas Municipal Airport (KSNS). These locations are shown in Figure 2. For contingencies, vertiport options were limited to WISK01 and WISK02.
Instrument Flight Procedures: Since there were no existing instrument procedures suitable for this route, a notional solution for takeoff to landing RNP 0.1 procedures was developed. This notional solution is scalable and called the “RF45” due to the usage of radius-to-fix (RF) legs for all course changes and 45° separation between departure/approach courses. See Appendix C: RF45 Construction for a detailed description of the rationale, construction, and features of this instrument procedure model.

For reference, the existing instrument procedure to fly from KCVH to KSNS requires a climb to 6,000MSL onto the SJC R-121 prior to proceeding on-course to KSNS. This is obviously impractical for the AAM use-case of a destination that is only 16NM away. See Figure 3.
FAA Services: Few assumptions of ATC services were made in order to encourage discussion of gaps and requirements needed to support this mission. A survey of current ADS-B coverage was completed and provided to show where FAA could provide traffic separation services today. Figure 4 shows the number of FAA ADS-B receivers capable of “seeing” ADS-B equipped aircraft as a function of MSL altitude and a direct line route from WISK01 to WISK02.

Figure 3 – Current KCVH Instrument Departure Procedure

Figure 4 – ADS-B Coverage Expectation on Direct Route
**Weather Conditions:** Weather conditions for the exercise were presented as follows in the traditional METAR/TAF format, but PSUs were encouraged to suggest and/or provide data formats for additional or more detailed weather source data.

**METARs:**
WISK01 01615Z AUTO 04020G25KT 10SM CLR 19/05 A3029
WISK02 011630Z AUTO 02009KT 10SM CLR 19/02 A3030

**TAFs:**
WISK01 No TAF available
WISK02 011000Z 0718/0818 03010KT P6SM SKC
           FM071700 02010KT P6SM SKC
           FM071800 30009KT P6SM SKC

In plain terms, the weather conditions were defined as follows:
Currently at WISK01, winds are from the northeast (040 deg) at 20 knots, gusting to 25 knots. Visibility is 10 miles, sky is clear, temperature is 19 deg C, dewpoint is 5 deg C.
Currently at WISK02, winds are from the northeast (020 deg) at 9 knots. Visibility is 10 miles, sky is clear, temperature is 19 deg C, dewpoint is 2 deg C.

The 1700Z forecast for WISK02 is winds from the northeast (030 deg) at 10 knots. Visibility is over 6 miles. Sky is clear.
The 1800Z forecast for WISK02 is winds from the northwest (300 deg) at 9 knots. Visibility is over 6 miles. Sky is clear.

**Role Player Interfaces:** A top level diagram of the role player interfaces was provided to facilitate discussion of role player functional allocation. While it is not part of an actual system diagram, it was adapted and simplified from the ATM-X airspace construction. See Figure 5.
The role players identified for each exercise are shown in Table 1.

Table 1 - Exercise Role Players

<table>
<thead>
<tr>
<th>Role</th>
<th>Played By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling Interface</td>
<td>Wisk</td>
</tr>
<tr>
<td>Wisk Operator Scheduler/Dispatcher</td>
<td>Wisk</td>
</tr>
<tr>
<td>C2CSP</td>
<td>AURA/Collins</td>
</tr>
<tr>
<td>MVS (RPIC)</td>
<td>Wisk</td>
</tr>
<tr>
<td>PSU</td>
<td>ANRA, Avision, Collins, OneSky, SkyGrid</td>
</tr>
<tr>
<td>NASA PSU</td>
<td>NASA ATI</td>
</tr>
<tr>
<td>FAA/ATC/Tower</td>
<td>NASA NC</td>
</tr>
<tr>
<td>Passenger Handling Services</td>
<td>Wisk</td>
</tr>
<tr>
<td>Ground Ops Team</td>
<td>Wisk</td>
</tr>
<tr>
<td>Vertiport Systems</td>
<td>NASA/Wisk</td>
</tr>
<tr>
<td>Aircraft/Maintenance</td>
<td>Wisk</td>
</tr>
</tbody>
</table>
The action points for the exercise are shown in Table 2.

Table 2 – Exercise Actions

<table>
<thead>
<tr>
<th>Actions</th>
<th>Actions (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pax transport request</td>
<td>Takeoff</td>
</tr>
<tr>
<td>Decision on flight plan intent</td>
<td>Depart KSNS airspace</td>
</tr>
<tr>
<td>Flight plan filed from WISK01 to WISK02 with alternates</td>
<td>WISK01 winds out of limits</td>
</tr>
<tr>
<td>Flight plan pending</td>
<td>Reroute options calculated</td>
</tr>
<tr>
<td>Flight plan acknowledged</td>
<td>ATC clearance approved reroute to WISK02</td>
</tr>
<tr>
<td>Pre-flight prep</td>
<td>Reroute selected</td>
</tr>
<tr>
<td>Charging complete</td>
<td>Enroute back to WISK02</td>
</tr>
<tr>
<td>Departure Clearance Communications</td>
<td>Inflight conflict with aircraft detected by PSU</td>
</tr>
<tr>
<td>Physical Repositioning</td>
<td>Altitude change to 2,500' or 3,000' requested</td>
</tr>
<tr>
<td>FATO All-Clear</td>
<td>While descending, DAA commands a hard right turn to avoid sUA traffic detected by RemoteID</td>
</tr>
<tr>
<td>Start Takeoff Sequence</td>
<td>Inflight non-conformance detected by acft/PSU</td>
</tr>
<tr>
<td>Takeoff clearance Communications</td>
<td>Reroute options calculated</td>
</tr>
<tr>
<td>Takeoff</td>
<td>ATC clearance approved for reroute</td>
</tr>
<tr>
<td>Transition</td>
<td>Reroute selected</td>
</tr>
<tr>
<td>Climb</td>
<td>Start descent</td>
</tr>
<tr>
<td>Depart KCVH airspace</td>
<td>Arrive WISK02 airspace</td>
</tr>
<tr>
<td>Level off (~3500' MSL)</td>
<td>Landing clearance received</td>
</tr>
<tr>
<td>Enroute</td>
<td>Land WISK02</td>
</tr>
<tr>
<td>Landing clearance received</td>
<td>Flight plan closed</td>
</tr>
<tr>
<td>Start descent</td>
<td>Safety report for inflight non-conformance due to collision avoidance maneuver</td>
</tr>
<tr>
<td>Arrive KSNS airspace</td>
<td></td>
</tr>
<tr>
<td>Land KSNS</td>
<td></td>
</tr>
<tr>
<td>Flight plan closed</td>
<td>*C2 Link Compromised</td>
</tr>
<tr>
<td>Physical Repositioning</td>
<td>*Rejected Takeoff</td>
</tr>
<tr>
<td>Gate Arrival</td>
<td>*Missed Approach</td>
</tr>
<tr>
<td>Post flight check</td>
<td>*Rescinded Take-off Clearance</td>
</tr>
<tr>
<td>Decision on Flight Plan Intent (turnaround)</td>
<td>*Passenger/ Cabin Emergency</td>
</tr>
<tr>
<td>Flight plan filed to WISK01 with alternates</td>
<td>*Aircraft Emergency</td>
</tr>
<tr>
<td>Takeoff clearance received</td>
<td>*Separation Conflict</td>
</tr>
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4 Exercise Summaries

Each tabletop was conducted amongst Wisk, NASA, and one of the airspace partners. In two of the tabletops, AURA played a role as the C2CSP as well. The exercise was set up as a passenger transport scenario between two simulated vertiports (WISK 01 at KCVH and WISK 02 at KSNS), broken up into distinct phases to assess each player’s role and actions, with a couple of contingency scenarios injected at the end if there was time. Additionally, one of the rules of engagement was that this tabletop would take place in UML-2B, meaning early infrastructure and very few players in the airspace at any given time. As a result, some of the discussion that ensued was what is possible now vs what is the ideal for a later UML when more infrastructure exists (such as data vs voice capability). Wisk played the roles of operator/scheduler/dispatcher, Remote Pilot in Command (RPIC), ground ops, passenger handling, and aircraft/maintenance team. NASA played the role of one of the PSUs, specifically the NPSU (NASA PSU), as well as the moderator for the exercise. The PSU was played by each of the airspace partners, with Collins playing the additional role of C2CSP. The phases of the exercise were broken out as shown in Table 2. (*not all contingencies were exercised in each of the tabletops due to time constraints):

4.1 ANRA

4.1.1 Exercise Date/Duration: 20 Oct 2022/3 hours

4.1.2 Participants: NASA, Wisk, ANRA

4.1.3 Major Discussion Points:

There were discussions on the role of the PSU in vertiport availability. Whereas the operator (Wisk) planned to communicate with the vertiport prior to filing their flight plan intent to understand availability, ANRA believed that while just prior to take-off and while in flight (tactically) it made sense for the operator to coordinate with the vertiport, it should be part of the PSU’s responsibility ahead of time as part of the overall route availability to coordinate with the vertiport based on the operator’s flight intent. Much of the differences in vision can be attributed to expectations at different UMLs – the operator sees having to coordinate with the vertiport directly in UML-2b, for example, so that THEN they can determine mission timing and intent to pass along to the PSU to now provide additional information back. The operator sees the PSU mainly providing information about their planned route in early UMLs, such as conditions of the proposed routes and perhaps a recommendation of the most viable route. This would be the capability that would set PSUs apart from each other – aggregating the raw data such as weather, obstacles, and terrain into a route recommendation.

Similarly, for filing flight intent, the operator’s plan is to file through the currently available options but in future UMLs, the flight plan would be filed through the PSU. Since eventually the PSU would aggregate all of the route information based on the known aircraft mission intent and all of the factors potentially affecting the route, a better term than route availability could be route viability, with a kind of alerting or status indicating whether a route is viable all the way through or if there might be issues or one might be faster (e.g., color-coded to relay viability). Additionally, route viability would be communicated by the PSU if something changes, such as the vehicle is delayed in completing ground ops and will not take off at its expected time. The PSU could help
the operator determine the viability and recommendations of departing later, flying at a different speed, or some other recommendation. One unknown is what information on aircraft performance the operators will share with the PSUs. At this point, Wisk has not decided if it will share such information such as crosswind or tailwind limits, which could limit the scope of the route viabilities the PSUs pass to the operators.

Airspace clearances would currently have to be handled via a mix of voice and data since there is not a set entity that can handle relaying/accepting the information entirely digitally. In later UMLs, due to resource constraints of using voice, departure clearance, for example, is envisioned to be all digital and no voice. There was also discussion about who provides deconfliction while traveling along the route. Currently, Wisk plans to handle that onboard and never plans to hand over safety-of-flight deconfliction (i.e., an imminent collision), but eventually that may be a role in which the PSU participates to help make airspace usage and any route changes to deconflict more efficient.

Eventually the PSU’s role will help to alleviate the need for every operator to talk to everyone else. The PSU will have visibility into all operators, their conformance, their limitations, etc. and can be the aggregator to relay information to other operators and/or help operators determine route viability and provide recommendations that fit into the entire air picture. Additionally, if the PSU can detect possible conflicts long before ATC or a DAA system does and can suggest reroute options, that would minimize impact to the airspace, vertiport availability, as well as the operator, and could improve airspace efficiency overall.

## 4.2 Avision

### 4.2.1 Exercise Date/Duration: 4 Oct 2022/3 hours

### 4.2.2 Participants: NASA, Wisk, Avision, AURA

### 4.2.3 Major Discussion Points:

Similar discussion took place with Avision as with ANRA, that the vertiport would be included in the route viability and therefore not treated differently from the enroute portion as far as PSU responsibilities. This tabletop included AURA, so there was more discussion about establishing the C2 link and the recognition that knowing the availability as well as the route info (including vertiport availability) were equally important. Coordination between the operator and the C2 provider would need to happen directly (i.e., not through the PSU) prior to the day of flight to ensure reservation of spectrum resources is completed in advance. In general, the C2 provider is providing assurance that the link will be available in time to support the filed flight plan/mission intent.

Certain PSU functions, such as providing potential alternative routes, are envisioned in future UMLs, but Wisk is expecting to have to carry some redundancy in those areas in earlier UMLs until that functionality is for certain available by the PSUs. For that reason, the raw data that would feed those alternative routes would still need to be provided by the PSU to the operator in earlier UMLs so the operator can execute the planning, even if it’s redundant. At the very least, the operator expects the PSU to provide conflict detection and recommendations. However, that may be limited depending on how much aircraft performance data the operators share with the PSUs. Additionally, tactical deconfliction (i.e., safety of flight and/or immediate threats) would happen
onboard with a DAA system vs relying on the PSU to provide safety-critical information (at least in early UMLs). PSUs would also detect non-conformance to mission intent and relay that to all other actors, including other PSUs and other operators in the area.

One challenging area that was identified as needing further discussion is how the communication happens at an airport with CTAF or UNICOM, especially when some of the operations, such as glider ops, would not have transponders and therefore the PSU has no visibility on those ops and cannot provide deconfliction or recommendations to the operator.

4.3 Collins Aerospace

4.3.1 Exercise Date/Duration: 28 Sep 2022/3 hours

4.3.2 Participants: NASA, Wisk, Collins

4.3.3 Major Discussion Points:

Operating from older requirements, the Collins PSU functional allocation included filing IFR flight plans and conveying predeparture and take-off clearances. This created much discussion as Wisk no longer desires the PSU to perform this function for the medium time frame implementation or UML-2b. Collins conveyed they file 2000 flight plans a day through their ARINCDirect service and will include flight filing services as a PSU service level option which potentially offers a more seamless transition to future maturity levels. An identified potential shortfall to de-coupling the PSU from flight filing is that there is no demand capacity balancing since operators would all be filing their flight plans without PSU involvement.

Another discussion items was whether the operator was going to share performance data, especially all information required to calculate the eVTOL equivalence of “bingo fuel”. As mentioned above, Wisk is unsure at this time, but Collins indicated that without aircraft performance data, route availability/viability would be limited to what C2 and surveillance coverage volumes and terrain or weather would dictate. Collins would not be able to make alternate flight plan recommendations with high probability of acceptance on specific routes without aircraft performance data.

In this tabletop exercise, Collins also spoke on behalf of the C2 role and envisioned that coordination would have to occur from the C2 player not only to the operator but also to the PSU to ensure viability of a planned mission intent based on C2 coverage and availability. Additionally, it was noted that the C2 needed to be available at the FATO, if not sooner (though masking from hangars where passengers might be boarding could present challenges).

There was a similar theme in this tabletop of who talks to the vertiport (operator or PSU or a combination) and when. Wisk sees a need to ensure, prior to filing flight plans, that a vertiport can meet their requirements and at other times they will need to confirm with the vertiport details about passenger handling services. Additionally, having a direct link to the vertiport to ensure the FATO is all clear before transitioning to it could be considered safety-of-flight, in which case Wisk would not be relying on the PSU. However, a PSU might need to act as a broker for airspace or vertiports. Future UAM planning will need to further vet this topic to determine if the PSU should
relay all of this or if there should be direct communication between the operator and the vertiport at certain times.

4.4 OneSky

4.4.1 Exercise Date/Duration: 6 Oct 2022/3 hours

4.4.2 Participants: NASA, Wisk, OneSky, AURA

4.4.3 Major Discussion Points:
Many of the discussion points were similar to what has already been laid out for the previous partners.

A further discussion on PSU involvement with flight plan filing centered around having an ability to at least predict that there may be multiple flight plans filed by multiple parties that could potentially create conflicts if they are flown at the time and state they are currently filed. The PSU could have an algorithm that calculates risk potential based on what is filed. Wisk mentioned that bucketing all potential conflicts (both potential and realized) with a confidence level might be the most useful way for PSUs to alert operators to potential conflicts even if they haven’t been realized yet. This could mitigate the conflict from even happening if the operator can make changes as a result.

4.5 Skygrid

4.5.1 Exercise Date/Duration: 24 Aug 2022/3 hours

4.5.2 Participants: NASA, Wisk, Skygrid

4.5.3 Major Discussion Points:
The PSU will not have direct contact with the aircraft; all comms would be between the operator and the PSU instead. One theme in this discussion (and many of the previous partners) was the eventual desire to eliminate voice and human-to-human contact. A related area of research to this would be what to do about uncontrolled airports since currently voice over CTAF is how all players in the area maintain situational awareness.
5 Lessons Learned

The following lessons learned follow from feedback received from NASA and partner participants. A significant amount of data is contained in Appendix B where many of these lessons learned were gleaned.

In UML-2B, the PSU plays less of a role than we thought. Most of the airspace partners were prepared to handle flight plan filing and associated interactions with FAA; however, the Wisk CONOPS included handling all of those interactions. In addition, this exercise did not include Demand Capacity Balancing (DCB) or much additional traffic.

So how smart does a PSU have to be? A relatively common perception is that the PSU takes on the role of FAA ATC and handles complex tasks such as DCB and inflight traffic separation responsibility. This vision for PSU functionality is required for UML-4 and beyond; however what does a PSU look like in the “crawl” or “walk” phase prior to “running” with full-up services analogous to ATC in the NAS today? In order for a PSU to perform advanced UML-4 functions, they will need to perfect the art of consuming, aggregating, and correlating disparate datasets related to weather, surveillance, C2 services, DCB, private vertiport statuses, and perhaps many more. So the first logical step for a PSU might be to start perfecting the art of acquiring these datasets, measuring data availability, understanding the data integrity, and experimenting with how to package this data to be most beneficial to aircraft operators.

What about System Wide Information Management (SWIM)? Many discussion occurred where partners expected to obtain data (e.g. traffic, weather). According to the FAA SWIM website, “SWIM provides the infrastructure, standards, and services needed to optimize the secure exchange of relevant data for NAS systems and the aviation community.” While SWIM may provide much of the input data needed by PSU’s, what that actually looks like to a PSU and how that would benefit the operator was unclear. For example the scenario involved winds that were just below/at/above takeoff limits. Whereas, a piloted aircraft would be getting real-time updates from a tower or visual reference to windsock, could SWIM data provide near real-time weather data to piloted aircraft for all vertiports? It seems more likely that these updates and augmented surveillance updates might be better provided by services utilizing 3rd party or local data from the vertiports themselves. Reliance on SWIM data for the AAM use-case seems unclear.

Better understanding needed on FAA flight plan filing, acceptance, and ATC clearance process. It became apparent that experienced operational understanding of the current ATC filing, acceptance, and clearance process was insufficient for all players to understand the system interactions required to obtain FAA clearance for the mission with high fidelity mission intent. In fact, it appears that likely that current FAA systems are inadequate for obtaining a common operating picture of high fidelity mission intent for the AAM use-case. A better understanding of the current system is needed in order to highlight the gaps and standards needed to file high fidelity mission intent (e.g. 4D trajectory), get clearance for same, and also begin to address how demand capacity balancing will be accomplished.
Operator data sharing. Fleet operators should determine what type of performance data they are willing to share with PSUs since it will impact the level of service they can expect to receive from a PSU. For example, if a PSU does not know wind or performance limits (e.g. environmentally dependent climb performance), then the PSU cannot assist the operator with route viability and route options.

Operations at uncontrolled airports/vertiports. Wisk chose one of the more challenging departure and arrival scenarios which is to conduct VTOL or vertiport operations at existing fixed-wing airports. The departure from WISK01, collocated with KCVH sparked a lot of discussion surrounding the voice communications and visual/detect-and-avoid requirements for operations at an uncontrolled airport. The voice communications standard worked out; however the ability to remain well clear of other traffic from an autonomic point of view was not 100% clear. For example, the Wisk FOC does not have any visual contact with the takeoff area and relies on ground crew to clear for traffic.

Distinction between different data exchanges. At the start of the exercise, there was not a common understanding of the different between C2CSP and Datalink. For the purpose of this exercises, it was understood that the term “datalink” would refer to traditional methods of data communication between and Air Operations Center (AOC) and/or ATC (e.g. CPDLC). Whereas C2 was specifically reserved for the direct link required between the aircraft and the operator’s FOC where the RPIC resides.
6 Recommendations

The following recommendations follow from lessons learned and feedback received from NASA participants and partners following the exercise.

Systems engineering review. A review of each exercise should be accomplished through the lens of a requirements engineer. While this would not produce a final set of requirements in any sense, the derived requirements would be extremely beneficial to operators in the CONOPS and top level system interface planning.

Near-term follow-up workshops. NASA, Wisk, Airspace and C2CSP partners should explore further explore specific areas where agreement was not reached; for example, FAA plans for receiving high fidelity mission intent. In addition, top level discussions on the NC-2 baseline infrastructure would be beneficial for receiving feedback and planning future systems integration testing.

NC infrastructure UML target. While industry certainly needs to look at near-term operations, the focus for NC might be better suited for “UML-3”. This exercise demonstrated that for low volume operations, the PSU serves a minimal role as compared to the vision of PSU providing actual traffic separation services. In order to test the system interfaces for the latter, it would be more beneficial to look beyond a scenario where the PSU basically just hands off weather and surveillance information to the operator to deal with on their own.

Mix of operators, PSUs, and vertiports. The goal of AAM is certainly not exclusive use of certain airspace but specific operators with one CONOPS and one aircraft type. Therefore, future simulations should include as many operators, PSUs, and mixed vertiports as possible. An example of mixed operators could include private piloted VFR traffic, traditional commercial 121/135 carriers, sUAS operations, and at least 2 eVTOL Part 135 carriers. An example of mixed PSUs would include bringing not just an airspace partner and NASA PSU together, but two or more airspace partners together. This could help explore the idea of PSU as a “broker” for vertiport/airspace management to ensure no party, such as a fleet operator, unfairly prioritizes their own operations over others. An example of mixed vertiports could include operations from both towered airports, untowered airports, commercial vertiports, and private vertiports. Such an approach could encourage discussion on prioritization and utilization of resources.

More complex R&D simulations. Since this was only a simple route without the need for DCB or many other real-world constraints, there is a significant chunk of expected functionality not yet under R&D. Concern was expressed that with multiple variables and PSUs interacting simultaneously, the system may go unstable depending on latencies. This concern should be tested in future simulations with higher fidelity models and multiple systems as in the previous recommendation.

FAA CONOPS 2.0. As previously recommended in the MVP notes, it is recommended that FAA release an updated CONOPS for AAM/UAM. Without common terminology and a common operating picture, it is difficult if not impossible for potential PSUs to develop the interfaces and services required to support safe and efficient AAM operations.
System criticality: It is recommended to plan future systems integration exercises or simulations to better understand the safety and/or efficiency implications of service interruptions or availability. Perhaps a primary example of this would be the implications of lost C2 link. An interesting concept presented during the exercise with Wisk was that a lost C2 link would not necessarily be considered safety critical since the aircraft is operating autonomously for the most part. But other data interruptions to study could include connectivity to PSU and the various data provided (e.g. interruption of weather data services at the arrival vertiport).

RNP 0.1 procedure, aircraft, and operator certification. With respect to current navigation capabilities, the technology supports RNP 0.1; however there needs to be focus on route definition and leg types which can support RNP 01. One specific recommendation is to start prohibiting course changes without the use of RF legs. This paper presents one takeoff to landing procedure that meets that requirement. In addition to certified procedures, FAA should plan and expect OEMs to demonstrate means of compliance for tighter RNP certifications and fleet operators to request operational approvals for same.
References

ASRS – Aviation Safety Reporting System (nasa.gov)

Concept-of-Operations-for-Uncrewed-Urban-Air-Mobility.pdf (boeing.com)

Digital – Terminal Procedures Publication (d-TPP)/Airport Diagrams (faa.gov)

FAA UAM CONOPS 1.0

National Campaign Development of Airspace Operations, Infrastructure, and Data. Prepared by Advanced Air Mobility National Campaign Team, AAM-NC-069-001

UAM Airspace Research Roadmap Orientation, June 13, 2022, Ian M Levitt
# Appendix A: Acronyms

This appendix contains acronyms that are used repeatedly throughout this document.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>C2</td>
<td>Command and Control</td>
</tr>
<tr>
<td>C2CSP</td>
<td>C2 Communications Service Provider</td>
</tr>
<tr>
<td>COP</td>
<td>Common Operating Picture</td>
</tr>
<tr>
<td>CTAF</td>
<td>Common Traffic Advisory Frequency</td>
</tr>
<tr>
<td>DAA</td>
<td>Detect and Avoid</td>
</tr>
<tr>
<td>DCA</td>
<td>Demand Capacity Balancing</td>
</tr>
<tr>
<td>FOC</td>
<td>Flight Operations Center</td>
</tr>
<tr>
<td>FATO</td>
<td>Final Approach and Takeoff</td>
</tr>
<tr>
<td>MVS</td>
<td>(Wisk) Multi Vehicle Supervisor</td>
</tr>
<tr>
<td>NC</td>
<td>National Campaign</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>PSU</td>
<td>Provider-of-Services for UAM</td>
</tr>
<tr>
<td>RPIC</td>
<td>Remote Pilot in Command</td>
</tr>
<tr>
<td>SDSP</td>
<td>Supplemental Data Service Provider</td>
</tr>
<tr>
<td>SWIM</td>
<td>System Wide Information Management</td>
</tr>
<tr>
<td>UAM</td>
<td>Urban Air Mobility</td>
</tr>
<tr>
<td>UNICOM</td>
<td>Universal Communications</td>
</tr>
</tbody>
</table>
Appendix B: Exercise Data

An Excel spreadsheet was used to document the role player communications for each exercise. The spreadsheet contains a tab for each exercise (per airspace partner). Each tab contains a row for the action item and columns for each role player. The cells contain the actual role and/or discussions that occurred at each step in the exercise by role player. The spreadsheet data is part of this report and should be attached. If missing, please contact National Campaign sub-project manager.
Appendix C: RF45 Construction

This appendix describes the motivation for RF45 procedure construction. The requirement from Wisk was to have a fixed route structure between vertiports. Since there are not any current departures, airways, or approaches that meet this criteria, the RF45 procedure was created to fill this void. Fixed routes could obviously be constructed directly between the vertiport centers but few, if any, aircraft would be capable of precisely tracking them. Due to a variety of factors, including air traffic, wind limits, terrain or obstacles, aircraft will not always be able to depart directly to the center point of the next vertiport. The features which the RF45 procedure was designed to address are:

- Definition of a geospatially unambiguous flight path that is repeatable by all user aircraft.
- Provides enough departure/arrival courses to account for air traffic, weather, and terrain/obstacle limitations.
- Accomplishes any course changes by RF legs. The rational for this is that no aircraft can remain on-course with Track-to-Fix (TF) to TF legs as is typically done. The aircraft will either lead the turn when the intermediate fix is a “flyby’’ waypoint of flies over and must track back to course in the case of a “flyover’’ waypoint.
- Reduce RF legs to the minimum radius practical to minimize total track distance.
- Use a minimum number of waypoints to reduce proliferation of aeronautical data.
- Scalable to any combination of vertiport pairs without proliferating too many new waypoints.

To expand on the “wheel” concept proposed by Zahn, the following pattern was devised to handle RF legs for all course changes onto a fixed route between two vertiports and into the next vertiport. There are 5 categories of legs in this model:

<table>
<thead>
<tr>
<th>Figure Label</th>
<th>Leg Category</th>
<th>ARINC424 Leg Type</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Departure/Approach Tracks</td>
<td>TF</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Inner RF Leg Alignment Leg (Radius = R1)</td>
<td>RF</td>
<td>Not required for straight-out departure or straight-in approach</td>
</tr>
<tr>
<td>C</td>
<td>“Wheel” RF Leg (Radius = R)</td>
<td>RF</td>
<td>Not required for straight-out departure or straight-in approach</td>
</tr>
<tr>
<td>D</td>
<td>Outer RF Alignment Leg (Radius = R2)</td>
<td>RF</td>
<td>Not required for straight-out departure or straight-in approach</td>
</tr>
<tr>
<td>E</td>
<td>RF Alignment to the Fixed Route</td>
<td>RF</td>
<td>Small course change; always less than 22.5°</td>
</tr>
<tr>
<td>F</td>
<td>Fixed Route between 2 Vertiports</td>
<td>TF</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – RF45 Leg Categories/Types
Figure 6 shows construction of the standard RF45 procedure where the outbound/inbound tracks are separated by 45°. A sample outbound or inbound route is highlighted in red with adjacent leg category labels from Table 3.
The selection of 45° separation between outbound/inbound tracks was based on:
- Logical factors of 360° which could represent track separations
- Final leg (A) length not less than 1NM
- Minimum RF leg radii of .5NM; chosen to support up to 100 knot outbound/inbound airspeeds
- Not too many waypoint required

Using trigonometric functions of the angle θ show in Figure 7, we are able to define the departure/approach leg (A), radius of inner RF leg (B), and radius of outer RF leg (D) as a function of the “wheel” radius (C).

![Figure 7 – Trigonometric Functions of Theta](image_url)
Where:
S=Number degrees track separation
R=Wheel Radius
R1 = Inner RF leg radius
R2 = Outer RF leg radius

\[ \theta = \left( 90^\circ - \frac{S}{2} \right) \]

**Final Segment** = \( R1 \times \tan \theta \)

\[ R = (R1 \times \text{exsec}\theta) + 2 \times R1 \]
\[ R = R1 \times (\text{exsec}\theta + 2) \]
\[ R1 = \frac{R}{\text{exsec}\theta + 2} \]
\[ R1 = \frac{R}{\text{sec}\theta + 1} \]

\[ R2 = (R2 \times \text{sec}\theta) - R \]
\[ R2 \times (1 - \text{sec}\theta) = -R \]
\[ R2 = \frac{R}{\text{sec}\theta - 1} \]

Figure 9 - RF45 Trigonometric Formulas for Final Distance and RF leg radii
Parameters for a “wheel” radius of 2NM (R = 2) are shown in Table 4 – Track Separation Parameters when R = 2. The formula for determining the final distance, R1, and R2 is show in Figure 9. The formula for the number of waypoints required for each selection of degrees serration is:

\[
\# \text{Waypoints Required} = 3 \times \frac{360}{S} + 1
\]

Parameters for a “wheel” radius of 2NM (R = 2) are shown in Table 4.

Table 4 – Track Separation Parameters when R = 2

<table>
<thead>
<tr>
<th>In/Out Track Separation (deg)</th>
<th>Final Distance (NM)</th>
<th>R1 (NM)</th>
<th>R2 (NM)</th>
<th># Waypoints Reqd</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.833</td>
<td>0.160</td>
<td>0.191</td>
<td>109</td>
</tr>
<tr>
<td>15</td>
<td>1.754</td>
<td>0.231</td>
<td>0.300</td>
<td>73</td>
</tr>
<tr>
<td>20</td>
<td>1.678</td>
<td>0.296</td>
<td>0.420</td>
<td>55</td>
</tr>
<tr>
<td>25</td>
<td>1.605</td>
<td>0.356</td>
<td>0.552</td>
<td>!</td>
</tr>
<tr>
<td>30</td>
<td>1.535</td>
<td>0.411</td>
<td>0.698</td>
<td>37</td>
</tr>
<tr>
<td>35</td>
<td>1.466</td>
<td>0.462</td>
<td>0.860</td>
<td>!</td>
</tr>
<tr>
<td>40</td>
<td>1.400</td>
<td>0.510</td>
<td>1.040</td>
<td>28</td>
</tr>
<tr>
<td>45</td>
<td>1.336</td>
<td>0.554</td>
<td>1.240</td>
<td>25</td>
</tr>
<tr>
<td>50</td>
<td>1.274</td>
<td>0.594</td>
<td>1.464</td>
<td>!</td>
</tr>
<tr>
<td>55</td>
<td>1.214</td>
<td>0.632</td>
<td>1.716</td>
<td>!</td>
</tr>
<tr>
<td>60</td>
<td>1.155</td>
<td>0.667</td>
<td>2.000</td>
<td>19</td>
</tr>
<tr>
<td>65</td>
<td>1.097</td>
<td>0.699</td>
<td>2.322</td>
<td>!</td>
</tr>
<tr>
<td>70</td>
<td>1.041</td>
<td>0.729</td>
<td>2.690</td>
<td>!</td>
</tr>
<tr>
<td>75</td>
<td>0.986</td>
<td>0.757</td>
<td>3.112</td>
<td>!</td>
</tr>
<tr>
<td>80</td>
<td>0.933</td>
<td>0.783</td>
<td>3.599</td>
<td>!</td>
</tr>
<tr>
<td>85</td>
<td>0.880</td>
<td>0.806</td>
<td>4.165</td>
<td>!</td>
</tr>
<tr>
<td>90</td>
<td>0.828</td>
<td>0.828</td>
<td>4.828</td>
<td>13</td>
</tr>
</tbody>
</table>

! Not a factor of 360° wheel

Final distance, R1/R2, and # wpts satisfactory

Final distance, R1/R2, and # wpts unsat
Both Table 4 and Figure 10 show the only logical separations as 40°, 45°, and 60°. Since 45° results in easy to visualize cardinal direction courses of 0°, 90°, 180°, and 270°, it was chosen as the separation for the exercise procedure.

![Final Distance vs Min RF Radius for R=2NM](image)

Figure 10 – Min Final Distance vs Min R1 Radius for R = 2NM

The final procedure characteristics are $R = 2\text{NM}$, $F = 1.34\text{NM}$, $R1 = .55\text{NM}$, and $R2 = 1.24\text{NM}$, with 25 total waypoints required for the procedure. This procedure meets initial design criteria by:

- Utilizing RF legs for all course change and thereby enabling extremely low Flight Technical Error (FTE) to support RNP 0.1
- Minimizing the number of waypoint for a comprehensive departure and approach procedure
- Sufficient course options to allow for low crosswind and tailwind component
- Consistent and fixed enroute TF leg require 2 additional waypoints for RF leg alignment
- Supports transition to wing CONOPS for vertiport to vertiport with a minimum of 8NM distance between; smaller hops will require lower airspeeds and smaller RF leg structure
- Scalable because the same procedure could be placed at any vertiport (although some tracks may need restrictions due to air traffic, terrain, or obstacles.

The following 4 pages contain procedure plates created for the exercise and to serve as candidate ideas for publishing departures and approaches for AAM instrument procedures.
Figure 11 – WISK01 Departures
Figure 12 – WISK01 Approaches
Figure 13 – WISK02 Departures
Figure 14 – WISK02 Approaches
Another feature of the RF45 procedure design is that it really doesn’t need additional waypoints. The trigonometric formulas are already worked out so that the only data required are:

- Vertiport latitude, longitude, elevation
- Radius of the “wheel” if different than 2NM
- Min safe altitude
- List of any unauthorized tracks

There is actually only 1 waypoint definition required for the whole set of procedures and that is the location of the vertiport. It would be possible to add the RF45 or similar consistent procedures to FMS in such a manner that 1000s of additional waypoints are not proliferated into the aeronautical data system for each new set of vertiports. For example, many FMS today have search patterns which can program circular or search pattern routes by inputting on the center point and 1 or 2 additional parameters. It should be possible to do the same with a procedure concept such as the RF45. This satisfies that last design criteria which was “Scalable to any combination of vertiport pairs without proliferating too many new waypoints”.

Finally a short format was designed to communicate mission intent during this exercise. The format provided the minimal information needed to communicate 4D trajectory. See Figure 15.

The expected flight plan intent given the mission and weather conditions should have looked similar to:

```
WISK01360L 225045S225  WISK02
13000130205150130130800130930
```
## Appendix D: Exercise Safety Report

### UAS INVOLVED IN EVENT (continued)

<table>
<thead>
<tr>
<th>Operator</th>
<th>Air Carrier</th>
<th>Commercial Operator</th>
<th>Military</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission</td>
<td>Agriculture</td>
<td>Banner Tow</td>
<td>Cargo / Freight / Delivery</td>
<td>Passenger</td>
</tr>
<tr>
<td>Flight Operated As</td>
<td>VLOS (Visual Line of Sight)</td>
<td>BVLOS (Beyond VLOS)</td>
<td>With Visual Observer? Yes</td>
<td>No</td>
</tr>
<tr>
<td>UAS Control Mode</td>
<td>Autonomous / Fully Automated</td>
<td>Manual Control</td>
<td>Waypoint Flying</td>
<td>Transitioning Between Modes</td>
</tr>
<tr>
<td>Flight Phase (at time of event)</td>
<td>Arrival</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was the UAS flying in, near or over: (select all that apply)
- [ ] Aerial Show / Event (e.g. fireworks, airshow)
- [ ] Aircraft / UAS
- [ ] Airport / Aerodrome / Heliport
- [ ] Critical Infrastructure
- [ ] Crowds (e.g. sporting event, concert, festival)
- [ ] Emergency Services (e.g. police, fire)
- [ ] Indoors / Confined Spaces
- [ ] Moving Vehicles (e.g. highways, busy streets, bridges)
- [ ] Natural Disaster
- [ ] No Drone Zone
- [ ] Open Space / Field
- [ ] People / Populated Areas (e.g. residential)
- [ ] Private Property
- [ ] Recreational Club / Fixed Flying Site
- [ ] Other: |

### UAS / AIRCRAFT 2 INVOLVED IN EVENT

<table>
<thead>
<tr>
<th>Make / Model: (or describe)</th>
<th>Unknown UAS</th>
<th>UAS</th>
<th>Manned Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAS Weight Category</td>
<td>Micro UAS</td>
<td>Small UAS</td>
<td>Medium UAS</td>
</tr>
<tr>
<td>UAS Configuration</td>
<td>Multi-Rotor</td>
<td>Fixed Wing</td>
<td>Helicopter</td>
</tr>
<tr>
<td>Operator</td>
<td>Air Carrier</td>
<td>Air Taxi</td>
<td>Commercial Operator (UAS)</td>
</tr>
<tr>
<td>Flight Phase (at time of event)</td>
<td>Cruise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If more than two aircraft or UAS was involved, please describe the additional aircraft / UAS in the "Describe Event / Situation" section.

### UAS LOCATION

- Altitude: 3,000 feet
- AGL (above ground level)
- MSL (mean sea level)

Estimated miss distance from UAS / Aircraft:
- Horizontal: 2,000.00 feet
- Vertical: 50.00 feet

How was the UAS / Aircraft conflict avoided?
- Operator commanded evasive action Yes No
- Collision avoidance system maneuver Yes No

### NEAR MISS CONFLICTS

### CONTRIBUTING FACTORS

What factors may have contributed:
- [ ] Airspace Authorization / Flight Planning App
- [ ] Command and Control (e.g. lost link, frequency interference)
- [ ] Environment (e.g. terrain, obstructions, lighting, fire)
- [ ] FAA Regulation Misinterpretation / Unaware
- [ ] Ground Control Station / Remote Control Transmitter (e.g. hardware failure, interface / display)
- [ ] Human Factors (e.g. fatigue, confusion, situational awareness)
- [ ] Software and Automation (e.g. geofencing, return to home)
- [ ] UA Equipment (e.g. components, sensors, payload)
- [ ] Weather Conditions (e.g. wind gust, lightning)
- [ ] Other: |

### DESCRIBE EVENT / SITUATION

Keeping in mind the topics shown below, discuss those which you feel are relevant and anything else you think is important. Include what you believe really caused the problem, and what can be done to prevent a recurrence, or correct the situation. (USE ADDITIONAL PAPER IF NEEDED)

While returning to KSNL, an unplanned descent to 3,000 was accomplished to avoid co-altitude traffic. After level at 3,000, automated systems detected a small UAS directly in front of the aircraft and commanded a hard left turn to avoid. Aircraft deviated 3NM off course to the south before obtaining updated ATC clearance for a new arrival at KSNL.

### CHAIN OF EVENTS

- How the problem arose
- Contributing factors
- Corrective actions

### HUMAN PERFORMANCE CONSIDERATIONS

- Perceptions, judgments, decisions
- Actions or inactions
- Factors affecting the quality of human performance

NASA ARC 277U (February 2021)
### Flight Tabletop Exercise

**Date of Occurrence:** 10/25/2022

**Type of Event / Situation:** NASA/Wisk Flight Tabletop Exercise

---

### Reporter

- **How were you involved in the UAS operation?**
  - Single Person Crew
  - Multi-Person Crew
  - Not Involved (e.g., eyewitness)

- **Crew Size:** 1
  - (total including reporter)

- **Role at time of event:**
  - Person Manipulating Controls
  - Remote Pilot in Command (RPC)
  - Visual Observer
  - Other Crew Member: Multi Vehicle Supvr

- **Reporter Location:**
  - Outdoor / Field Station
  - Indoor / Ground Control Station
  - Repair Facility
  - Other: __________

- **Time manipulating controls of UAS**
  - (Estimated Time, round to nearest quarter hour)
  - Total Time to Date in all UAS Make / Models: 100.00 hrs (e.g. 14.25)
  - Time Last 90 Days in all UAS Make / Models: 100.00 hrs (e.g. 9.50)
  - Time to Date in UAS Make / Model involved in event: 100.00 hrs (e.g. 0.75)

- **Manned aircraft flight experience (if applicable):** Total Time: 0.00 hrs

- **FAA Certificates / Ratings held:**
  - Remote Pilot / Part 107
  - Private - Manned
  - Commercial - Manned
  - ATP - Manned
  - Flight Instructor - Manned
  - Instrument - Manned
  - Multiengine - Manned
  - N/A (non-certificated recreational flyer)
  - Other: MVS

---

### Weather Elements

- Clear
- Haze/Smoke
- Snow
- Wind
- Thunderstorm
- Wind shear
- Turbulence
- High Winds

- Dawn
- Night
- Daylight
- Dusk
- Cloud Ceiling __________ feet
- Visibility __________ miles

---

### UAS Involved in Event

- **UAS Make / Model / Series:** Wisk Aero Gen6
  - (do not include registration or serial number)

- **Weight Category** (at takeoff with payload)
  - Micro UAS (< 0.55 lbs)
  - Small UAS (at or above 0.55 lbs < 1320 lbs)
  - Medium UAS (at or above 1320 lbs)

- **Configuration**
  - Multi-Rotor
  - Fixed Wing
  - Helicopter
  - Hybrid (e.g., VTOL)
  - Other: __________

- **How many UASs were you controlling?** (at time of event)
  - __________

- **Rule Flying Under**
  - 91 (Private / non-commercial)
  - 107 (UAS)
  - 133 (Helicopters w/ external loads)
  - 135 (Chartered / non-scheduled flights)
  - 137 (Agricultural Operations)
  - 138 (Public Aircraft Operations)
  - 44809 (Limited Recreational Operations)
  - Other: __________

- **Airworthiness Approval Certification (if applicable)**
  - Standard AC
  - Special AC
  - Special Authorization / Section 44807

- **Waivers / Exemptions / Authorizations**
  - Were you operating under any Waivers / Exemptions / Authorizations? Yes No
  - FAR Section Number / Other: __________
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA has established an Aviation Safety Reporting System (ASRS) to identify issues in the aviation system which need to be addressed. The program of which this system is a part is described in detail in FAA Advisory Circular 00-46F. Your assistance in informing us about such issues is essential to the success of the program. Please fill out this form as completely as possible, enclose in a sealed envelope, affix proper postage, and send it directly to us.

The information you provide on the identity strip will be used only if NASA determines that it is necessary to contact you for further information. THIS IDENTITY STRIP WILL BE RETURNED DIRECTLY TO YOU. The return of the identity strip assures your anonymity.

NOTE: AIRCRAFT ACCIDENTS SHOULD NOT BE REPORTED ON THIS FORM. SUCH EVENTS SHOULD BE FILED WITH THE NATIONAL TRANSPORTATION SAFETY BOARD AS REQUIRED BY NTSB Regulation 830 (49CFR830).

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If you want to mail this form, please fold pages, enclose in a sealed, stamped envelope, and mail to:

NASA AVIATION SAFETY REPORTING SYSTEM
POST OFFICE BOX 189
MOFFETT FIELD, CA 94035-0189

NASA Document Number: AAM-NC-113-001