FAA/Skyward Memorandum of Agreement (MOA) Bimonthly Report

March 2022*

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*Redactions and corrections made by Verizon February 2024

1. Table of Contents

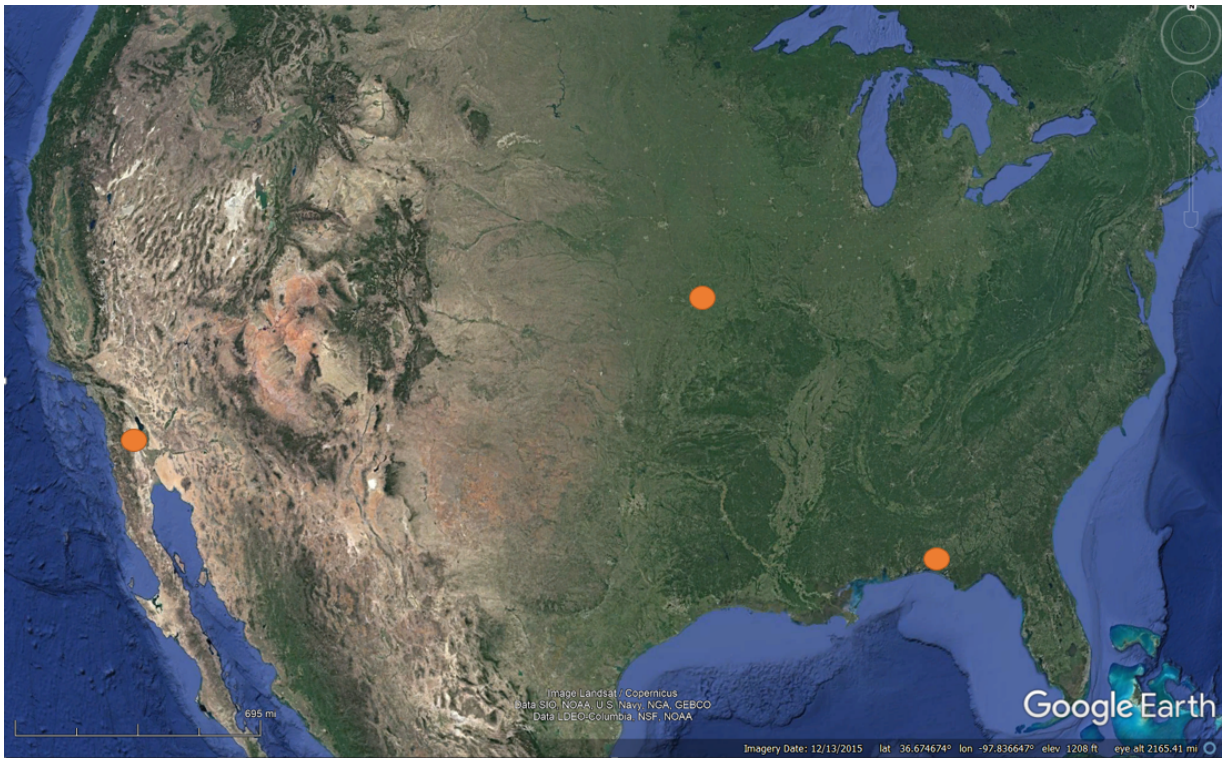
2. Revision History

Revision	Date	Description of Revision
1.0	03/01/2022	Initial report

3. Overview of Flight Campaigns

Flight campaign start date: Dec 6th 2021
Flight campaign completion date: January 31st 2021
Total quantity of flight hours: 165
Total quantity of flights: 274 flights (244 flights have data)
Percentage of time with full C2 Link Connection: 98.22%
Percentage of time with full Cellular Network RF Environment: 50.030%
Uncrewed aircraft OEM and Model:

- Hitec Xeno Fx - Fixed wing
- Delair UX11 Ag - Fixed wing



Censys Sentaero V2 - VTOL Fixed Wing

Figure 3.1 Overview of Operation areas

Figure 3.2 Sentaero VTOL FW LTE

Daytona, FL Photo credit: Tanmay Naik of Censys Technologies

4. Overview of Analysis Method

4.1 Altitude

For statistical reporting, only those logs corresponding to aircraft altitude > 5m are considered in order to filter out ground-based logs. Total quantity of flight hours includes all logged time corresponding to records where barometric height is greater than 5m

4.2 Full Connectivity

In order to accurately represent the impact of the RF environment and cellular connection availability on the performance of the C2 link, the concept of full connectivity is separated into two metrics: C2 link connection and cellular network RF environment. A degradation of the cellular network RF environment is expected to cause a degradation in the C2 link connectivity statistics.

Percentage of time with a “full C2 link connection” is defined as the amount of time that the UA is connected to the cellular network for command and control as represented by successful heartbeat messages logged at the same frequency as modem parameters, divided by the total amount of time that the UA is in flight and using LTE for the C2 link. This metric excludes flights that were executed to

intentionally exercise areas of known communication holes (see Section 4.3 “Replicate Communication Holes”).

Percentage of time with a “full cellular network RF environment” is defined as the amount of time that the onboard UE reports sufficient RF parameters such as RSRP and RSRQ divided by the total amount of the time that the onboard UE reports RF parameters. This metric excludes flights that were executed to intentionally exercise areas of known communication holes (see Section 4.3 “Replicate Communication Holes”).

4.3 Replicate Communication Holes

Communication failures occur for various reasons. If communication issues are observed in any of the campaigns, flight routes are executed to fly through, above, below, and around those areas to attempt to replicate issues that were observed. This effort aims to help us understand the conditions where the command and control link might fail.

5. Operational Area and Environment

5.1 DOEFLT-125 Panama City Beach FL

Operation ID: DOEFLT-125
Operational area name: Panama City Beach
Environment: Urban
Total quantity of flight hours: 34.98 hours
Total quantity of flights: 62 flights
Average altitude (50th Percentile): 93m
Maximum altitude: 134
Operational Risk Assessment (ORA): Moderate
Objective: Baseline Mobile Field/Area Survey

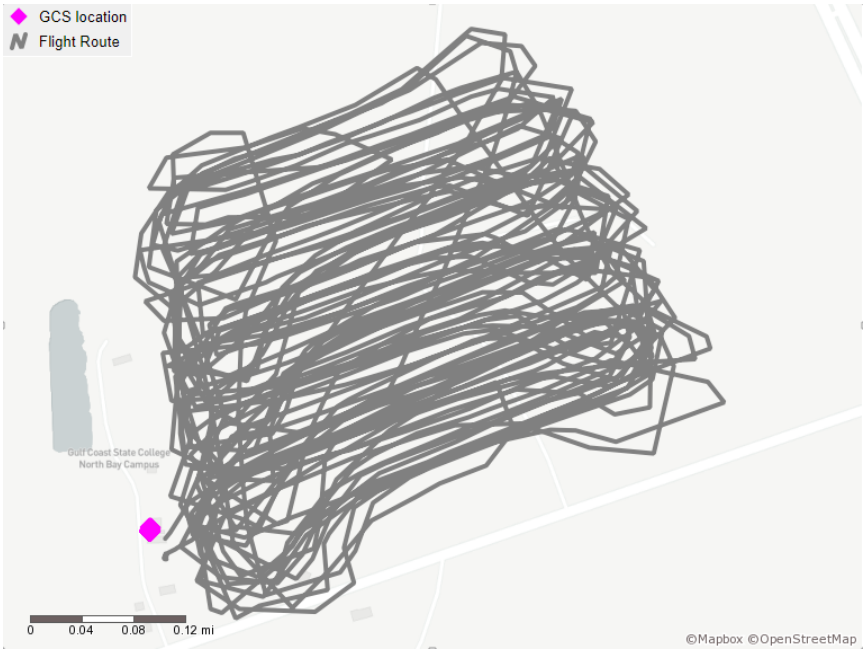


Figure 5.1.1 Flight route of single flight (CTC0421042_12_21_21-181728_Flight2_1000.3.csv)

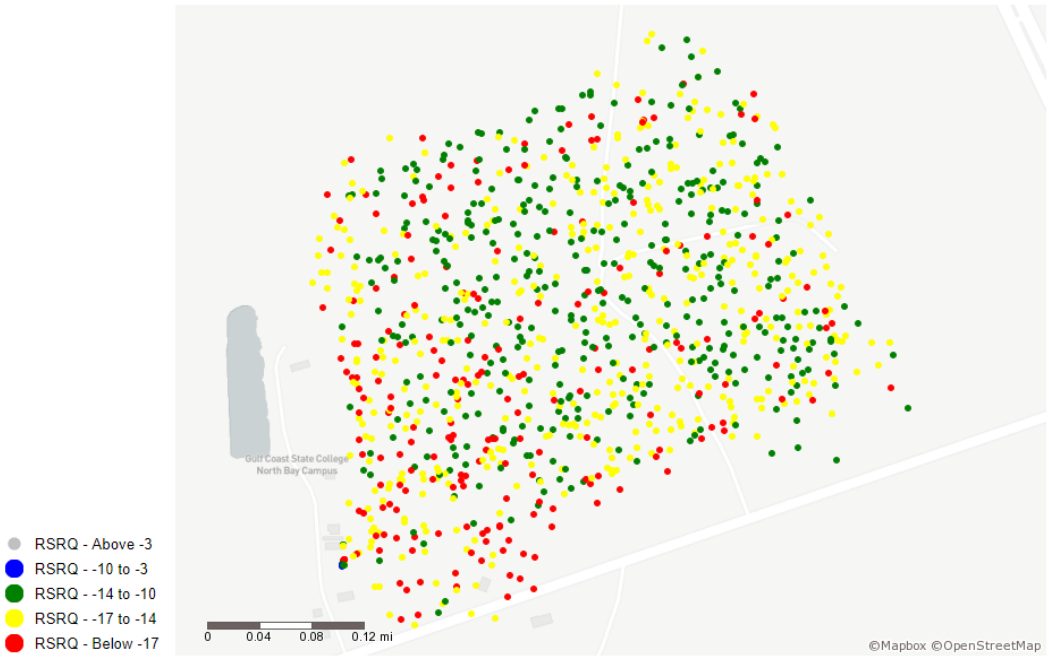


Figure 5.1.2 RSRQ plot for single flight

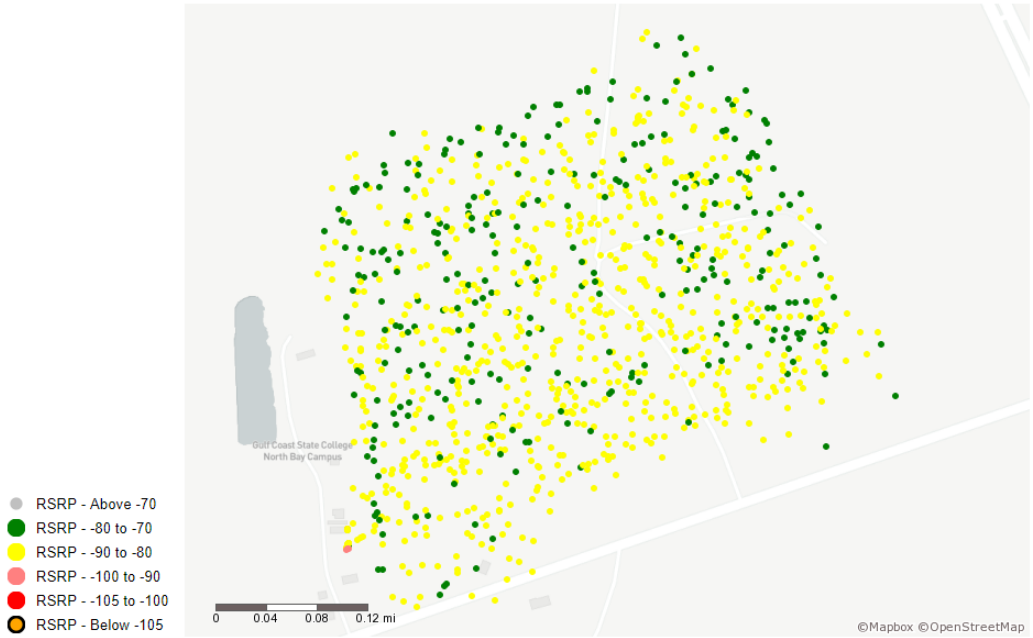


Figure 5.1.3 RSRP Plot Single flight

5.2 DOEFLT-126 Black Mountain

Operation ID: DOEFLT-126
Operational area name: Black Mountain CA
Environment: Urban
Total quantity of flight hours: 3.55 hours
Total quantity of flights: 6 (only 5 flights have complete data)
Multi-ops hours: All flights were multi ops.
Average altitude (50th percentile): 119m
Maximum altitude: 126m
Operational Risk Assessment (ORA): Moderate
Objective: Baseline Local Infrastructure inspection, long linear inspection, Survey

Figure 5.2.1 Flight Routes in Black Mountain (104112_combined_file_12162021102548_Flight1_1000.3.csv)

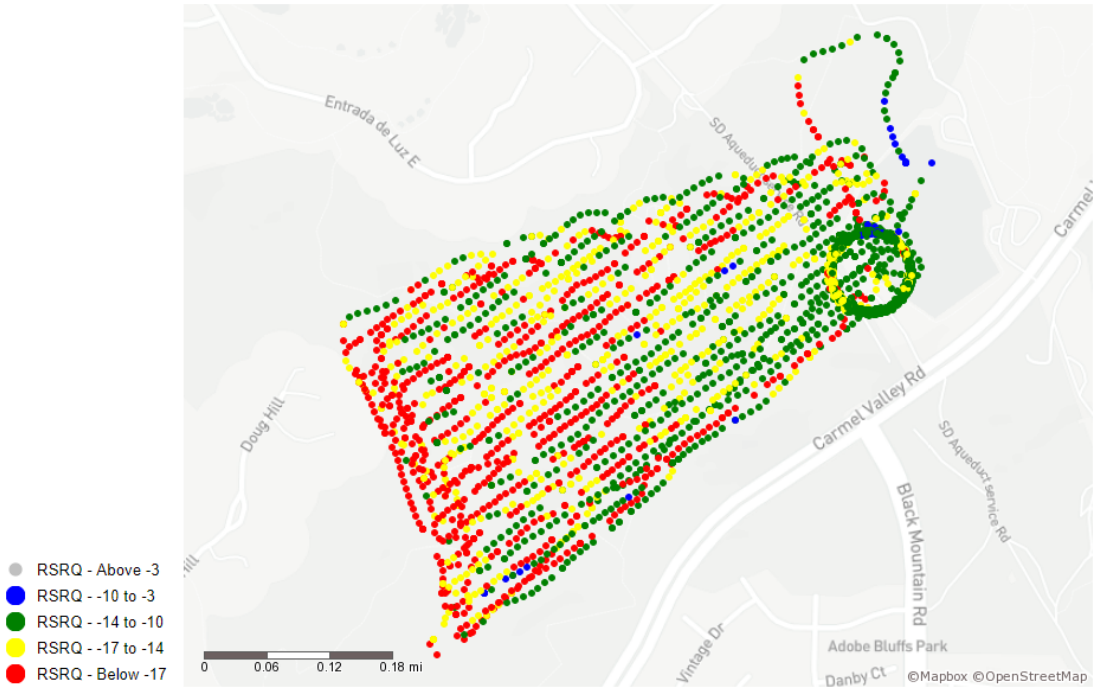


Figure 5.2.2 RSRQ plot single flight

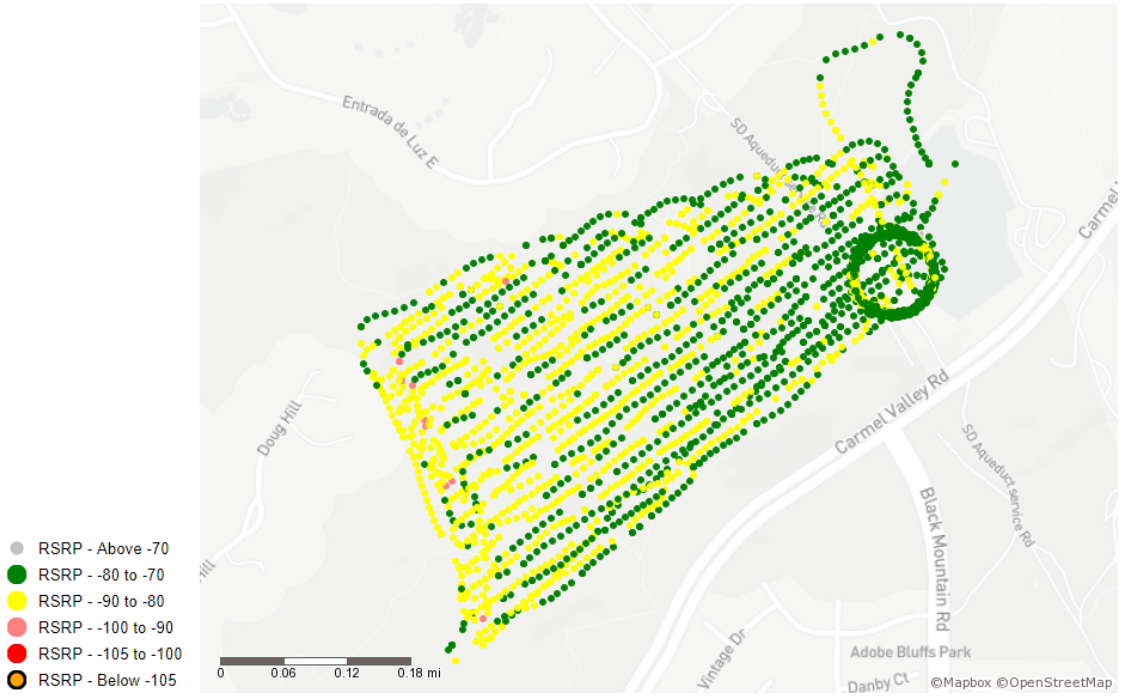


Figure 5.2.3 RSRP plot single flight

5.3 DOEFLT-133 Kansas City MO

Operation ID: DOEFLT-133
Operational area name:
Kansas City Softball field
Kansas City Rosedale park
Kansas City Smithville lake
Environment: Urban
Total quantity of flight hours: 126.88 hours
Total quantity of flights: 208
Average altitude (50th Percentile): 74m
Maximum altitude: 128m
Operational Risk Assessment (ORA): Low
Objective: Baseline Local Infrastructure inspection, long linear inspection

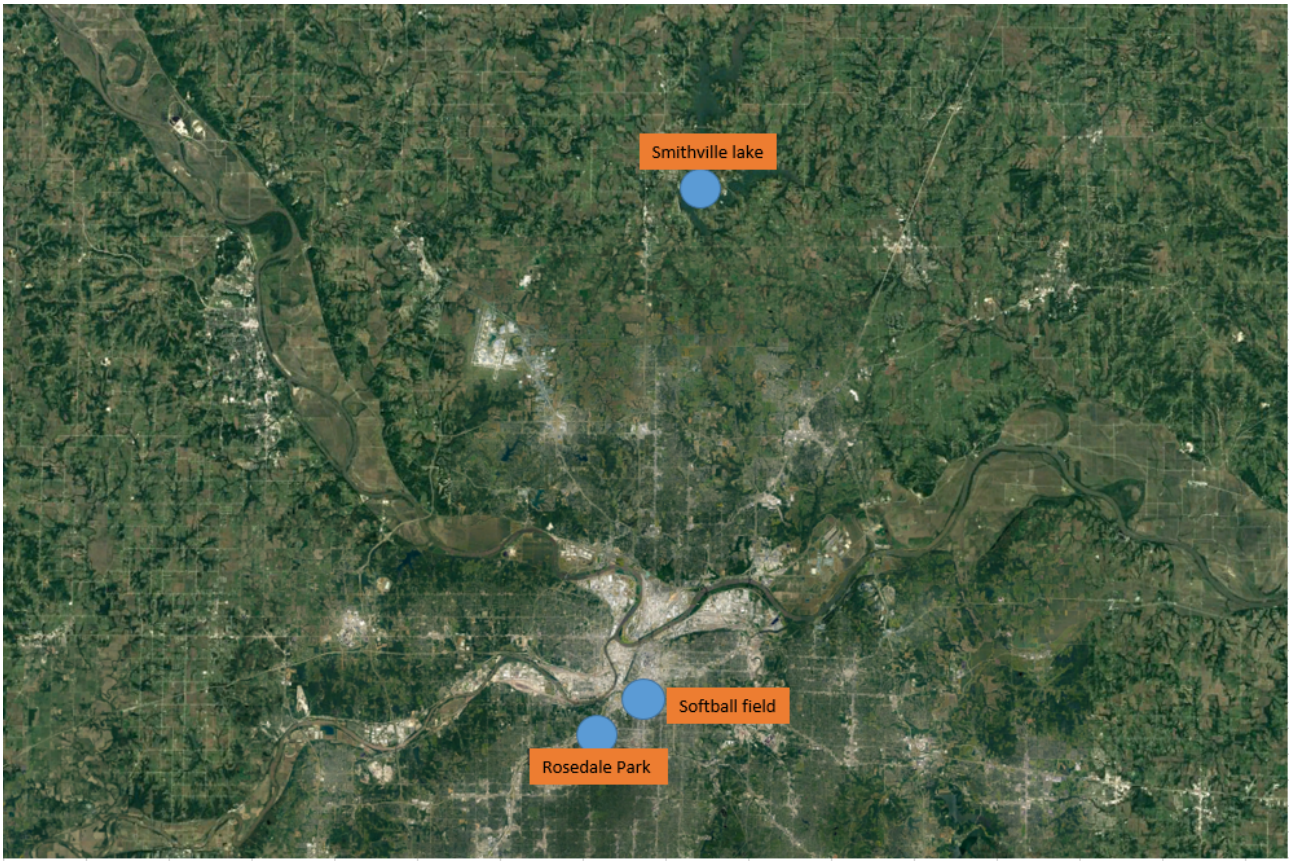


Figure 5.3.1 Various Flight Locations in Kansas City Campaign

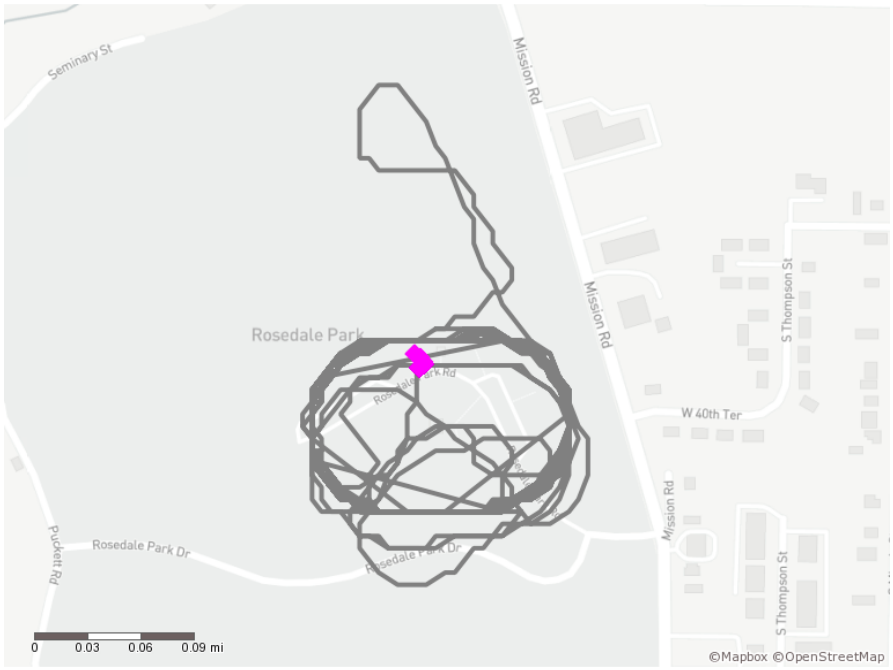


Figure 5.3.2 Rosedale Park flight route (single flight) with GCS location (pink diamond)

Figure 5.3.3 KC softball field flight route (single flight) with GCS location (pink diamond)

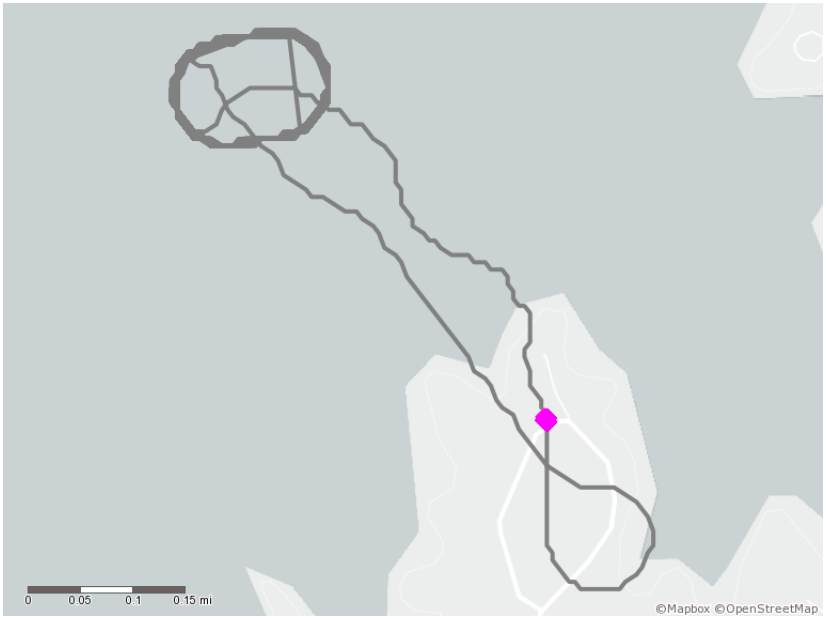


Figure 5.3.4 Smithville Lake flight route (single flight) with GCS location (pink diamond)

6. UAS Configuration and Architecture

6.1 Reporting and Polling Frequency

Average reporting frequency for the aircrafts flown is as follows:

Hitec Xeno Fx: 1 seconds
Delair UX11 Ag: 1 seconds
Censys Sentaero V2: 3.54 seconds

6.2 C2 Network Architecture

Round trip latency is measured (UA>Verizon Network [redacted] >CS>Verizon Network [redacted])>UA). Regardless of location of flight, all C2 data traffic is going through the Verizon core network site [redacted]

[redacted]

[redacted]

6.3 UAS Performance

Average Cruise Speed:

Hitec Xeno Fx: 11.51 m/s
Delair UX11 Ag: 14.46 m/s
Censys Sentaero V2: 16.08 m/s

7. Operational Environments

Environmental definitions come from the Census Bureau Urban and Rural classification. For more information please visit https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2000-urban-rural.html.

Percentage of time flown in the following classifications:
Urbanized Area: 100%
Urban Cluster: 0%
Rural: 0%

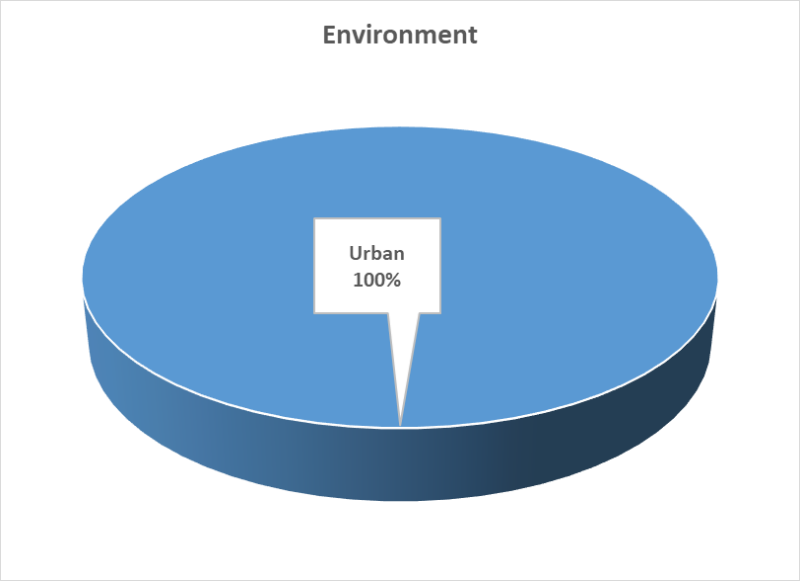


Figure 7.1 Environment Pie Chart

8. Cellular Metrics

8.1 Cellular Carriers and Bands

There were 3 bands utilized during the flight campaigns. Band 13 was utilized most often. The LTE link was used for C2 for 99.57% of the flight campaign. In a few instances the pilot switched to an unlicensed band (Wifi - ISM LOS) to assume control of the aircraft. Each aircraft used one SIM card provided by Verizon.

Band	Name	Bandwidth (MHz)	Mode	Downlink Frequency (MHz)		
				Low	Middle	High
2	1900 PCS	60	FDD	1930	1960	1990
4	AWS-1	45	FDD	2110	2132.5	2155
13	700 c	10	FDD	746	751	756

Table 8.1.1 Band and Frequency

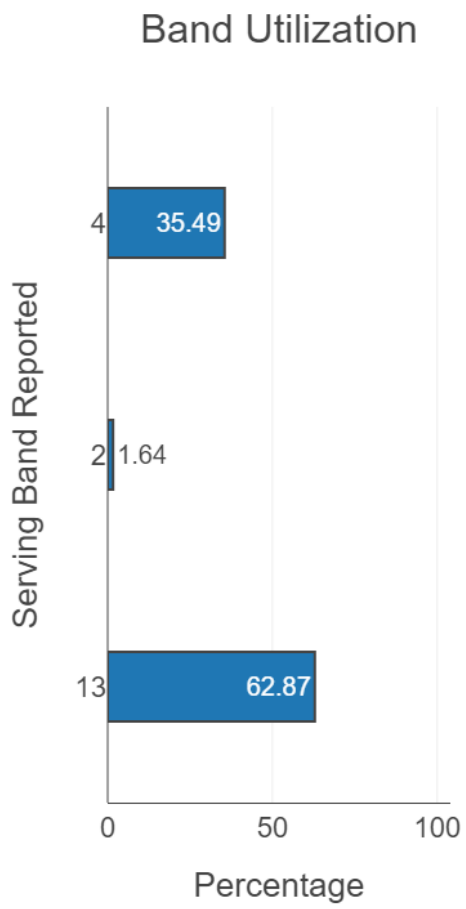


Figure 8.1.1 Band Utilization Chart

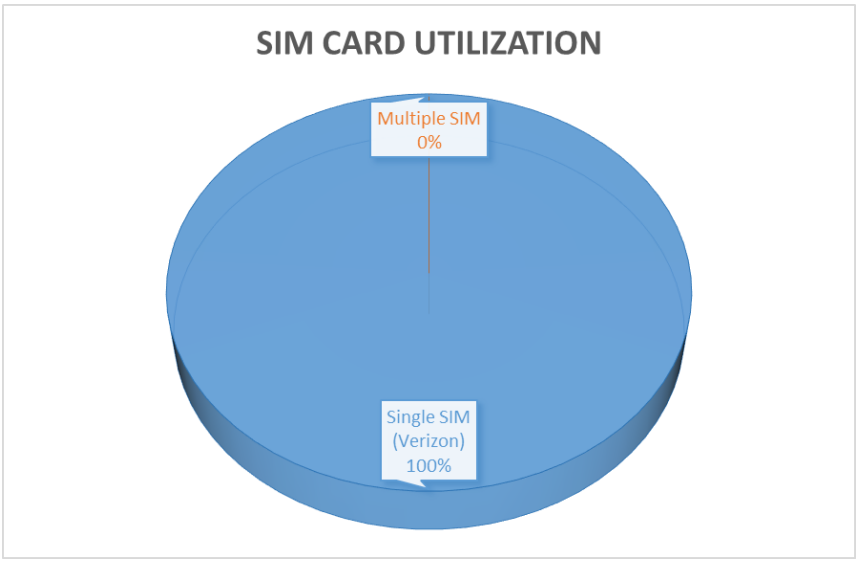


Figure 8.1.2 SIM Card Utilization Chart

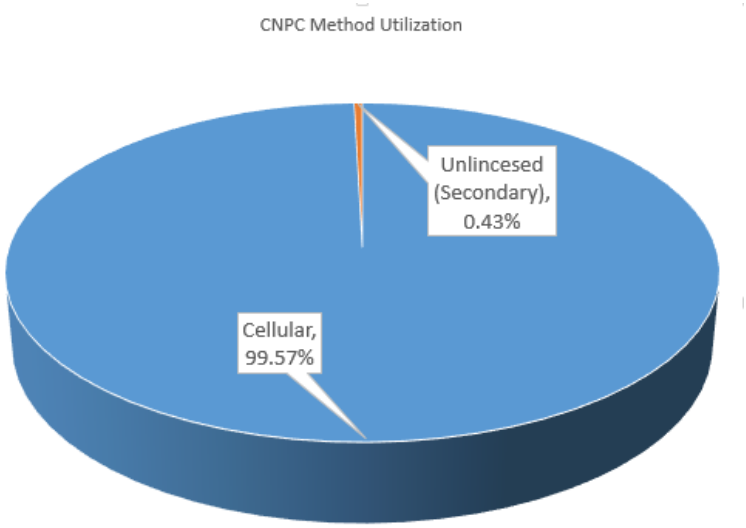


Figure 8.1.3 CNPC Method Utilization

8.2 Altitude

Altitude reporting mechanism: Barometric altitude. Calibrated at the takeoff location.
Average altitude: 77m

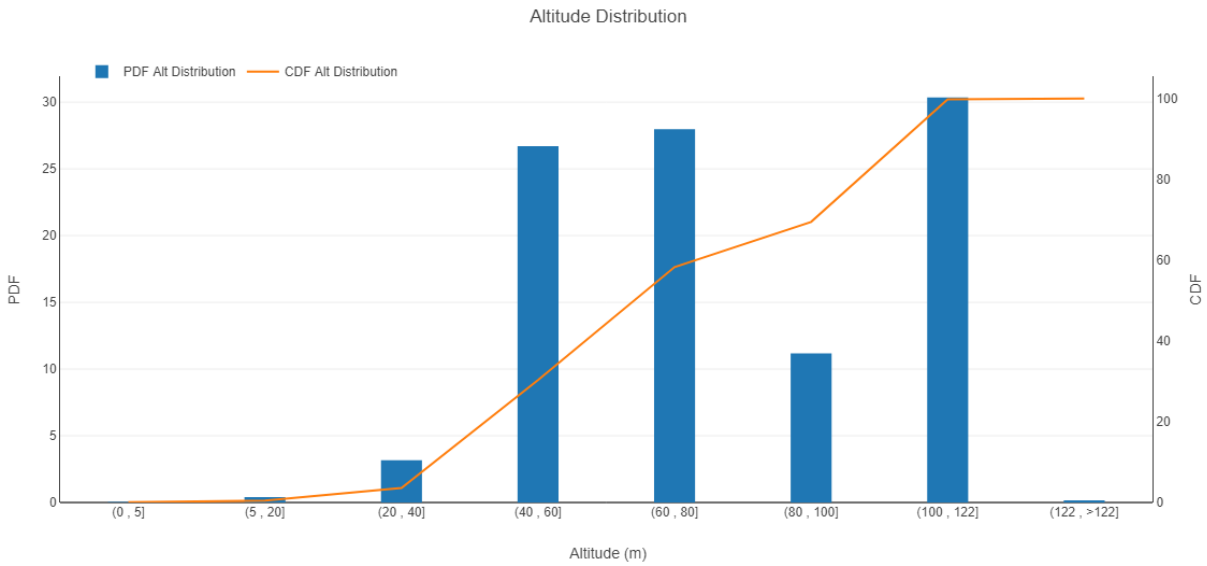


Figure 8.2.1 Operational Altitude Distribution Chart

Metric	Altitude (m)

5th Percentile	42
50th percentile	77
99th Percentile	120
Max	134* (All flights calibrated at take off location> 0.17%)

Table 8.2.2 Operational Altitude Distribution Table

8.3 Distance

The “distance between the CS and UA” is defined as the calculated linear distance. This parameter is commonly of interest when analyzing UAS data due to the use of line of sight radios connecting the CS and UA. In this case the UA is connected to the CS via the cellular network, therefore the “distance between the CS and UA” does not depict the traveled distance of the communication link. See Section 6.2 for a description of the network architecture and the traveled distance of the communication link.

Average distance between UA and CS (50th percentile): 230m
Maximum distance between UA and CS: 1,255m
The CS was stationary at all times and the take-off and landing location is in close proximity to the CS.

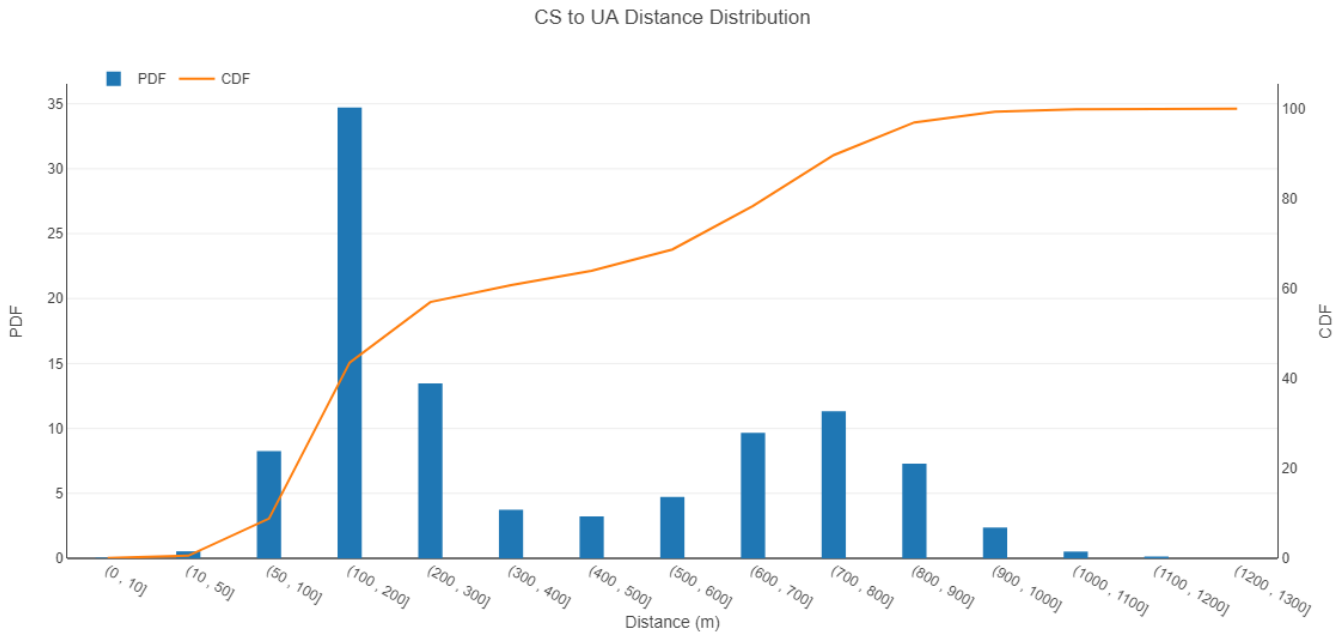


Figure 8.3.1 CS to UA Distance Distribution Graph

Metric	Altitude (m)
5th Percentile	82

50th percentile	230
95th Percentile	865
Max	1,225

Table 8.3.1 CS to UA Distance Table

8.4 Control Mode

Control modes reported as Loiter, Hold, Goto, and Auto are classified as automatic control modes. However, their usage is shown individually in the figure below.

Percentage of time in automatic control mode (barometric altitude > 5m): 94.27%

During the remaining 2.4% of flight time the UA was in a combination of semi-manual and other modes. (https://ardupilot.org/plane/docs/quadplane-flight-modes.html)

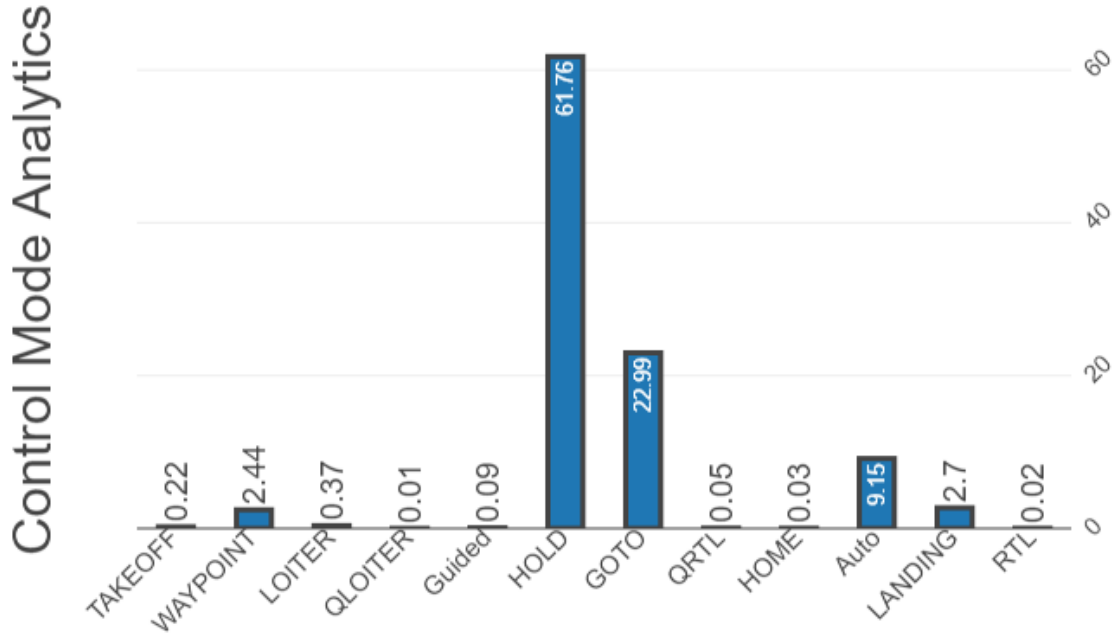


Figure 8.4.1 UA Control Mode Graph

8.5 Latency

Latency 99 percentile: 1,946ms
Latency 95 percentile: 638ms
Maximum latency: 19,978ms

Round trip latency is measured (UA>Verizon Network [redacted]
>CS>Verizon Network ([redacted])>UA). Regardless of location of

flight, all C2 data traffic is going through the Verizon core network site [redacted]

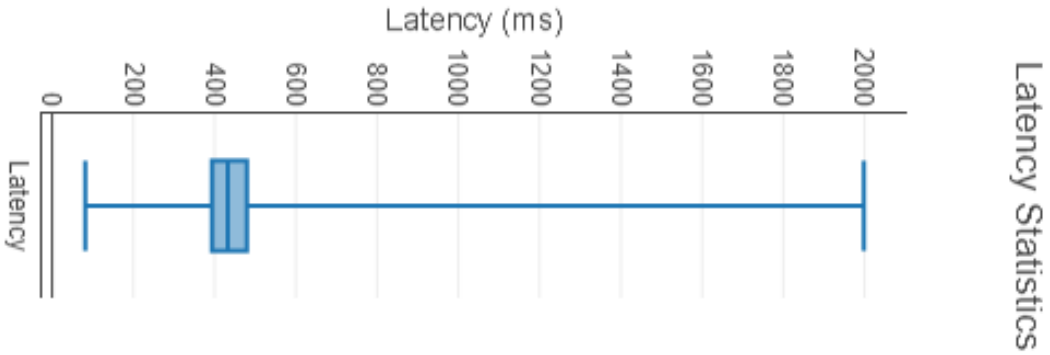


Figure 8.5.1 Latency Graph

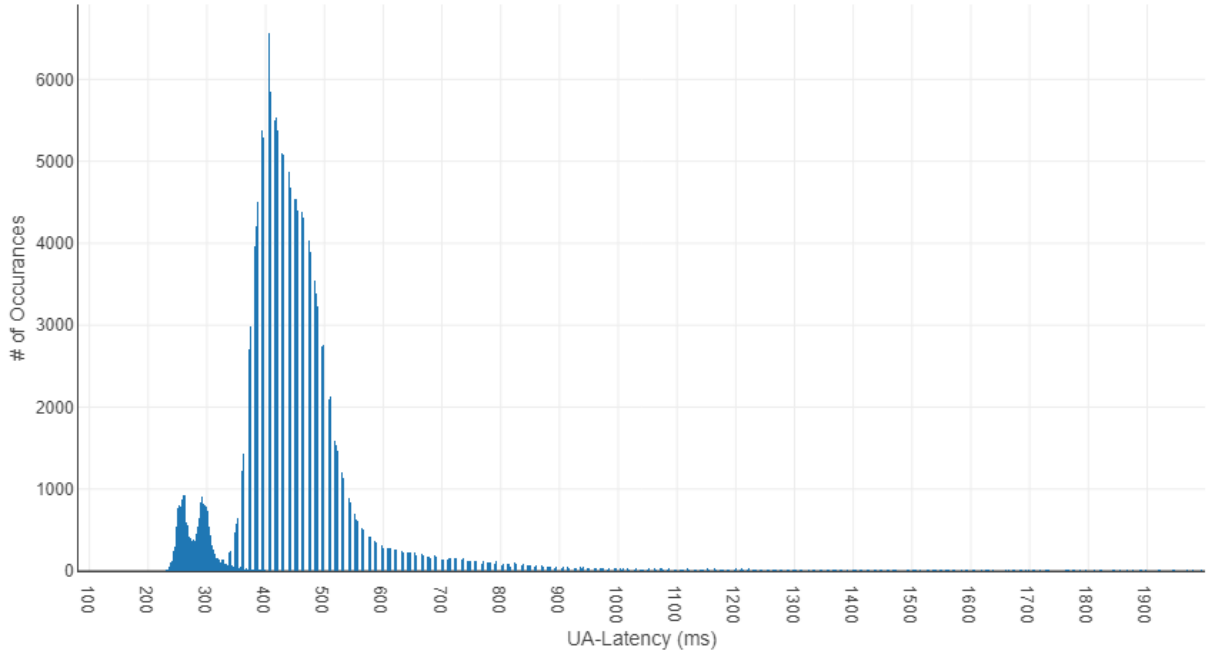


Figure 8.5.2 Latency distribution

Metric	Latency (ms)
5th Percentile	277
50th percentile	432
95th Percentile	670
99th Percentile	1,962

Max	19,978

Table 8.5.1 Latency Table

Aircraft (Autopilot)	Lost link trigger setup timer
Censys Sentaero (Pixhawk)	10s
Hitec Xeno Fx (Cube Black on custom carrier board)	10s
Delair UX11 Ag (Proprietary Autopilot)	10s

Table 8.5.2 Lost Link Declaration Duration

8.6 Signal Parameters

Minimum RSRP: –109dBm
Minimum RSRQ: -20dB

RSRP and RSRQ charts are not separated per band.

RSRP value reporting range is defined from -140 dBm to -44 dBm with 1 dB resolution per 3GPP standards. For more information please see section 9.1.4 RSRP measurement report mapping at this link: https://www.etsi.org/deliver/etsi_ts/136100_136199/136133/08.15.00_60/ts_136133v 081500p.pdf

RSRQ value reporting range is defined from -19.5 dB to -3 with 0.5 dB resolution per 3GPP standards. For more information please see section 9.1.7 RSRQ measurement report mapping at this link: https://www.etsi.org/deliver/etsi_ts/136100_136199/136133/08.15.00_60/ts_136133v 081500p.pdf

SINR and SNR are not standardized 3GPP parameters and measurement and logging can vary from OEM to OEM. In order to accurately present a comparison of different UAS configurations, SINR and SNR are not analyzed.

In all campaigns in this report, SINR or SNR was recorded but not analyzed.

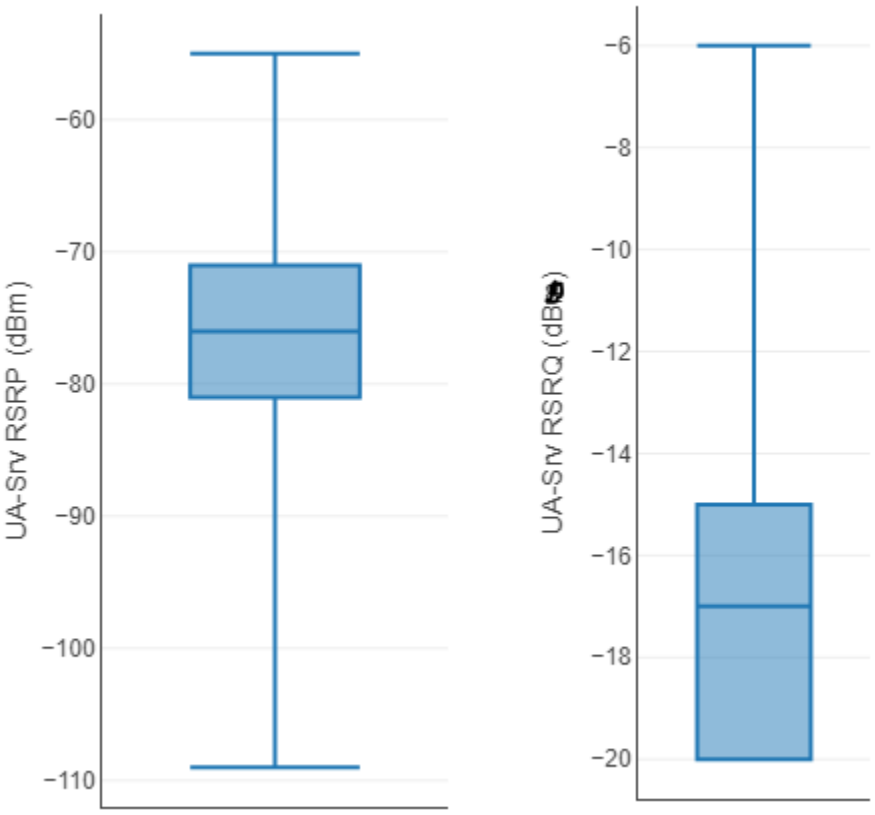


Figure 8.6.1 RSRP & RSRQ Box and Whisker plots

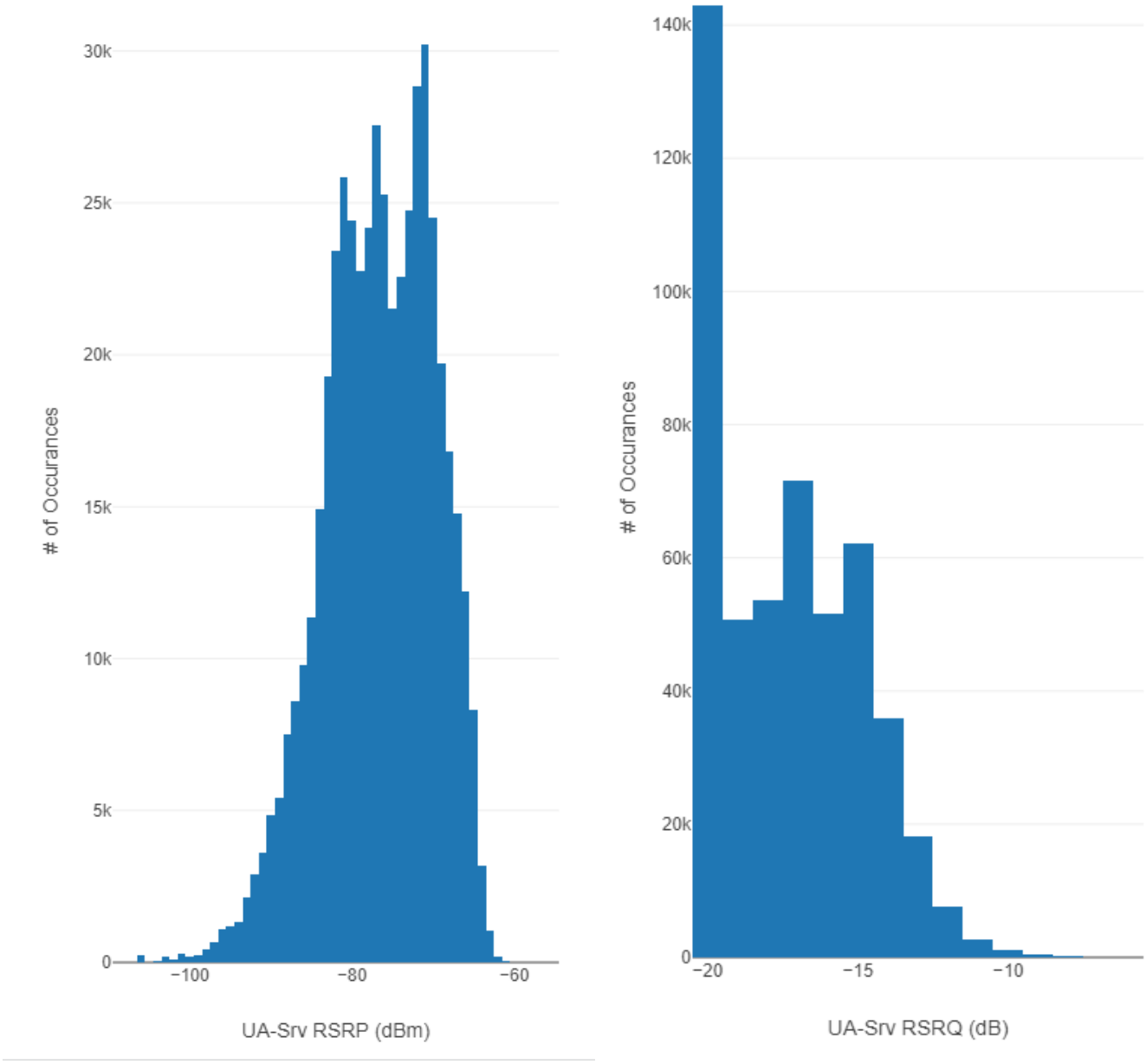


Figure 8.6.2 RSRP (left) & RSRQ (right) distribution

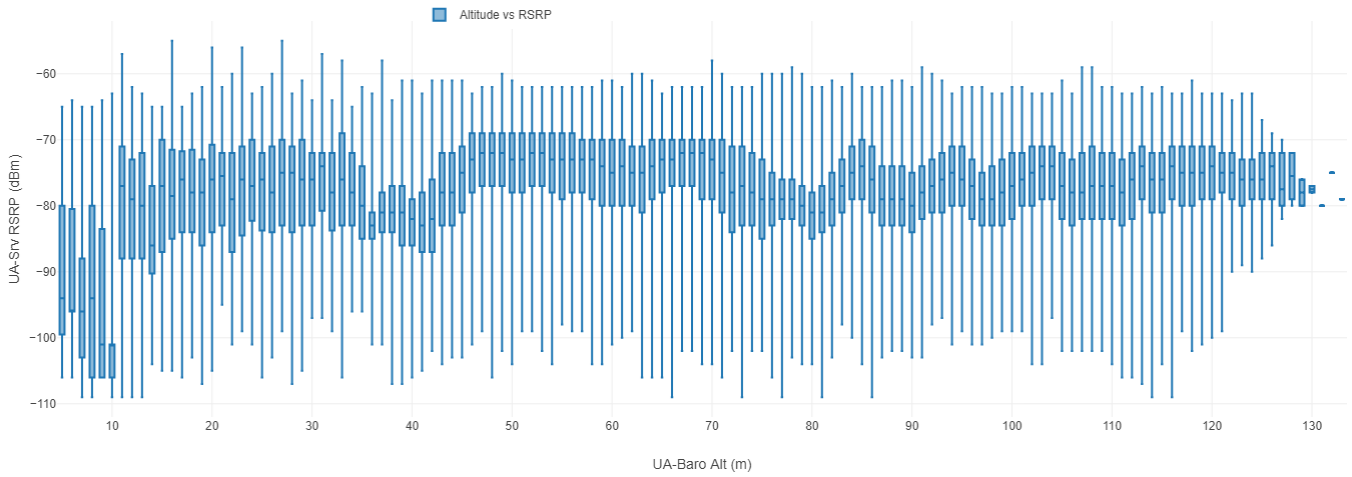


Figure 8.6.3 RSRP vs Altitude

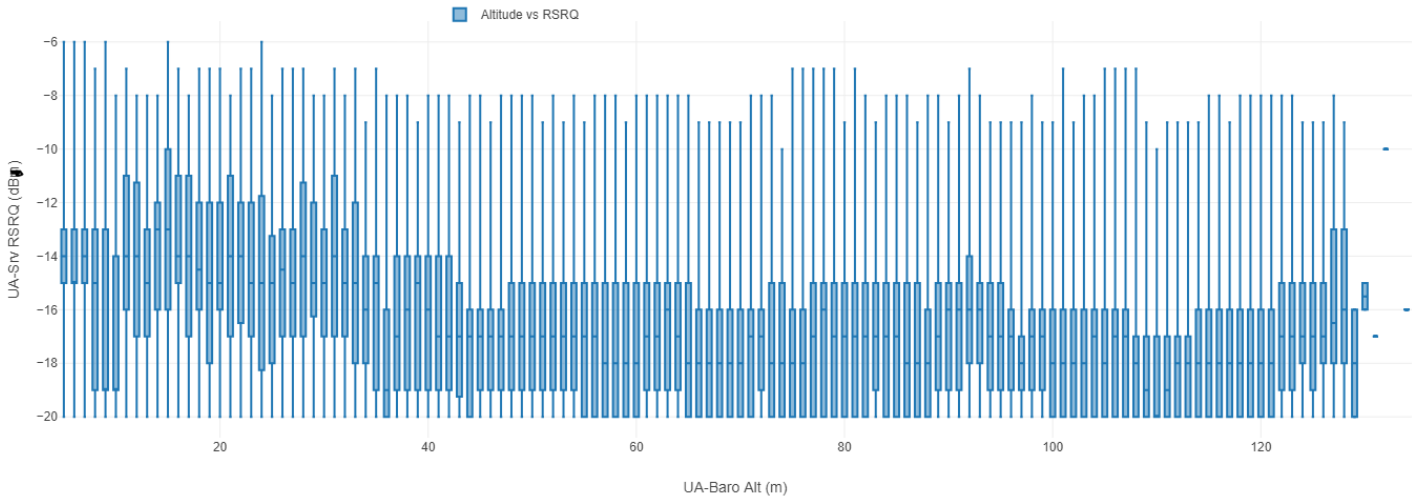


Figure 8.6.4 RSRQ vs Altitude

Metric	RSRP (dBm)	RSRQ (dB)
MIN	-109	-20
5th percentile	-88	-20
50th percentile	-76	–17
95th percentile	–66	–13
99th percentile	-65	–12

Table 8.6.1 RSRP & RSRQ Table

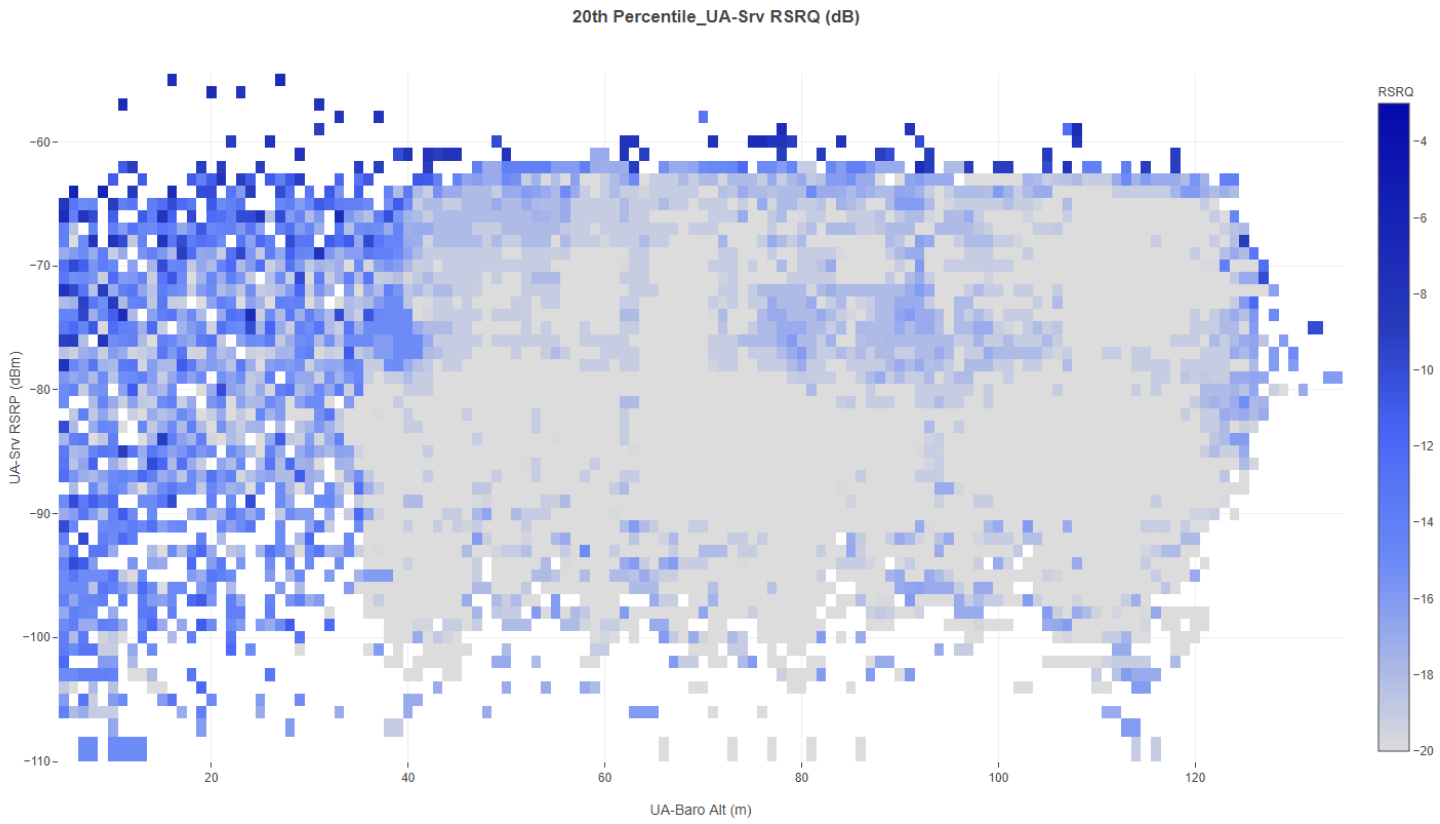


Figure 8.6.5 Relationship between RSRP, Altitude and RSRQ

Based on Figure 8.6.5, it can be observed that as we fly at higher altitudes and if the UA encounters weaker RSRP (less than -80dBm or so), there is a 20% chance that the value of RSRQ is less than -18dB or so.

8.7 Cellular Network Handovers

Quantity of observed handovers: 64,291
Total quantity of flight hours: 165.42 hours
Average cruise speed: 14 m/s

In cellular network systems a handover is defined as the process of transferring a data session from one cell to another cell. Handover logic may consider signal strength, channel utilization, channel capacity, cell density and other parameters when determining which channel to transfer the session to. The objective of the handover logic is to prevent interruptions to the session that could result in a dropped call or termination of the connection.

A cellular site may have multiple different cells with different bands and frequencies representing different sectors of the cell site. Due to the complex nature of handover

trigger settings and cell selection algorithms, as well as the varying cell site design possibilities, a comparison of the quantity of handovers per mile of flight between different locations or UAS would not be a valid comparison. While handover failures may occur due to signal interference, cell availability and other causes, the UE is unable to record instances of unsuccessful handover attempts due to limitations of device logging capabilities.

8.8 Interference

There were about 6 hours of multi-UAS operations in the Black Mountain area under campaign DOEFLT-131, along with single UA operations in various locations. Local Verizon Network Performance team members were notified of flight operations prior to and during the flight campaigns referenced in this report. The Network team members were instructed to provide reporting on any observed abnormalities, such as interference KPI's, in the area of flight operations.

Additionally, 15min interval network data was analyzed for the serving and neighboring nodes/cells reported by UA. There was not any abnormal interference KPI's observed.

There were no reports of such abnormalities presented during the flight campaigns referenced in this report.

The frequency bands used during these campaigns do not include bands with aeronautical restrictions. There were no RPIC reports of interruptions to the C2 link caused by interference.

9. Anomalies and Accidents

9.1 UX11 Flyaway

9.1.1 Event

On 12/31/2021 at approximately 9:42am on flight #2 with the UX11 UX11RGB-FA3H34R4K4-"VZ1", the CS experienced a complete loss of C2 link. The RPIC received an alarm 4 VZ++ alert with the UA directly above the RPIC at 160ft AGL. The UA proceeded to fly away from the CS as well as the landing zone. Multiple unsuccessful attempts were made by switching the control link from cellular to wifi and vice versa while the UA continued to fly beyond where the RPIC could visually observe the UA.

Chronology of Events / Timeline

- 12-31-2021 09:42 – First alert of the Alarm 4 VZ++
- 12-31-2021 09:55 - The CS was showing the UA was still moving away at roughly 1.7mph and the UA was reporting at -47ft AGL
- 12-31-2021 10:00 - We proceeded to search for the UA.
- 12-31-2021 10:15 - We decided to search closer to the takeoff area as it did not seem accurate with the readings the CS was showing.

• 12-31-2021 10:25- We found the UA in a wooded area about a ¼ to ½ mile away from the CS

9.1.2 Findings and Root Cause:

The cause of the disconnect is unknown as all parameters shown were in safe levels. According to the Delair user manual, alarm 4 shows that it aborts its uploaded flight plan and proceeds to land on the ground as a stall fail-safe procedure and does not initiate an RTL.

- The CS had a complete loss of link. RPIC received an alarm 4 VZ++ alert
- The UA was directly above the RPIC at 160ft at the time of the incident
- The RPIC maintained visually observed of the UA until they could no longer visually see the UA
- The RPIC attempted multiple times to regain a connection to the UA by swapping to Wi-Fi and back to 3G.
- The Battery levels were in safe levels at the time of the incident
- The GNSS satellites were found to be within safe levels

9.1.3 Corrective Action and Recommendations:

The root cause of the behavior is unknown at this time. Skyward is working closely with UA OEM Delair to retrieve the necessary device logs to share with the OEM for further investigation.

9.2 Censys Incident

9.2.1 Event

On Jan 10, 2022, Skyward was notified of an incident involving the Censys UA. Conrad H. Wright from Censys indicated that the UA is non-recoverable.

9.2.2 Finding and Root Cause:

Censys was later contacted to share the incident report with us. Censys send us the following information:

On Jan 12 2022, Conrad responded with the following message:

> "*The full incident report is still being finalized, however we have completed our initial incident review and analysis. We have determined it was a part fatigue failure in the tail assemblage of the aircraft, and as such we are going to be replacing the tail assembly of the backup aircraft before we resume operations ….*"

When followed up again on Feb 2nd 2022, Conrad responded with the following message:

> "*While we are confident in the component that caused the failure (part fatigue in a tail control linkage, due to a nose heavy CG) we are still working to finalize the precise root cause. As such our full incident report has been delayed until that can be finalized. I can confirm however that the issue was unrelated to the LTE network or the control link through the LTE network*."

9.2.3 Corrective Action and Recommendation:

We are not aware of the final investigative report status as of Feb 13 2022. We will be following up with the OEM to understand the root cause of the problem and report it when available. However, it is to be noted that the root cause is not related to the LTE network.

9.3 RTL Analysis

There were 13 instances of invocation of “Return to Land (RTL)” behavior in 13 of the flights out of 244 flights that have data in this reporting period. After an RTL event, if the communication link is regained and the pilot has determined it is safe to proceed with the mission, the pilot is requested to continue the mission without landing. This is represented in the log files that were analyzed by the presence of continued flight operation after RTL invocation.

Additionally, some flight routes were executed that intentionally exercised the areas where RTL was observed in order to gather more information and understand behavior. Pilots were instructed to associate these experimental flights with a unique objective id provided to them by skyward.

9.3.1 DOEFLT-125 Panama City Beach RTL Root Cause Analysis

There were a total of 6 RTL events that were verified to have occurred in Panama City Beach based on the log files. There were 7 additional instances of RTL reported on the post flight report, however, log file analysis of these 7 flights does not show reports of RTL to confirm the pilots’ observation. A detailed analysis of the potential cause of RTL’s in the area that occurred during the Jan 2022 reporting cycle and was presented in the January 2022 report. Flight operations have continued in the same area and it was observed that these additional RTL have similar signatures to the reports in the January 2022 report, i.e. a combination of poor RF in the area, and RPY changes during a change in heading. However some of the RTL events cannot be explained given the granularity of data produced. One of the unexplained scenarios occurred during flight 2 on 12/07/2021.

Flight 2 on 12/07: RTL was observed at approximately 214819 and heartbeat loss was reported around 214808. Based on the time delta it can be observed that the RTL triggered after 10s of heartbeat loss as planned. However, no RF degradation was observed during this time period. PCI 195 was reported as serving before RTL, during QRTL and until the UA landed. Figure 9.3.1.1 is produced for this event.

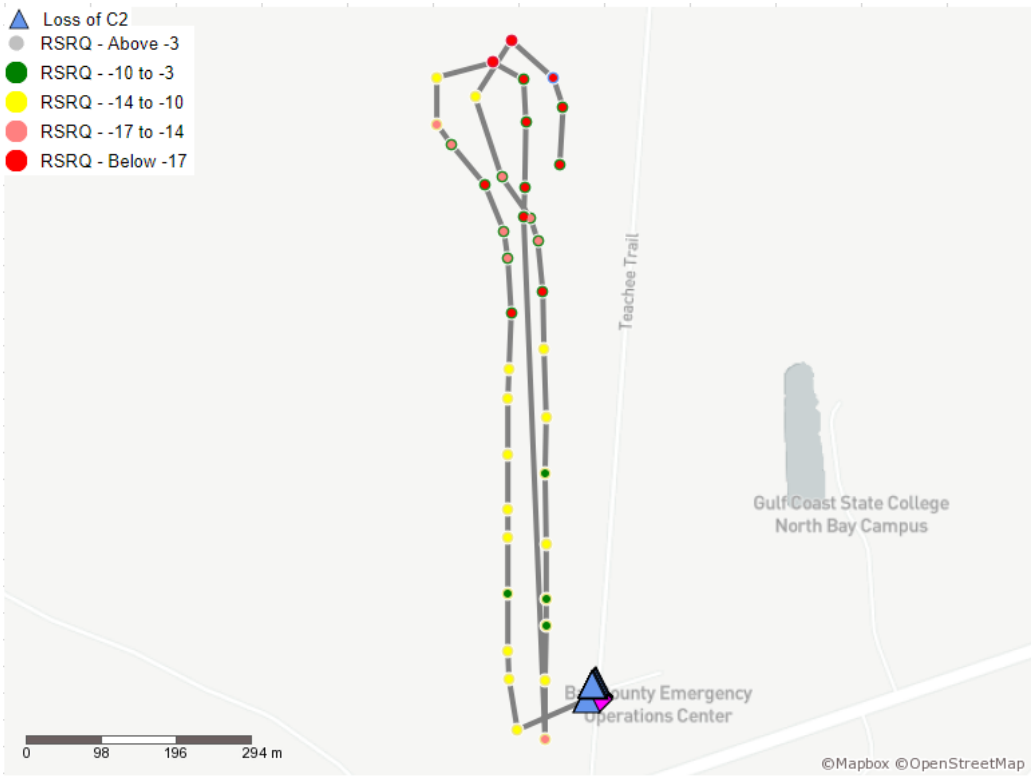


Figure 9.3.1.1 Panama City Beach RTL events (File: CTC0421042_12_07_21-214641_Flight2_2000.1)

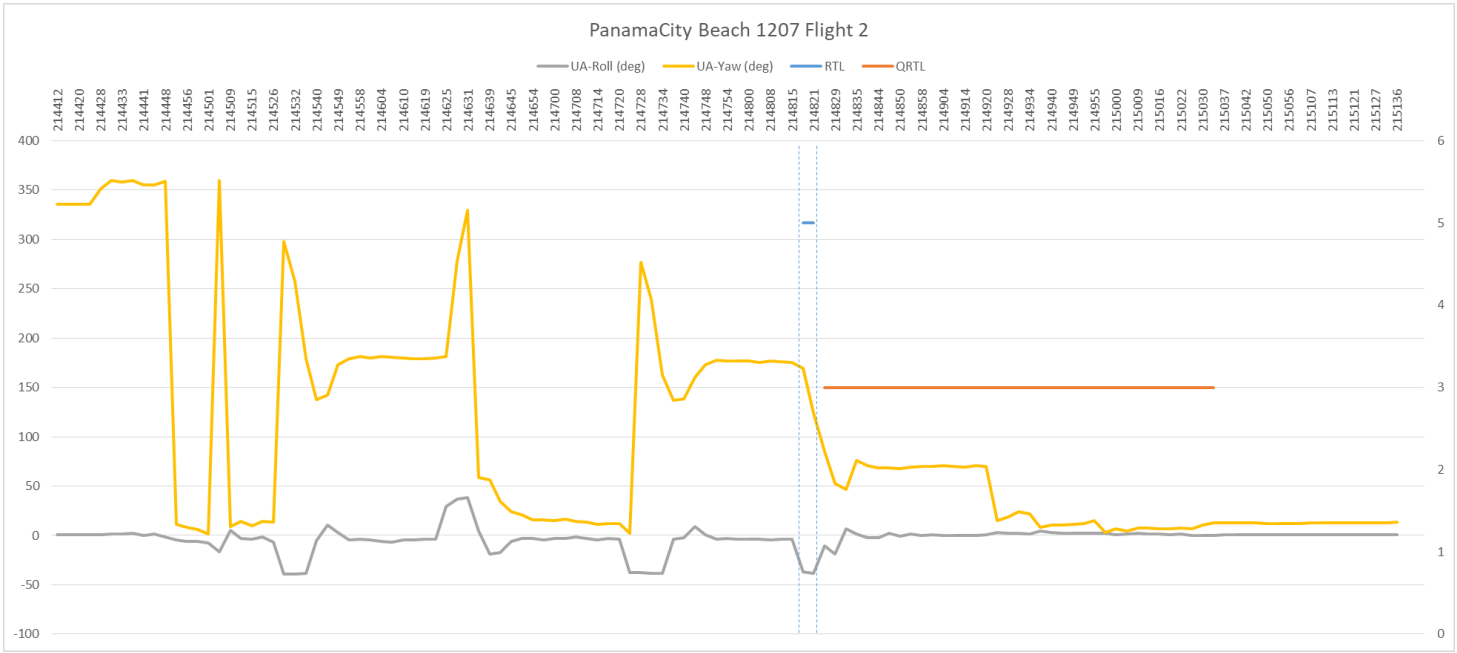


Figure 9.3.1.2 Panama City Beach- Aircraft Yaw, Roll vs RTL

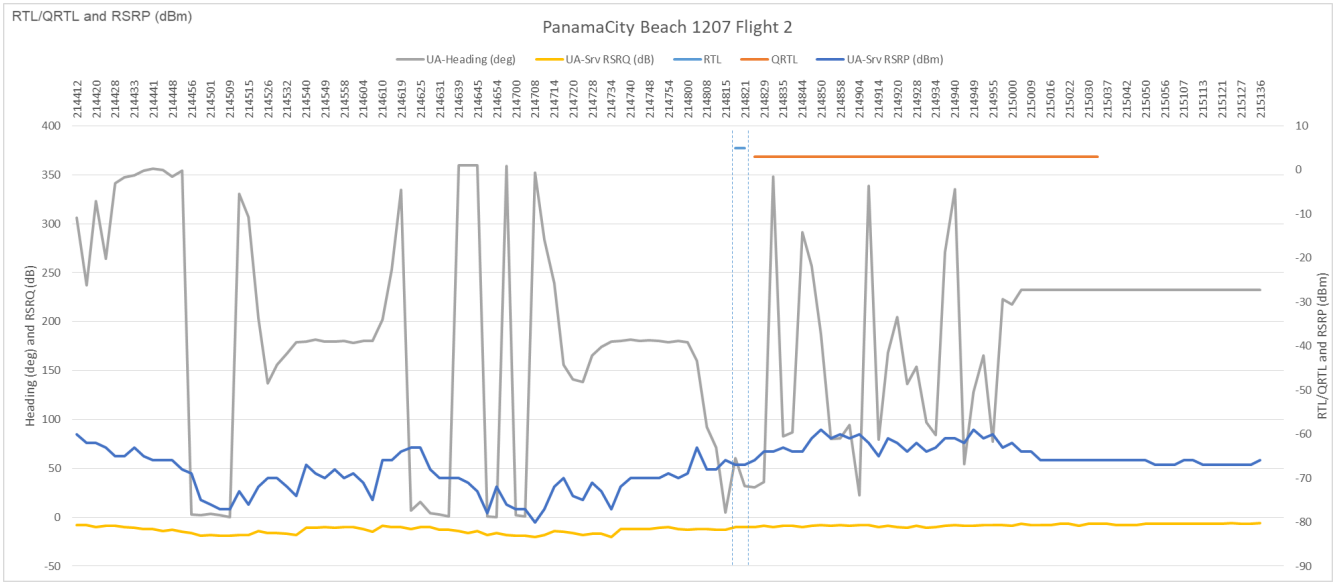


Figure 9.3.1.3 Panama City Beach RF conditions, UA Heading and RTL indication

9.3.2 DOEFLT-126 Black Mountain RTL Root Cause Analysis

A total of 1 RTL event was reported during the Black Mountain campaign on 12/16/2021. The investigation performed by the Flight Service Provider (FSP) found that the cause of RTL was that the GCS battery had run out. Stephen W. from OEM notes:

> *"we discovered that the true cause of the GCS failsafe was that the battery in the radio had ran out of power. The flight team neglected to check the battery indicator lights during operations and the sudden disconnect was caused by the battery management system (BMS) turning off the system to protect the battery."*

9.3.3 DOEFLT-133 Kansas City RTL Root Cause Analysis

Three different areas were flown in Kansas city: KC Softball field, KC Rosedale park and Smithville lake.

9.3.3.1 KC Softball field

This was the FSP's first time flying the UX11 aircraft. Issues with logging and reporting were encountered in initial states of this campaign. Out of the 24 flights that were flown in the softball field, only 12 included properly logged data. There were also 12 reports of RTL in the area but unfortunately they could not be analyzed and verified due to the absence of data. Only 4 logs corresponding to RTL were able to be analyzed.

12/14/2021 Flight 1: There was one occurrence of RTL reported in this flight. Based on the observed number of cells serving (Figure 9.3.3.1.3 PCI plot with RTL events) UA in the area, it can be noted that the area lacked RF dominance at the altitude where the UA was flying. Furthermore it can also be observed that there was frequent change in band and PCI throughout the flight (Figure 9.3.3.1.4 PCI and Band plot along with Loss of C2 indication). It can also be noted that the RSRQ in the area is poor (Figure 9.3.3.1.1 RSRQ plot with RTL events). However, RSRP does not show a large degradation preceding the loss of C2 event (Figure 9.3.3.1.2 RSRP plot with RTL events).

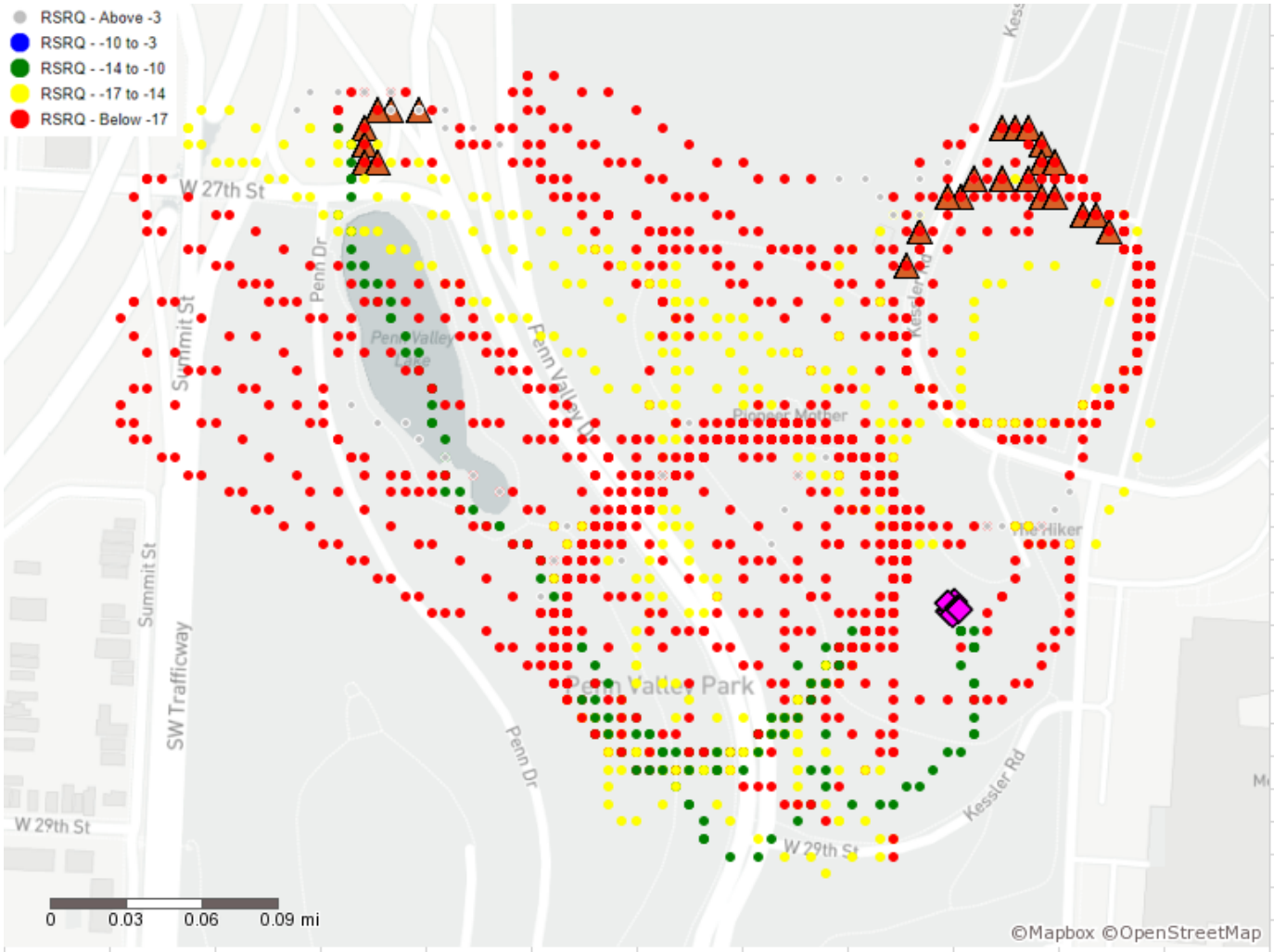


Figure 9.3.3.1.1 RSRQ plot with RTL events

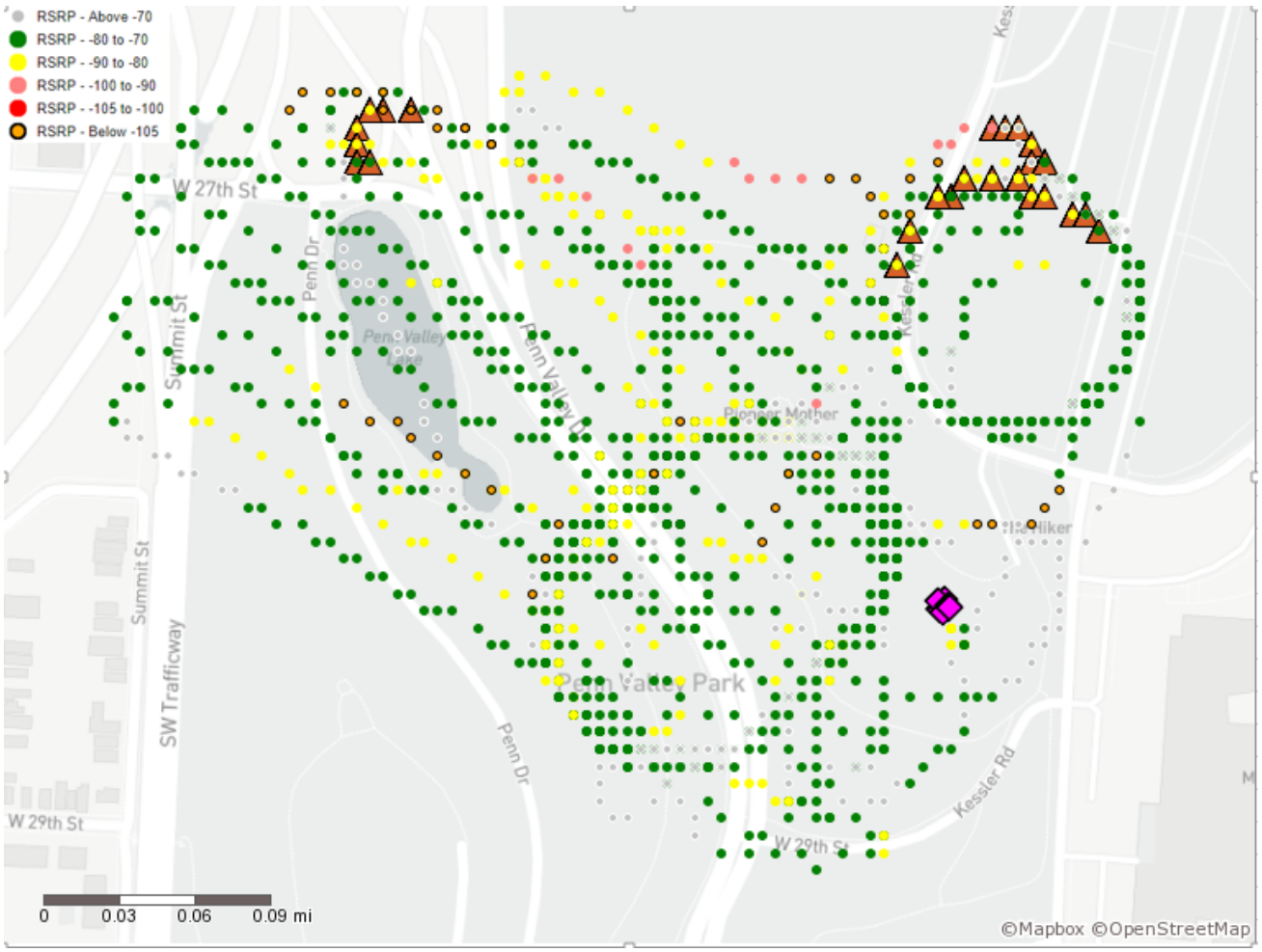


Figure 9.3.3.1.2 RSRP plot with RTL events

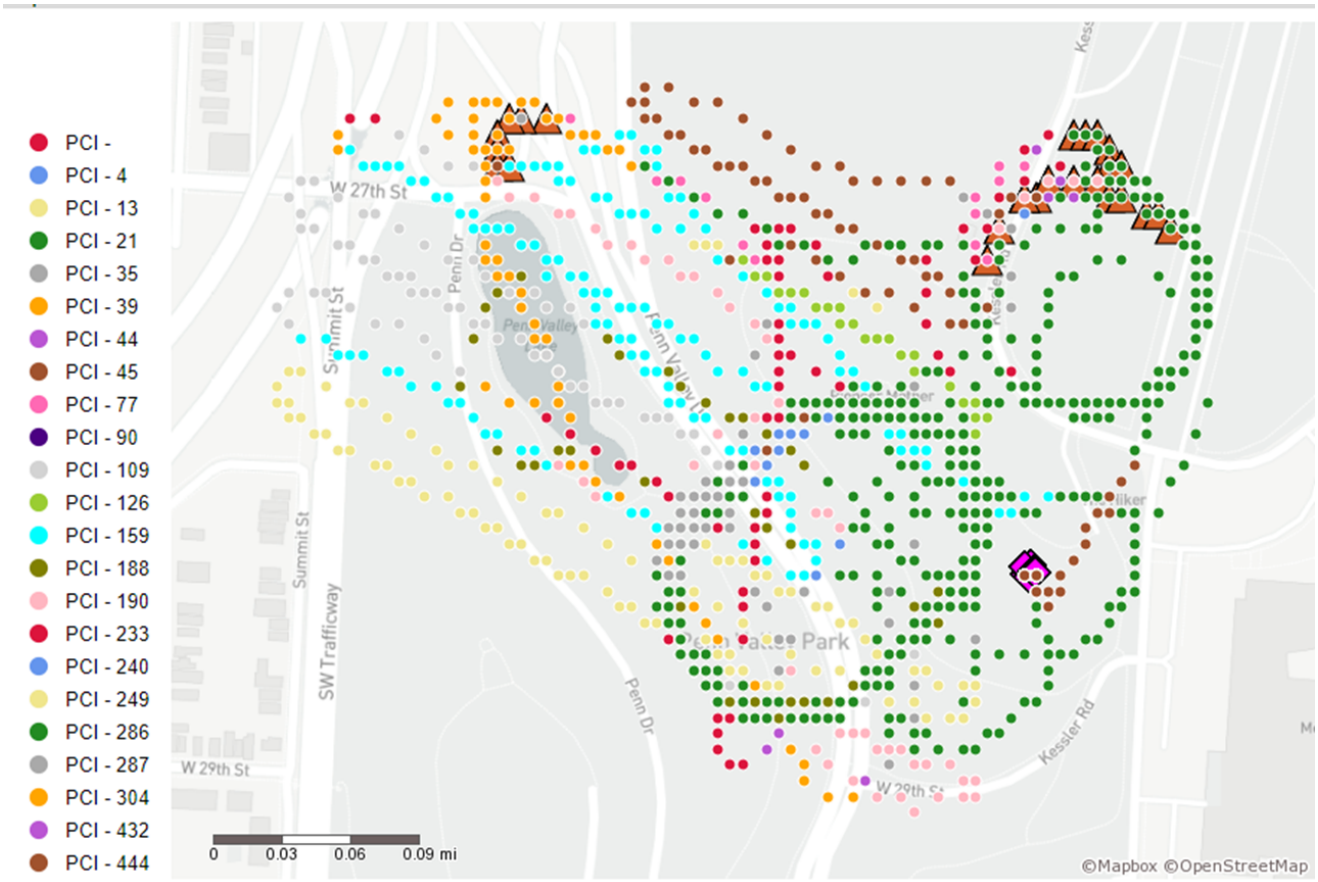


Figure 9.3.3.1.3 PCI plot with RTL events

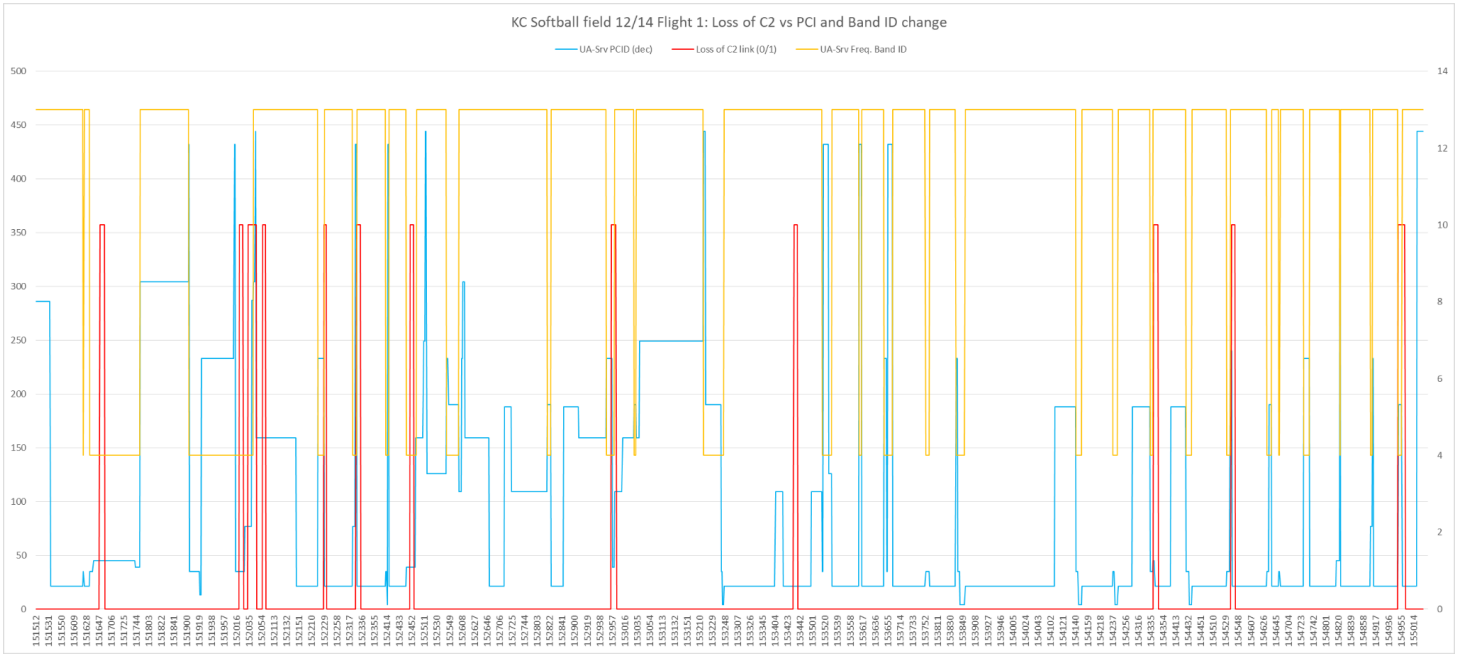


Figure 9.3.3.1.4 PCI and Band plot along with Loss of C2 indication

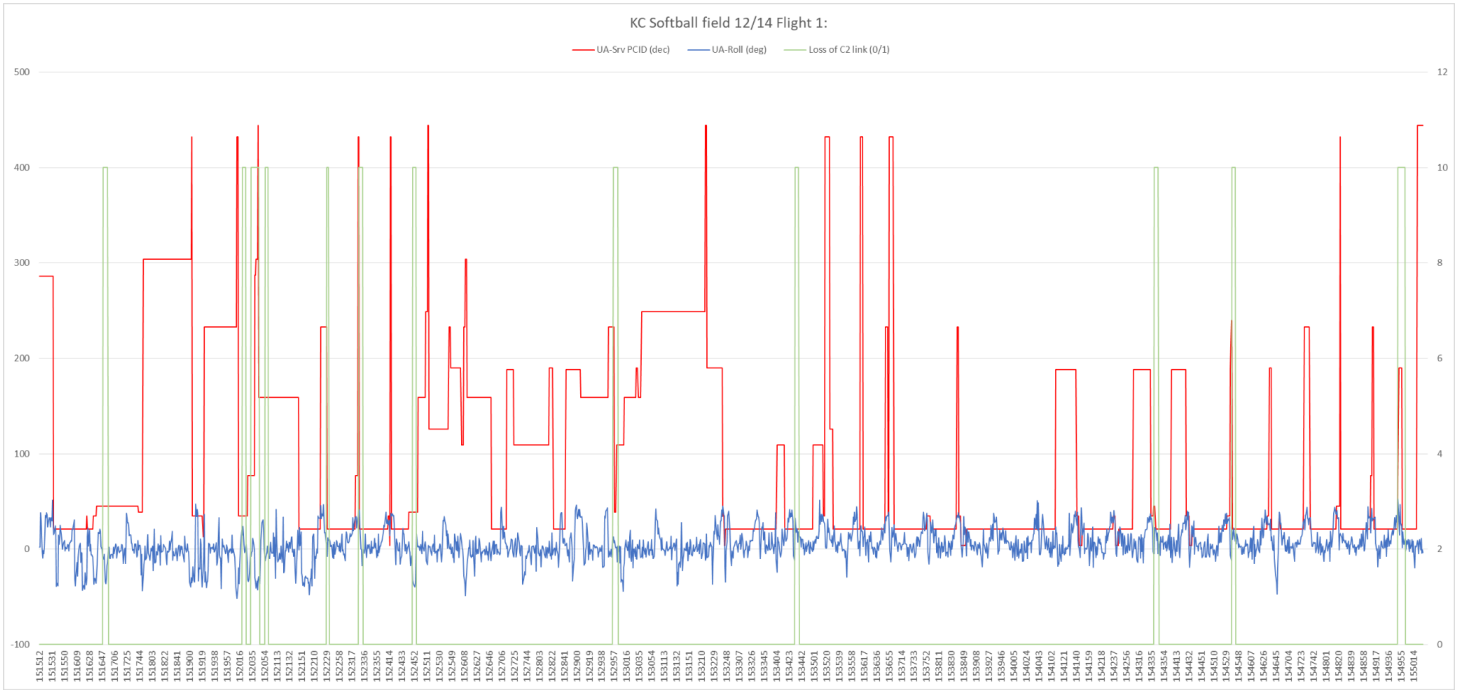


Figure 9.3.3.1.5 PCI change, Roll and loss of C2 indication

9.3.3.2 KC Rosedale Park

Out of 106 flights conducted in this area, only 3 flights reported RTL with loss of C2. One of those 3 flights, i.e., Flight 2 on 12/31/2021, was addressed under section 9.1. Final root cause for this flyaway incident is not yet known.

Flight #4 on 12/18/2021: Loss of C2 was declared at approximately 182420 and RTL was triggered at 182426. Per the system design of the UX11, loss of C2 is noted when heartbeat is missed for 5s. Based on this it can be confirmed that the automatic invocation of “landing” aka “RTL” occurred per our desired timer setting of 10s.

Preceding the loss of C2 leading up to the RTL event, a change in roll was observed to go from approximately -30 to approximately +30 degrees, heading changed from approximately 230 to approximately 140 degrees, and RSRP dropped from approximately -68 to approximately -79dBm. Presence of the same PCI and band but different ECI (column BS in Figure 9.2.3.2.1 Log file snippet of RF parameters) suggest that there might be PCI collision in this area. It is to be noted that at approximately 182429 i.e after around 14s, the UA deregistered from the network and did not reconnect until 38 seconds later. Layer3 messages, which we are not able to capture, would need to be analyzed in order to understand what caused this behavior.

It is noted that the pilot switched to an unlicensed band represented by presence of “ISM LOS” in column M row # 2360 in Figure 9.2.3.2.1 Log file snippet of RF parameters to take control of UA for the time being and later continued flight after successful cellular connection.

It can also be noted from Figure 9.2.3.2.2 that there were other temporary interruptions during this flight.

[redacted]

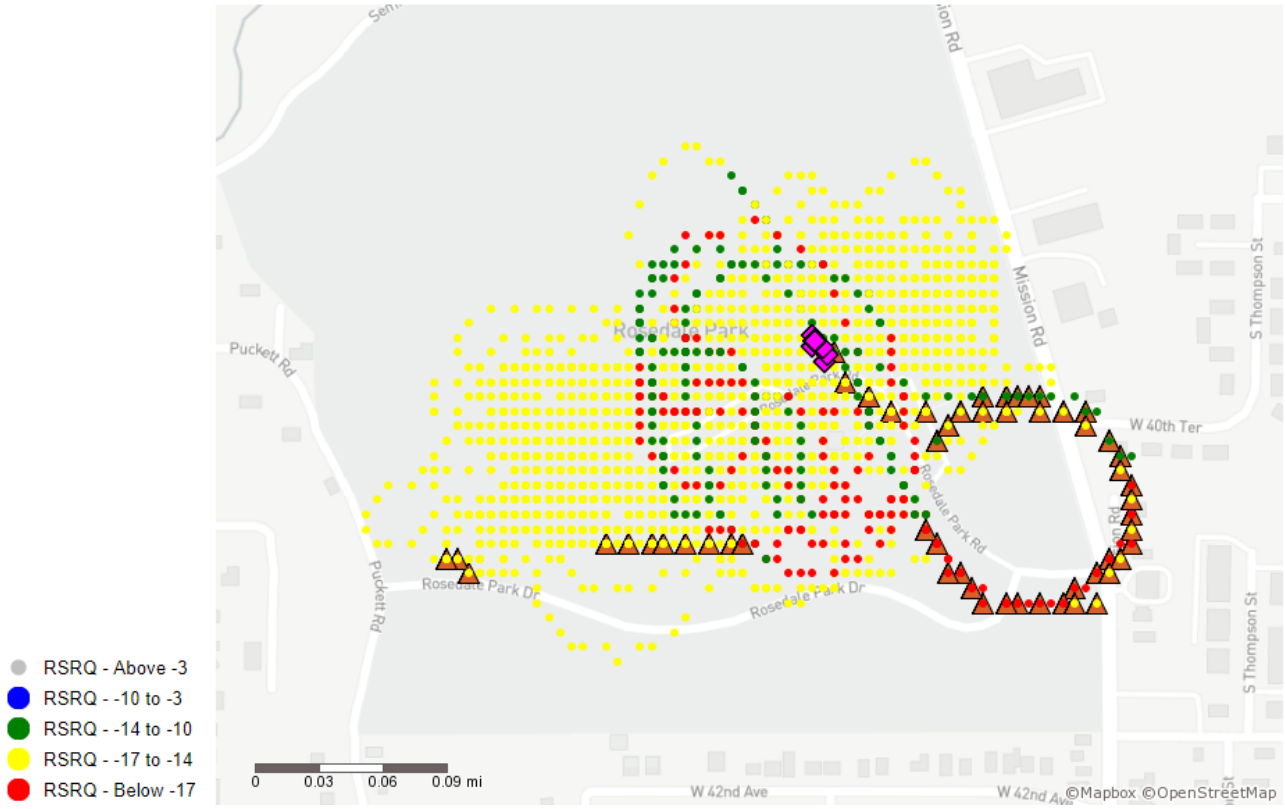


Figure 9.3.3.2.2 Flight #4 on 12/18/2021 RSRQ plot with loss of C2 points along with GCS location

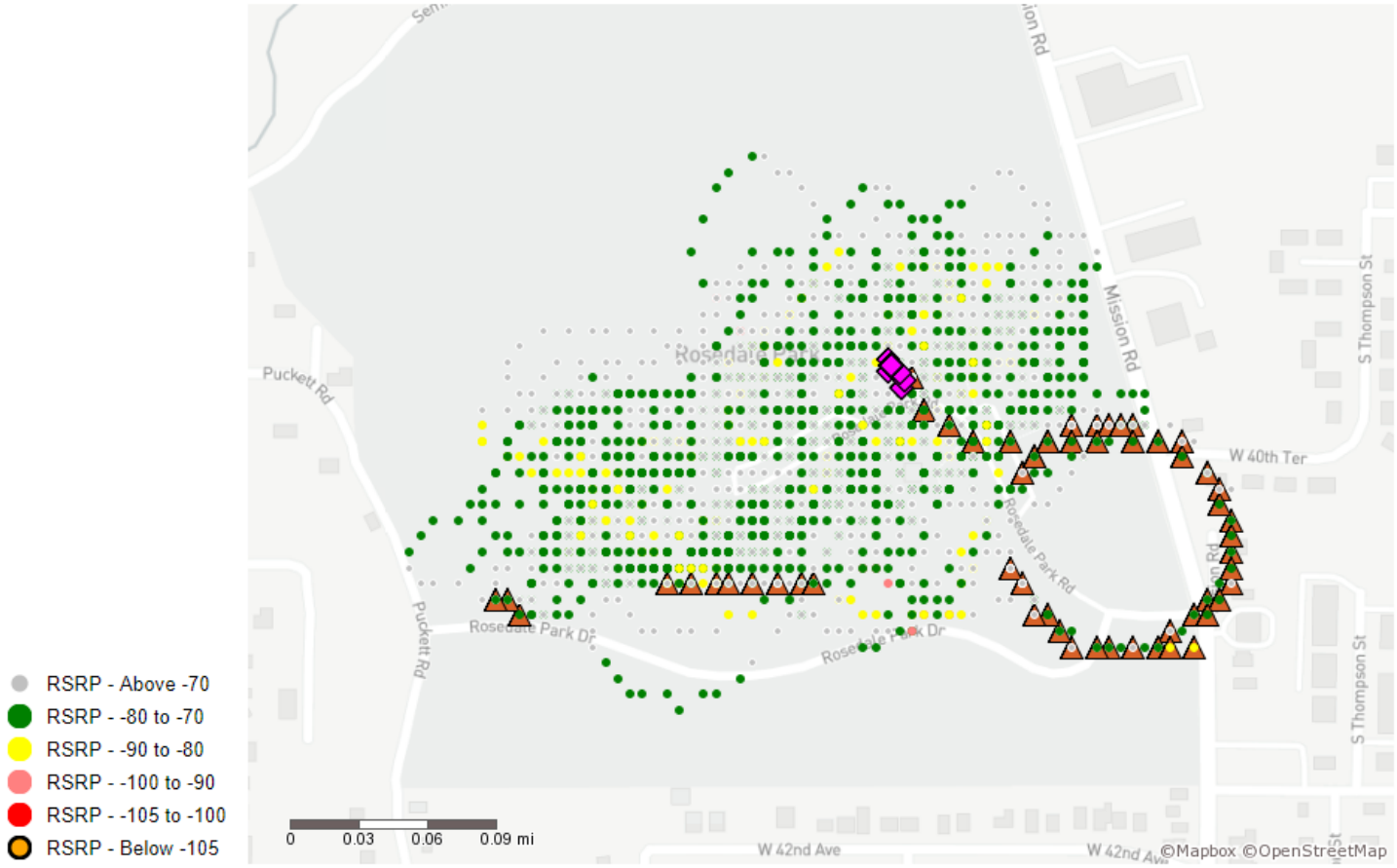


Figure 9.3.3.2.3 Flight #4 on 12/18/2021 RSRP plot with loss of C2 points along with GCS location

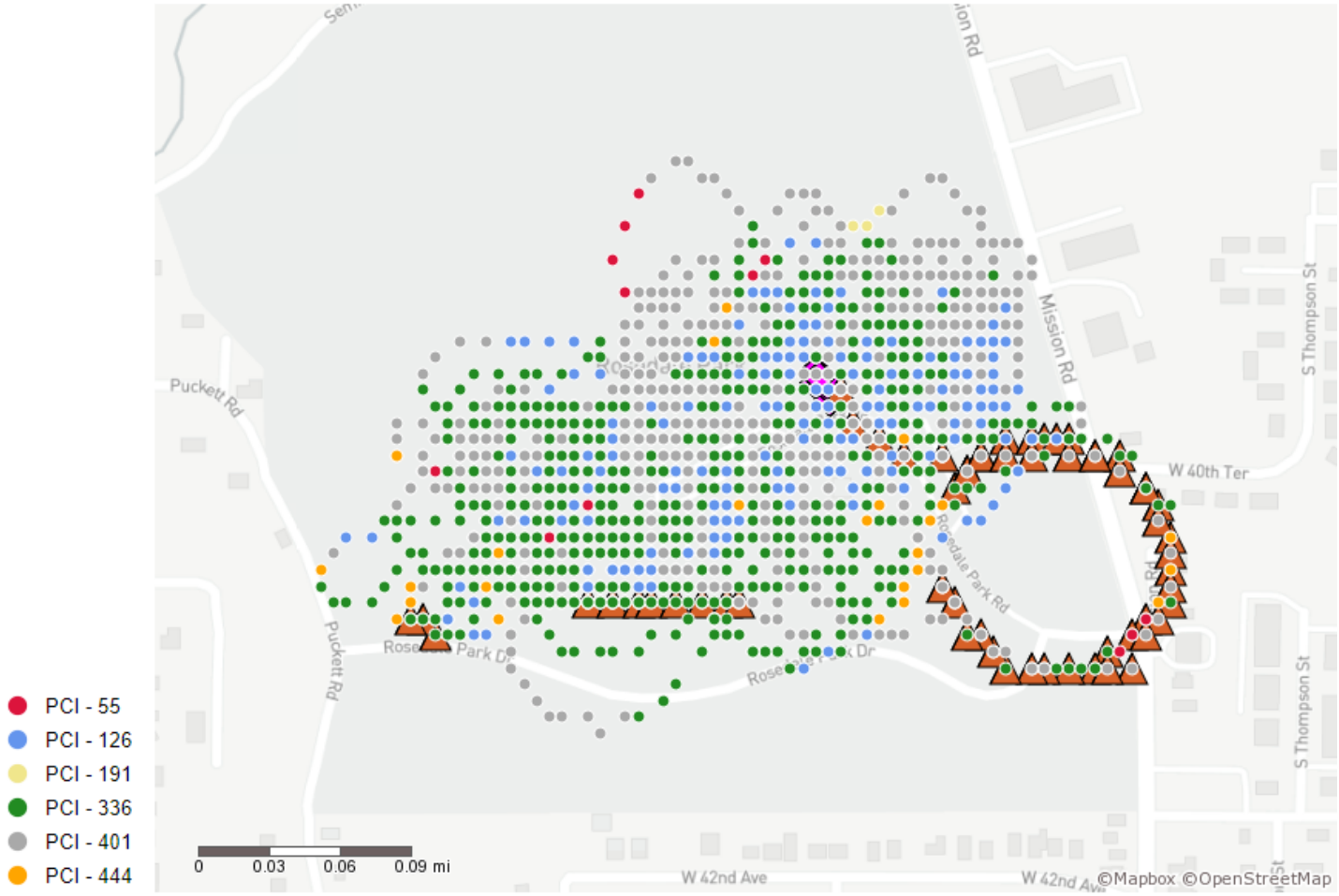


Figure 9.3.3.2.4 Flight #4 on 12/18/2021 PCI plot with loss of C2 points along with GCS location

Flight #3 on 01/08/2022: This flight had 1 RTL invocation reported. It can be noted that immediately after loss of C2 was at approximately 160304, there is an absence of RF data for approximately 15 seconds until 160319 (Figure 9.3.3.2.8). The UA invoked RTL at 160324, i.e., after around 25 seconds (based on system knowledge where initial loss of C2 is recorded after 5s without a logged heartbeat). It can be noted that there was a change in PCI from 444 to 126, Band changed from 4 to 13 (Figure 9.3.3.2.8), RSRQ changed from -14 to -20 (Figure 9.3.3.2.9), and heading changed from 200 degree to 35 degree. The absence of RF parameters for 15s is unexplainable, however, it can be observed that the loss of link was likely due to an abrupt change in heading which might have triggered an inter-frequency HO. It is also noted that the UA reconnected after around 39 seconds (160300 to 160339).

[redacted]

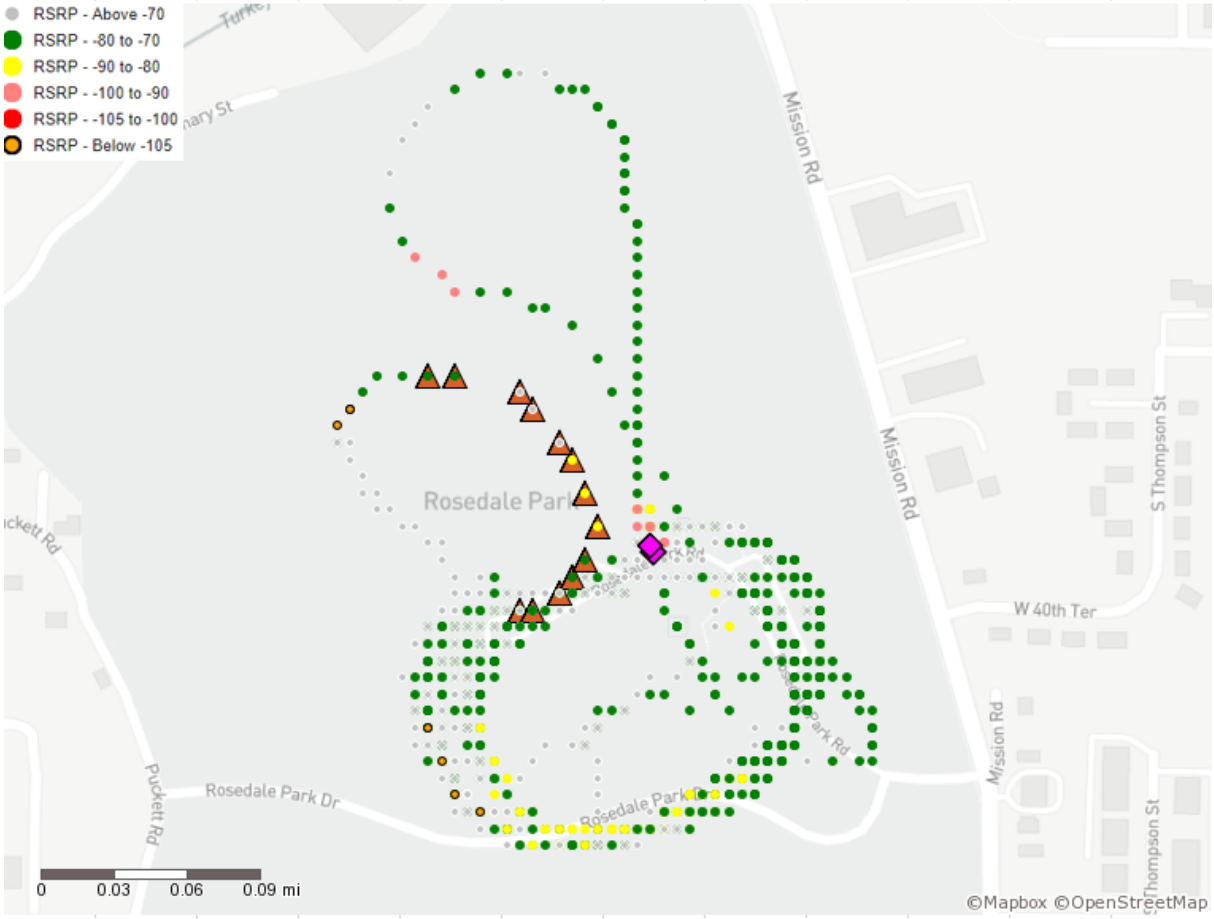


Figure 9.3.3.2.6 Flight #3 on 01/08/2022 RSRP plot with loss of C2 points and GCS location

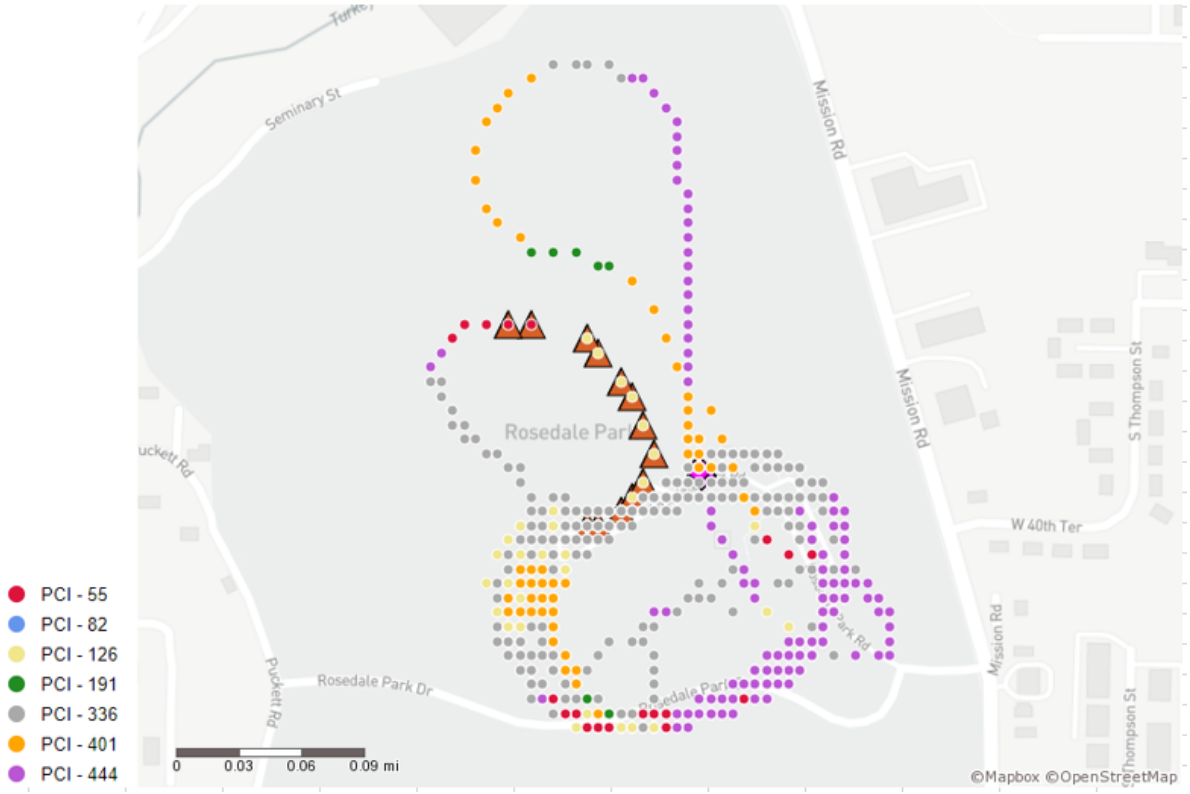


Figure 9.3.3.2.7 Flight #3 on 01/08/2022 PCI plot with loss of C2 points and GCS location

Figure 9.3.3.2.8 Flight #3 on 01/08/2022 PCI plot with loss of C2 points and GCS location (focus area)

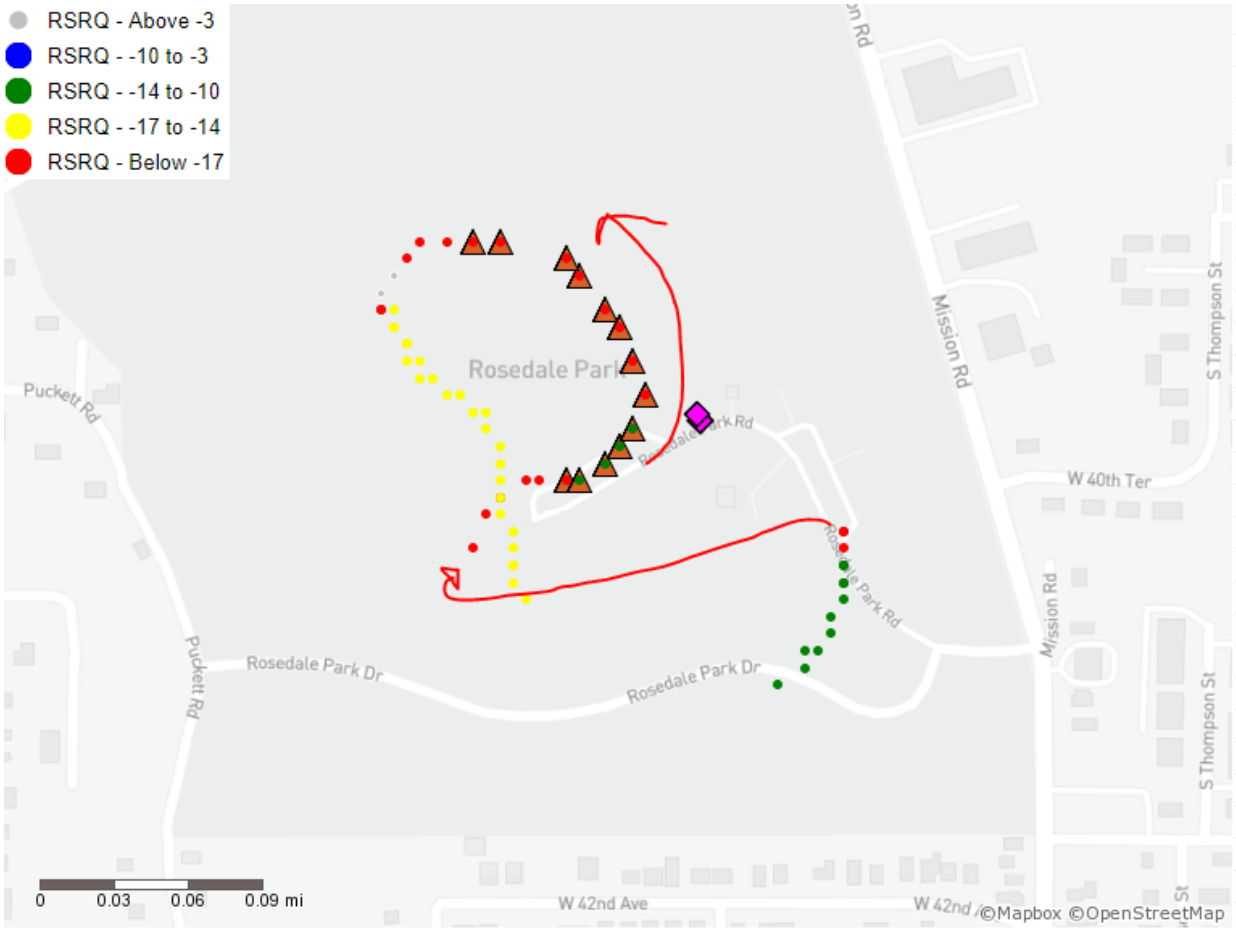


Figure 9.3.3.2.9 Flight #3 on 01/08/2022 RSRQ plot with loss of C2 points and GCS location (focus area)

9.3.4 RTL Root Cause Analysis Conclusions

Occurrences of RTL were analyzed in four operational areas with varying RF conditions. Based on the analysis of data from the Panama City Beach and Kansas City softball field, it appears that the major contributing factor to the reported occurrence of RTL is poor RF conditions. In these two campaigns, RTL events were successfully replicated over multiple flights. However, in the KC Rosedale park campaign the occurrences of RTL events were not consistently replicated. In Rosedale park, there were 2 reports of RTL which appeared to have been caused due to inadequate RF conditions, such as a possible failure during HO after changes in heading. Both of these RTL occurred in separate areas of the flight campaign. One of the flights that flew away in Rosedale park is still under investigation and a final report will be available after the OEM investigates the UA system logs.

Analysis shows that in some cases there is a correlation between changes in UA roll, pitch and yaw, PCI changes and the loss of C2 link. It is suspected that a change in roll, pitch and yaw of the UA could result in simultaneous degradation of the serving cell signal and improvement of the neighbor signal strength, triggering a PCI change via a handover attempt. Frequent changes in PCI, both inter- and intra- band, could have a detrimental impact on the LTE C2 link performance. It is suspected that UA design decisions such as the location and orientation of the cellular modem antennas could impact the frequency or severity of occurrences of loss of C2 link due to change in aircraft orientation relative to the serving and neighbor cells. It is noted that the three UAs flown during the period of this

report have dissimilar antenna configurations, including different combinations of antenna make/model, RF characteristics, quantity of onboard antennas installed (such as main and diversity antennas) and antenna orientation relative to the body of the aircraft.

10. Lessons learned

The following lessons have been learned from the analysis of the data:

- There appears to be correlation between changes in UA roll, pitch and yaw, cell changes and the loss of C2 link.
- It is observed that the duration from the time the UE deregisters from the network until it can register to the network can take approximately 38 seconds. This finding is based on 2 data points from 16122021 flights 1 and 4 delair UX11 flight data.
- RSRQ observed by UA while flying appears to get worse as the flight altitude increases.

11. References

11.1 Operational Risk Assessments

The following ORA was used to document preparation for the flights that were conducted in this reporting period.

Verizon - Skyward - Corporate

Volusia_Daytona_Beach_FL

Risk Assessment

Last Updated On Aug 06, 2021 16:43 PM UTC by Bri O'Neill

20 LOW	1 MODERATE	21 RISKS IDENTIFIED	MODERATE FINAL RISK 21 of 21 Completed
		13 RISKS MITIGATED	

Notes

Crew

1.1	Is the pilot certified and qualified for this mission?	Yes	LOW
	Mitigation: they have flown these systems or similar systems in these locations before		LOW
1.2	Has the pilot recently flown a similar mission?	Yes	LOW
1.3	Is the pilot qualified to fly this aircraft?	Yes	LOW
1.4	Is any crew member affected by fatigue or other factors that could impact performance?	No	LOW
1.5	Have all crew members been briefed on the operation?	Yes	LOW

Aircraft

2.1	Has the aircraft been inspected and determined to be airworthy?	Yes	LOW
2.2	Have Return-to-Home and Maximum Altitude values been checked?	Yes	LOW

	Mitigation: part of pre-flight checklist		LOW
2.3	Is the GPS signal within minimum required parameters?	Yes	LOW
	Mitigation: part of pre-flight checklist		LOW

Weather

3.1	Are cloud cover and ceiling within acceptable limits?	Yes	LOW
	Mitigation: part of pre-flight checklist		LOW
3.2	Is temperature within acceptable limits?	Yes	LOW
	Mitigation: part of pre-flight checklist		LOW
3.3	Is visibility within acceptable limits?	Yes	LOW
	Mitigation: part of pre-flight checklist. no night waiver in Volusia. checking on Panama City.		LOW
3.4	Are wind conditions within acceptable limits?	Yes	LOW
	Mitigation: part of pre-flight checklist		LOW
3.5	Is precipitation forecast during the scheduled operation?	No	LOW
	Mitigation: part of pre-flight checklist, will not fly if rain is forecast		LOW
3.6	Will the operation finish after civil twilight?	No	LOW

	Mitigation: unless we get night waiver		LOW

Location

4.1	Is the operation authorized in the airspace?	**Yes**	LOW
4.2	Are there populated areas near the operation such as parks, schools, or stadiums?	**No**	LOW
	Mitigation: well clear of populated areas, no flights over people		LOW
4.3	Are there heliports or congested air traffic near the operation?	**No**	LOW
	Mitigation: banner planes on beach but will be limited during weekdays during flights. No air traffic in Panama City.		LOW
4.4	Is there uneven terrain or significant elevation change in the area of operation?	**No**	LOW
	Mitigation: pretty much flat (Florida)		LOW
4.5	Are there hazards or obstructions in the area of operation?	**Yes**	MODERATE
	Mitigation: trees under 100 ft in Panama City waypoint file setup will disallow descending near trees		MODERATE
4.6	Are people other than the crew present in the area of operation?	**No**	LOW
4.7	Have takeoff and landing area(s) been surveyed?	**Yes**	LOW

Black Mountain

Hitec Commercial Drone Services

Black Mtn Day 2

Risk Assessment

Last Updated On Nov 10, 2021 18:00 PM UTC by Jim Bonnardel

18 LOW	3 MODERATE	21 RISKS IDENTIFIED 0 RISKS MITIGATED	MODERATE FINAL RISK 21 of 21 Completed

Notes

Crew

1.1	Is the pilot certified and qualified for this mission?	Yes	LOW
1.2	Has the pilot recently flown a similar mission?	No	MODERATE
1.3	Is the pilot qualified to fly this aircraft?	Yes	LOW
1.4	Is any crew member affected by fatigue or other factors that could impact performance?	No	LOW
1.5	Have all crew members been briefed on the operation?	Yes	LOW

Aircraft

2.1	Has the aircraft been inspected and determined to be airworthy?	Yes	LOW
2.2	Have Return-to-Home and Maximum Altitude values been checked?	Yes	LOW
2.3	Is the GPS signal within minimum required parameters?	Yes	LOW

Weather

3.1	Are cloud cover and ceiling within acceptable limits?	Yes	LOW
3.2	Is temperature within acceptable limits?	Yes	LOW
3.3	Is visibility within acceptable limits?	Yes	LOW
3.4	Are wind conditions within acceptable limits?	Yes	LOW
3.5	Is precipitation forecast during the scheduled operation?	No	LOW
3.6	Will the operation finish after civil twilight?	No	LOW

Location

4.1	Is the operation authorized in the airspace?	Yes	LOW
4.2	Are there populated areas near the operation such as parks, schools, or stadiums?	No	LOW
4.3	Are there heliports or congested air traffic near the operation?	No	LOW
4.4	Is there uneven terrain or significant elevation change in the area of operation?	Yes	MODERATE
4.5	Are there hazards or obstructions in the area of operation?	Yes	MODERATE
4.6	Are people other than the crew present in the area of operation?	No	LOW
4.7	Have takeoff and landing area(s) been surveyed?	Yes	LOW

Kansas City

DroneHive MOA

Smithville 2000.1 2022-01-29

Risk Assessment

Last Updated On Jan 30, 2022 05:56 AM UTC by Cody Soper

21 LOW	21 RISKS IDENTIFIED	LOW FINAL RISK 21 of 21 Completed
	0 RISKS MITIGATED	

Notes

Crew

1.1	Is the pilot certified and qualified for this mission?	Yes	LOW
1.2	Has the pilot recently flown a similar mission?	Yes	LOW
1.3	Is the pilot qualified to fly this aircraft?	Yes	LOW
1.4	Is any crew member affected by fatigue or other factors that could impact performance?	No	LOW
1.5	Have all crew members been briefed on the operation?	Yes	LOW

Aircraft

2.1	Has the aircraft been inspected and determined to be airworthy?	Yes	LOW
2.2	Have Return-to-Home and Maximum Altitude values been checked?	Yes	LOW
2.3	Is the GPS signal within minimum required parameters?	Yes	LOW

Weather

3.1	Are cloud cover and ceiling within acceptable limits?	Yes	LOW
3.2	Is temperature within acceptable limits?	Yes	LOW
3.3	Is visibility within acceptable limits?	Yes	LOW
3.4	Are wind conditions within acceptable limits?	Yes	LOW
3.5	Is precipitation forecast during the scheduled operation?	No	LOW

3.6	Will the operation finish after civil twilight?	No	LOW
Location			
4.1	Is the operation authorized in the airspace?	Yes	LOW
4.2	Are there populated areas near the operation such as parks, schools, or stadiums?	No	LOW
4.3	Are there heliports or congested air traffic near the operation?	No	LOW
4.4	Is there uneven terrain or significant elevation change in the area of operation?	No	LOW
4.5	Are there hazards or obstructions in the area of operation?	No	LOW
4.6	Are people other than the crew present in the area of operation?	No	LOW
4.7	Have takeoff and landing area(s) been surveyed?	Yes	LOW

12. Acronyms & Abbreviations

Acronym or Abbreviation	Definition
C2	Command and Control
CNPC	Control Non-Payload Communications

CS	Control Station
EKF	Extended Kalman Filter
FSP	Flight Service Provider
FW	Fixed Wing
GCS	Ground Control Station
KM/H	Kilometers Per Hour
LTE	Long Term Evolution (4G)
MPN-GW	Mobile Private Network Gateway
OEM	Original Equipment Manufacturer
ORA	Operational Risk Assessment
PCI	Physical Cell ID
P-GW	Packet Gateway
PNW	Pacific Northwest
RC	Remote Control
RF	Radio Frequency
RPIC	Remote Pilot in Command
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RTL	Return to Launch
SIM	Subscriber Identity Module
SINR	Signal to Interference Plus Noise Ratio
SNR	Signal to Noise Ratio
UA	Uncrewed Aircraft
UAV	Uncrewed Aerial System
UE	User Equipment
VTOL	Vertical Takeoff and Landing