uAvionix skyBeacon/tailBeacon
GPS Performance Troubleshooting

UAV-1004106-001
Revision B

http://www.uavionix.com
http://www.uavionix.com/support

Revision History

Revision	Date	Reason for Change
A	4/16/2020	Initial release
B	4/21/2020	Updated references to Advisory Circulars

Table of Contents

1 Introduction

1.1 Purpose

The purpose of this document is to assist in the identification and troubleshooting of issues related to GPS performance on the skyBeacon and tailBeacon products. uAvionix support is available to assist in the troubleshooting process.

2 Service Bulletins

2.1 Verify Latest Service Bulletin

Verify the installation and device firmware comply with the latest posted support bulletin. Each service bulletin details the requirements and instructions for installation or compliance. uAvionix does not recommend engaging in any additional troubleshooting until the installed device complies with the latest service bulletin.

The latest service bulletins can be accessed under the appropriate product at:
https://uavionix.com/support/

3 Assumptions

3.1 Installation/Equipment Assumptions

The uAvionix skyBeacon and tailBeacon are designed to be easy to install and configure. The performance of the skyBeacon and tailBeacon is dependent on the condition of the systems of the host aircraft. The skyBeacon/tailBeacon will not meet the performance of 91.227 if the host aircraft systems are not in good working order. The following are assumed as part of the installation of the skyBeacon/tailBeacon.

- The skyBeacon or tailBeacon has a reasonably unobstructed view of the sky and ground when installed on the aircraft. Installing skyBeacon/tailBeacon under a significant portion of the aircraft structure will result in poor performance. Example: tailBeacon should not be installed on an aircraft where the elevator will shadow or cover the tailBeacon GPS antenna.
- Aircraft wiring is in good working order
- Grounding/bonding resistance of the installed equipment meets AC 43.13-1B Section 15
- Aircraft alternator/generator and regulator are supplying between 11-32VDC
- The skyBeacon or tailBeacon will be installed using environmental splices as per AC 43.13-1B Section 13
- Existing transponder, encoder and static system have been tested within the last 24 months as per AC 43-6D

The above requirements are for any avionics installation and/or operation of an aircraft equipped with an altitude reporting system.

3.2 Operational Evaluation Flight Assumptions

In order to properly diagnose performance issues, the flight used for review should be flown under the following conditions:

- The aircraft had sufficient run-up with no movement, minimum 5 minutes after avionics and skyBeacon or tailBeacon is powered on.
- Flown in excellent radar and ADS-B coverage, generally 3000' AGL or higher for 30+ minutes.
- Avoid banks greater than 30 degrees as per AC 20-165B.
- No prolonged unusual or aggressive maneuvers or attitudes including aerobatics.

The following reference is from the PAPR (Public ADS-B Performance Report) automated report system:

> *Be advised that flight operations occurring at the fringe of ADS-B ground station coverage (refer to the FAA ADS-B Coverage Map) can cause intermittent signal losses with aircraft avionics. This condition may generate various false failure indications (red flag for Percent Failure - PF and/or Maximum Consecutive Failure - MCF flag) within a Public ADS-B Performance Report (PAPR). Such failures will vary depending on the duration of the flight in this condition.*

uAvionix does not recommend maintenance actions using data from flights flown in suspected fringe coverage.

3.3 Public ADS-B Performance Report

The FAA provides a service to quickly obtain a PAPR (Public ADS-B Performance Report). A PAPR can be requested from the following FAA website:

https://adsbperformance.faa.gov/paprrequest.aspx

4 Identifying the GPS Performance Issue

The corrective action required to resolve GPS performance depends on the type of issue. In many cases, identification of the specific issue requires review of extended data available from the FAA. The extended data is extremely valuable as it provides not only what type of failure occurred but it also displays where and/or when the failure occurred.

4.1 Extended Data Requests

In addition to a summarizing PAPR, extended data in KMZ (Google Earth) format can be requested from:

9-AWA-AFS-300-ADSB-AvionicsCheck@faa.gov

In the e-mail, note the aircraft tail number, Zulu time and date of operation. Let the FAA representative know you are requesting the KMZ (Google Earth) data. If there were multiple flights on a single day provide a time in Zulu during the operation. The ADS-B team is busy. The request should be courteous, short and to the point.

> *I'd like to request the KMZ data set for N79GS flown 12/28/2019 during 22:20Z.*

The operation date and time is noted in the Operation Summary on page 2 of the PAPR report. You can refer to the PAPR for the aircraft when making your request to ensure you receive the correct data back.

Operation Summary

Operation Id:	417337834	**Start Time:**	12-28-2019 22:12:03	**End Time:**	12-28-2019 22:55:59
Broadcast ICAO:	AAB653 (52533123)		**Duration:** 00:43:56	**Mod:** 00:43:56	**Rule:** 00:00:00
Tail Number:	N79GS	**Reports:**	7741	**Best Msg:** 2602	**TIS-B Client:** 0.0%
Country:	United States - Civil	**Stationary:**	No	**Baro Alt (ft):**	2700 - 6400

It may take 24-72 hours to receive the extended dataset. Note a single request is sufficient.

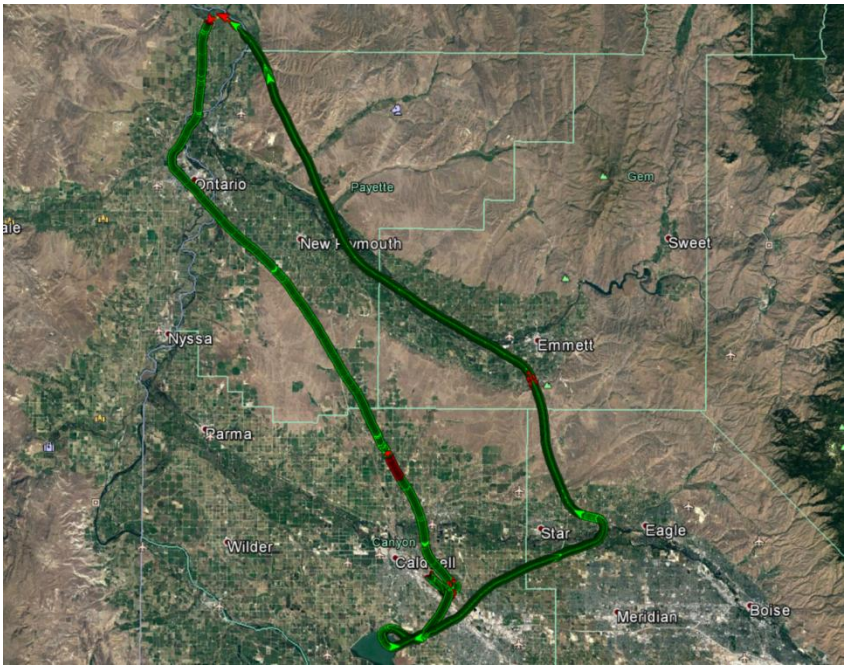
4.2 Extended Data Review

Once you receive the extended data from the FAA you can open the file in Google Earth. You will need to have the Google Earth application installed on a tablet or computer to review the file.

When the file opens the application should zoom to an overview of the requested flight. Compliant transmits are displayed as green icons and non-compliant transmits are shown as red icons. A review of this information can assist in determining the actions necessary to resolve the performance issue. GPS performance issues generally appear in the data in three categories:

- Lower than acceptable integrity
- Loss of position or
- Misreporting of position

Characterizing the failure can provide insight into the actions required to resolve the performance issue.



4.3 Characterizing Apparent GPS Failure

4.3.1 Failing PAPR NIC / NACp Values

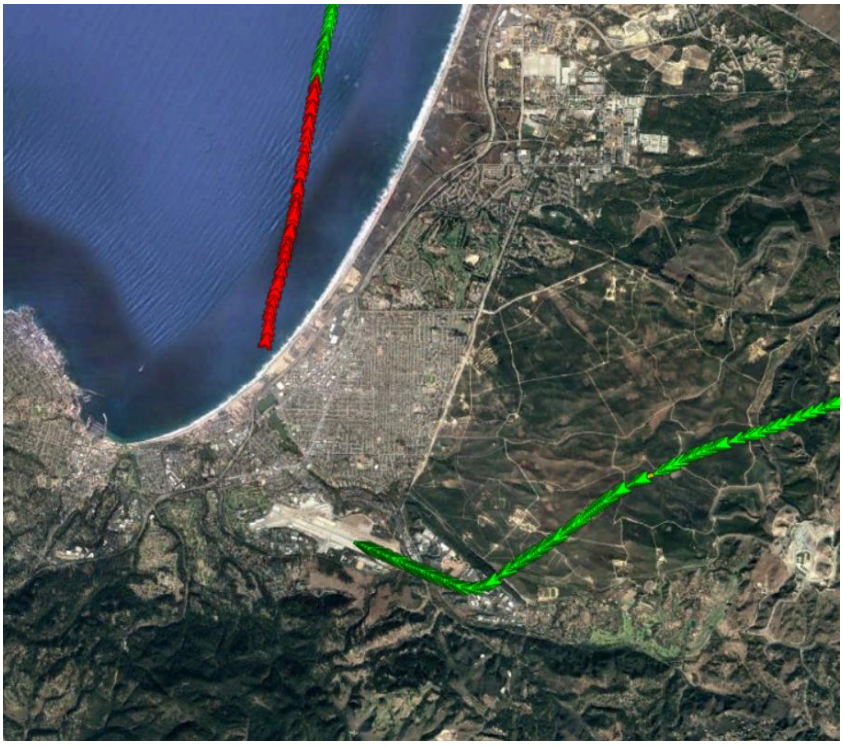
ADS-B systems report two values describing the integrity and accuracy of the calculated GPS position. These are NIC (Navigation Integrity Category) and NACp (Navigation Accuracy Category – Position). The following sections describe possible causes for a PAPR indicating failing NIC or NACp values.

4.3.1.1 Terrain, Maneuvering, and Aerobatics

Aggressive maneuvers, extreme bank angles, or aerobatics can all contribute to failing GPS integrity metrics. Aerobatics will result in failing GPS performance. Aircraft with regular operations involving unusual attitudes will need to address the performance with the Flight Standards representative. At the time of the writing of this document, ADS-B A demonstration that the system performs in compliance with 91.227 will likely be required. The FAA has not yet published AC-9145D which will contain further guidance for aerobatic and formation flying with ADS-B. More information on ADS-B and Aerobatics can be found here: https://www.faa.gov/nextgen/library/aerobatics/

4.3.1.2 Insufficient Run Up

Review where the failures occurred. If the failures occur during takeoff roll and climb out with no further failures occurring in the flight track, the cause is likely insufficient runup time for the skyBeacon/tailBeacon. A high integrity fix takes time to acquire. The owner/operator might consider altering the aircraft checklist to help reduce this issue and improve compliance.



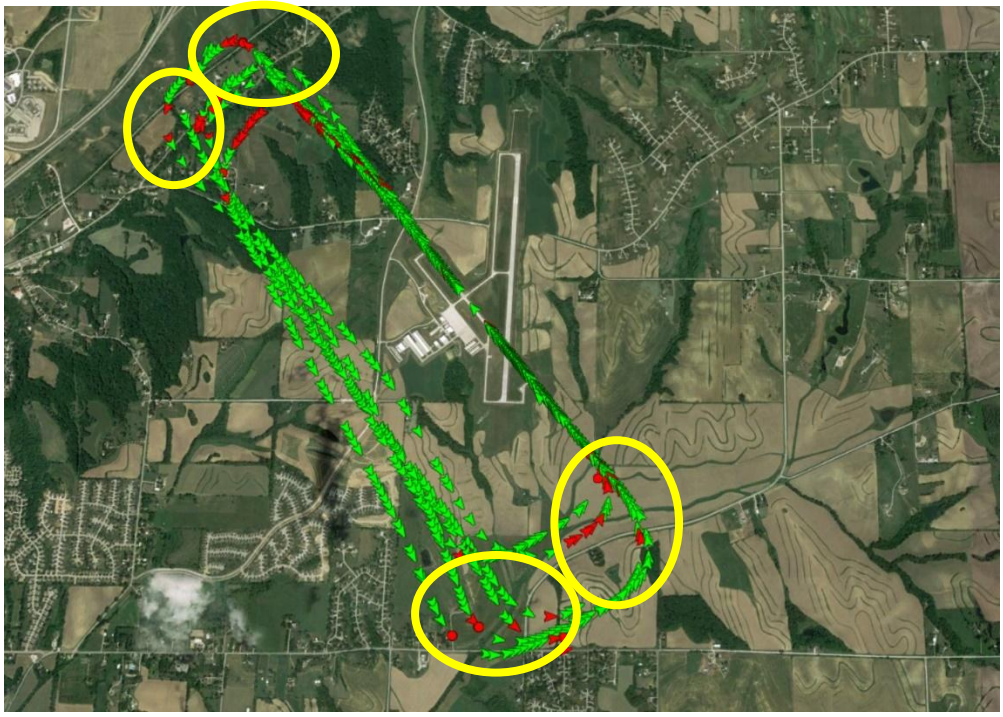
The aircraft above took off prior to having a high integrity fix. Turning on the navigation lights and skyBeacon/tailBeacon early in the aircraft runup helps prevent this type of failure.

4.3.1.3 Radio Frequency (COM) Interference or Other Interference (EMI)

If the GPS failures occur at regular radio call locations there may be an EMI issue. COM radios have been shown to disrupt SBAS/WAAS GPS systems. This is not a skyBeacon/tailBeacon specific issue but

a phenomenon that has been observed in certain installations. When reviewing the failure locations in the extended data, consideration should be given as to whether or not any aircraft equipment was in operation during the failure. While this section is focused on Radio Frequency (RF) interference, the operation of other equipment could contribute to a failure. Review the area of failure and consider the following questions about that moment of the flight:

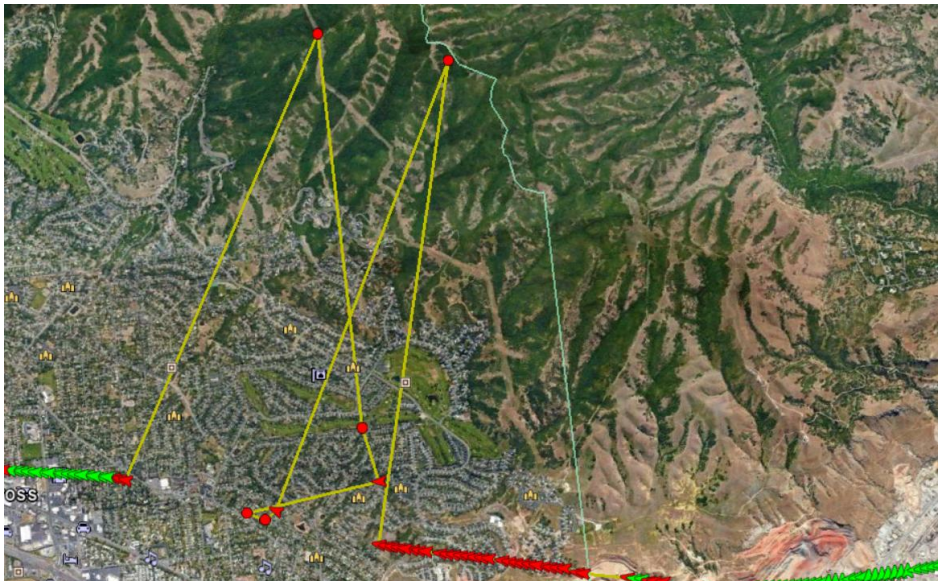
- Was there an aircraft configuration change?
- Power setting change, operation of flaps or some other equipment?
- Operation of any radio or navigation equipment?



In the image above the GPS reporting fails integrity or loses position each time the COM radio is keyed. The positions of failure match normal call up locations during pattern work. This aircraft appears to be experiencing RF interference. See Section 5.2 for guidance on RF Interference troubleshooting.

4.3.2 Misreported GPS Position (Position Jumping)

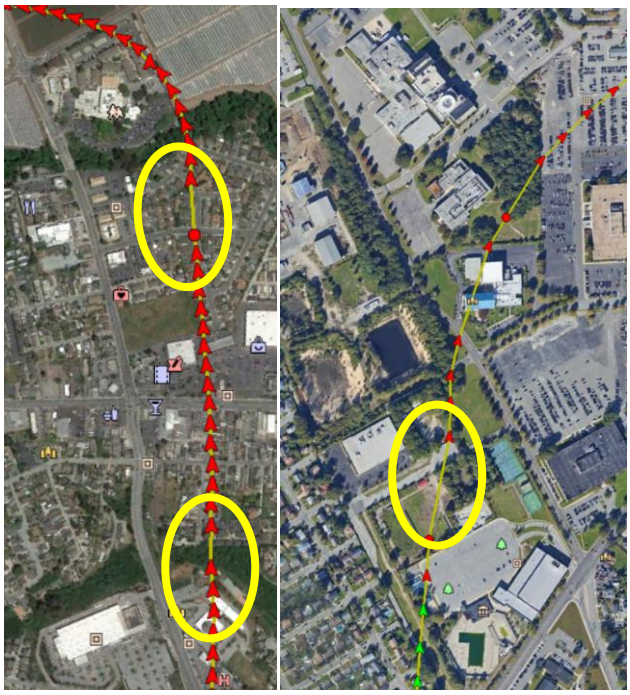
Misreported GPS position is easy to identify from the flight track. The flight track should appear smooth without any unexpected changes. The flight shown below has clear examples of misreported GPS position.



As shown above the flight track jumps unexpectedly and well outside the capability of the aircraft.

4.3.3 Loss of GPS Position

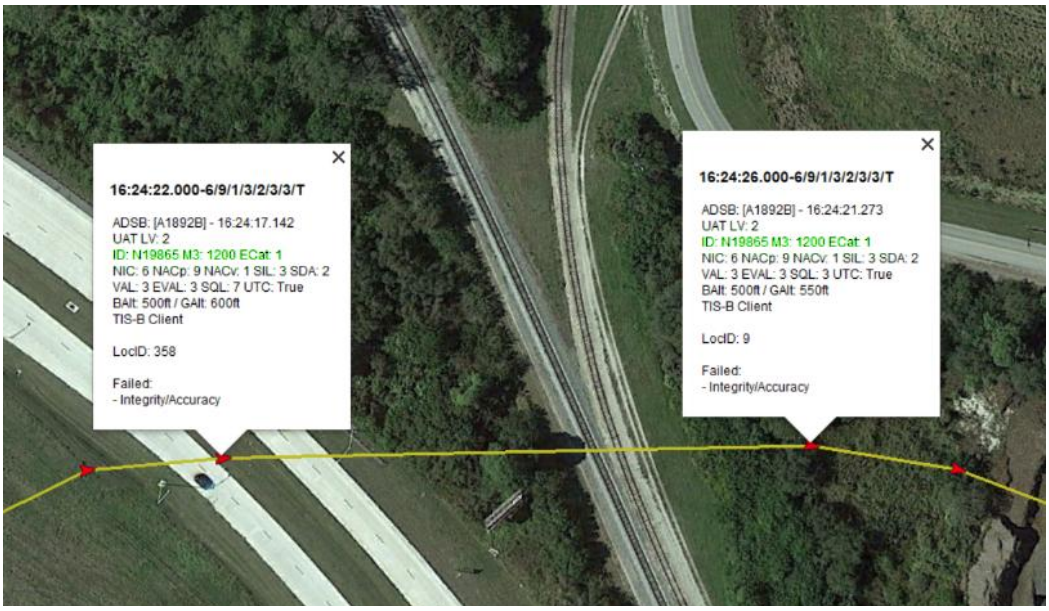
A loss of GPS position will appear as gaps in the flight track. Typically, the gap is larger than a single missing message. Due to the nature of radio performance, focus on gaps greater than 5 seconds.



There are multiple causes of apparent GPS position loss. Further review is necessary to determine whether the loss of position is the result of a loss of GPS fix or a reset of the skyBeacon/tailBeacon hardware. A review of the ADS-B messages around the gap can be used to determine if the GPS lost position or the skyBeacon/tailBeacon reset due to a power event.

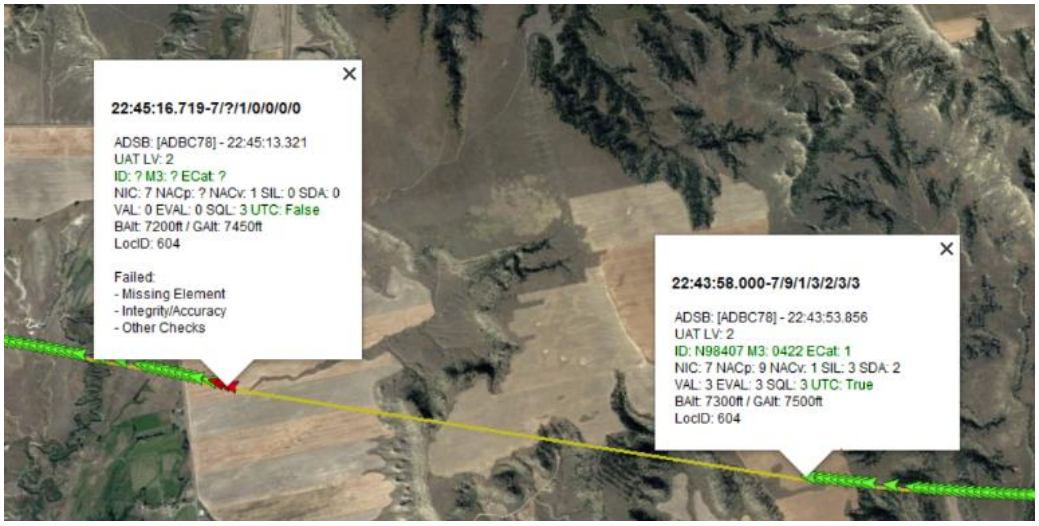
All GPS receivers require line-of-sight for proper operation. Terrain, structures, and aircraft attitude all impact the availability or visibility of GPS signals. Banks in excess of 30 degrees, prolonged unusual attitudes including during aerobatics can cause loss of GPS position. Low level flight in canyons or urban environments can also block or *shadow* the GPS receiver on the skyBeacon or tailBeacon. The loss of view to several satellites, or even a changing sky view, can cause transients that greatly impact reported NIC and NACp values.

A loss of position without reset can be identified by reviewing the messages on either side of the gap. Each message on either side of the gap will contain a valid call sign and squawk. The UTC value will also remain unchanged, i.e. *True.*



The data in both transmits above contains valid information on either side of the gap. No fields are missing or invalid which indicates the skyBeacon/tailBeacon hardware did not reset or lose power.

In cases where the device has reset due to power loss the messages immediately after the gap will show missing or invalid data.



In the example above the aircraft callsign (ID), Mode A (M3), and emitter category (ECAT) are missing/invalid after the unit resumes transmission. The UTC sync is also *False*. The unit above is experiencing resets due to a power related event. The reset appears in the data as a loss of GPS reception but the supporting date indicates the skyBeacon/tailBeacon hardware momentarily lost power.

4.4 Unable to Determine the Type of GPS Failure?

Contact uAvionix Support. A support ticket can be submitted at https://uavionix.com/support. Please include any PAPR reports and extended data to improve our response time.

5 Corrective Actions

The following summarizes several corrective actions observed to resolve GPS performance issues with skyBeacon/tailBeacon across aircraft installations. The issues below have been observed to affect skyBeacon/tailBeacon GPS performance.

5.1 Wiring Considerations

5.1.1 Existing Electrical System and Wiring Condition

The skyBeacon/tailBeacon is a complex piece of electronics, with numerous tightly integrated radios and microprocessors. Consideration should be given to the aircraft existing wiring. A navigation light that pulses, flickers or occasionally loses power may not have been apparent to the owner/operator. As with any avionics the skyBeacon/tailBeacon will be sensitive to fluctuation in power supply, high resistance, poor termination and grounding and bonding issues. Any interruption in power to the skyBeacon/tailBeacon will result in a loss of GPS and/or transmission. These gaps result in failure of the installation to meet the requirements of 91.225/91.227.

The following pre-existing electrical issues have been determined to be the root cause of ADS-B performance issues:

- Panel switches both toggle, 3-way and rheostat/potentiometer style switches
- Circuit Breakers
- Use of *knife* or *handshake* connectors
- Chains of multiple unnecessary terminations/connectors
- Failed/incorrect crimps/termination
- Corroded bonding/ground lugs

- Malfunctioning Alternators/Generators/Regulators

If an ADS-B performance issue has been observed and any of the above items are suspect, uAvionix recommends thorough review and corrective action.

5.1.2 Panel Switches

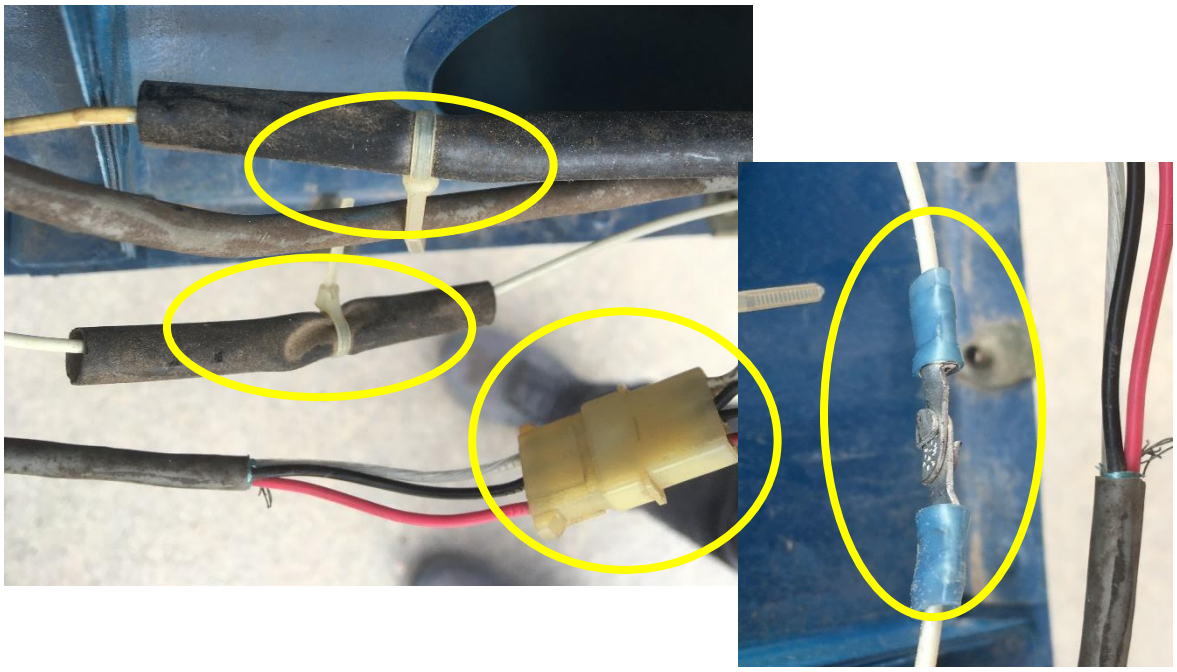
Some aircraft use a rheostat to control the Nav lights for dimming purposes. We recommend replacing these style switches. Many of these rheostats or potentiometers are several decades old and it has been observed that a little vibration or a slight change in position will break the connection. The skyBeacon/tailBeacon will not operate correctly without proper voltage and grounding. A switch that is malfunctioning and or not delivering a consistent connection will result in failure to meet the performance of 91.225 and 91.227.

5.1.3 Handshake, Knife or Blade Style Termination

While popular, the knife or blade style termination does not meet the recommendations of AC 43.13-1B. The connectors are not sealed and the nature of the connection can result in a high-resistance. The same is true for the common unsealed Molex style plugs. AC 43.13-1B recommends an environmental (sealed) splice.

skyBeacon/tailBeacon include high quality Molex environmental splices. When crimped with an insulated crimper and heated they will provide a high-quality low-resistance connection sealed from the environment. If a removable connector is desired please use a positive locking environmentally sealed connector.

Below are examples of termination that do not meet the requirements of AC 43.13-1B.



5.1.4 Chains of Multiple Unnecessary Terminations/Connectors

Avoid using multiple terminations to extend a power or ground wire. If existing connectors are discovered we recommend removing all of the unnecessary terminations/extensions. The greater the number of splices the greater the chance termination failure will occur.

A single termination is recommended. In extreme cases a new wire should be pulled to the skyBeacon/tailBeacon. If a new wire is required, we recommend installing a dedicated ground wire at the same time. 22 AWG or larger is advised.

The photo above shows a series of wiring with three butt splices and a Molex plug on the same short section of power wiring. Presumably the mating side under the wingtip also has the same chain of wiring, compounding the chances of a failed connection and increasing the resistance. If both sides of the installation have three additional butt splices there are a total of twelve additional and unnecessary failure points.

5.1.5 Corroded or Improper Bonding/Grounding

Grounding and bonding issues on aircraft have been a significant driver of performance issues. AC 43.13-1B Section 15 states:

> *One of the more important factors in the design and maintenance of aircraft electrical systems is proper bonding and grounding.* ***Inadequate bonding or grounding can lead to unreliable operation of systems,*** *e.g., EMI, electrostatic discharge damage to sensitive electronics, personnel shock hazard, or damage from lightning strike.*

Most avionics technicians and aircraft maintenance professionals understand how important grounding is but it is an easy item to overlook. Please review and refer to AC 43.13-1B and verify that the installation meets the requirements. The AC recommends the following:

- Self-tapping screws should not be used for bonding purposes. Only standard threaded screws or bolts of appropriate size should be used.
- Use appropriate washers when bonding aluminum or copper to dissimilar metallic structures so that any corrosion that may occur will be on the washer.
- Exposed conducting frames or parts of electrical or electronic equipment should have a low resistance bond of less than 2.5 milliohms to structure. If the equipment design includes a ground terminal or pin, which is internally connected to such exposed parts, a ground wire connection to such terminal will satisfy this requirement.
- Bonds should be attached directly to the basic aircraft structure rather than through other bonded parts.

The photos of the above ring terminal and ground location show significant corrosion. The high resistance connection resulted in failure of the attached avionics. Removing the existing corrosion and existing paint/coatings along with replacement of the ring terminal resolved the performance issues.

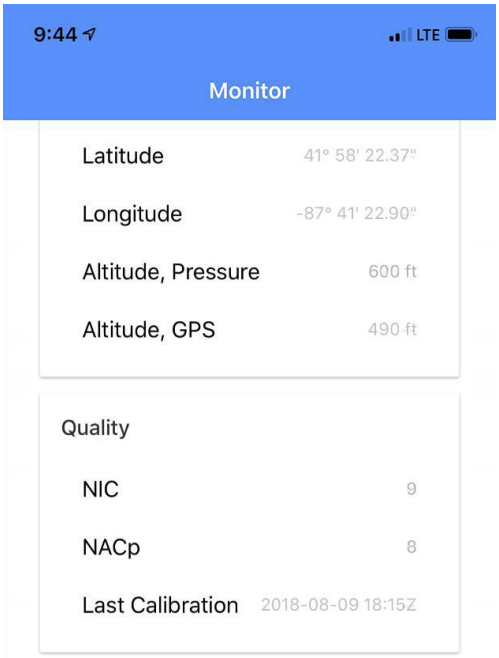
5.1.6 Malfunctioning Alternators/Generators/Regulators

The skyBeacon/tailBeacon are rated to perform correctly across the entire DO-160 range for 12/14V and 24/28V aircraft, which from 10-32V DC. In cases where the aircraft's engine driven electrical system is malfunctioning and generating voltage in some excess of 32V, the skyBeacon/tailBeacon will go in to a self-protection mode until the abnormal voltage condition ceases. This self-protection will appear as a device reset in the extended data. In most cases a maintenance professional can use a multimeter with a *Hold* or *Max* function to monitor the voltage during ground testing and determine whether or not the electrical system is delivering a current outside the acceptable range. This issue has primarily been observed on 24V/28V aircraft, as the high limit is most often exceeded with a regulator failure, and 24V/28V aircraft have less margin available.

Under some circumstances, if the airspace and aircraft operation permits, the pilot can perform a segment of flight where the skyBeacon/tailBeacon are powered exclusively by the aircraft battery. UTC start and stop times of flight in this configuration can help determine/support if the aircraft electrical system is contributing to the performance issue. This analysis of each leg of the flight can be used to determine if there is an issue with the engine driven electrical system. Aircraft operation and airspace requirements should be carefully considered before performing this type of test.

5.2 RF Interference Troubleshooting

GPS L1 signals are received by the skyBeacon/tailBeacon on 1575.42 MHz. Radio transmitters in the aircraft, including COM radios and ELTs, can transmit unwanted interference on harmonics of their intended transmission frequency, jamming the relatively weak GPS signal. If RF Interference has been identified as a potential source of interference, a series of ground tests can be performed to confirm the issue. RF Interference will typically appear as a loss of GPS position in the flight track at locations where the RF transmitter (radio) was in operation.



The following instructions are intended to help isolate the equipment and frequencies where the interference is occurring. The instructions below are intended for testing COM radio interference

1. Place the aircraft outside with an unobstructed view of the horizon. Do not perform this testing inside a hangar or near a structure that will obstruct satellite reception.
2. Power on the skyBeacon/tailBeacon.
3. Connect to the skyBeacon/tailBeacon using the skyBeacon Mobile Installer app.
4. Access the monitor screen.
5. Verify the GPS high-integrity fix has been achieved. A 3D Fix with NIC of 8 or greater is required before beginning the testing.
6. Power on the COM radio.
7. Select a frequency of 121.50 MHz.
8. Transmit for 35-40 seconds.
9. Verify that during the transmission the skyBeacon/tailBeacon does not lose position and that the NIC/NACp do not change significantly. A loss of position or a drop in NIC/NACp indicates an interference issue.
10. For each of the following COM frequencies, repeat Step 9:

    121.150, 121.175, 121.200, 121.225, 121.250, 131.200, 131.225, 131.250, 131.250, 131,250, 131.275, 131.300, 131.325, 131.350

11. If interference is observed, we recommend contacting the radio manufacturer for guidance on correcting the harmonics issue.

If you are testing a radio transmitter other than a COM radio, verify the GPS does not lose fix and that the integrity metrics (NIC/NACp) do not change while transmitting on each available channel/frequency for 35-40 seconds.

The radios listed below have been observed to cause GPS issues. RF interference issues are not limited to the radios below. Ground testing can help identify sources of RF interference. In an article from Aviation Consumer dated February 15th, 1994, several NAV/COM radios were tested alongside an independent GPS receiver. Radio Frequencies that may jam GPS receivers are shown in the table below.

Model	Com	Nav
Narco MK12D/E	810/811 131.220 and 119.285	824/825 115.464 and 109.672
King KX 155/165	131.820 and 119.885	116.128 and 109.564
King KX 170/175	122.285 and 130.186	113.651
Collins Microline	132.720 and 120.785	116.028 and 109.464

Notes: KX 155/165 transmitting on 118.15 was shown to jam an external mounted antenna. Narco MK 16 tuned to any 115 or 109 Nav channel was shown to jam a hand held GPS. Narco MK 12D/E and Nav 824/825, if not wired with memory keep alive, will default to 115.5 MHz in the active channel and will jam any GPS receiver.

6 Need Additional Support?

Contact uAvionix Support. A support ticket can be submitted at https://uavionix.com/support. Please include any PAPR reports and extended data to improve our response time.