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# Aviation Safety Analysis & Training Solutions

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## Introduction

This document is intended to improve general aviation and airline safety through a statistical analysis of past accident causes, a breakdown of the Airmen Certification Standards (ACS), an guide to risk management, solutions to top C-FIT causes that lead to fatal accidents, and what we can learn from loss of control in-flight (LOC-I). We've compiled a list of data from different official sources. Preventing aviation accidents comes down to staying proficient and having a mindset in the cockpit at all times.

## Statistical Analysis of Past Aviation Accidents

The charts below show the number of total general aviation accidents and their causes from 1990 to 2019, respectively.

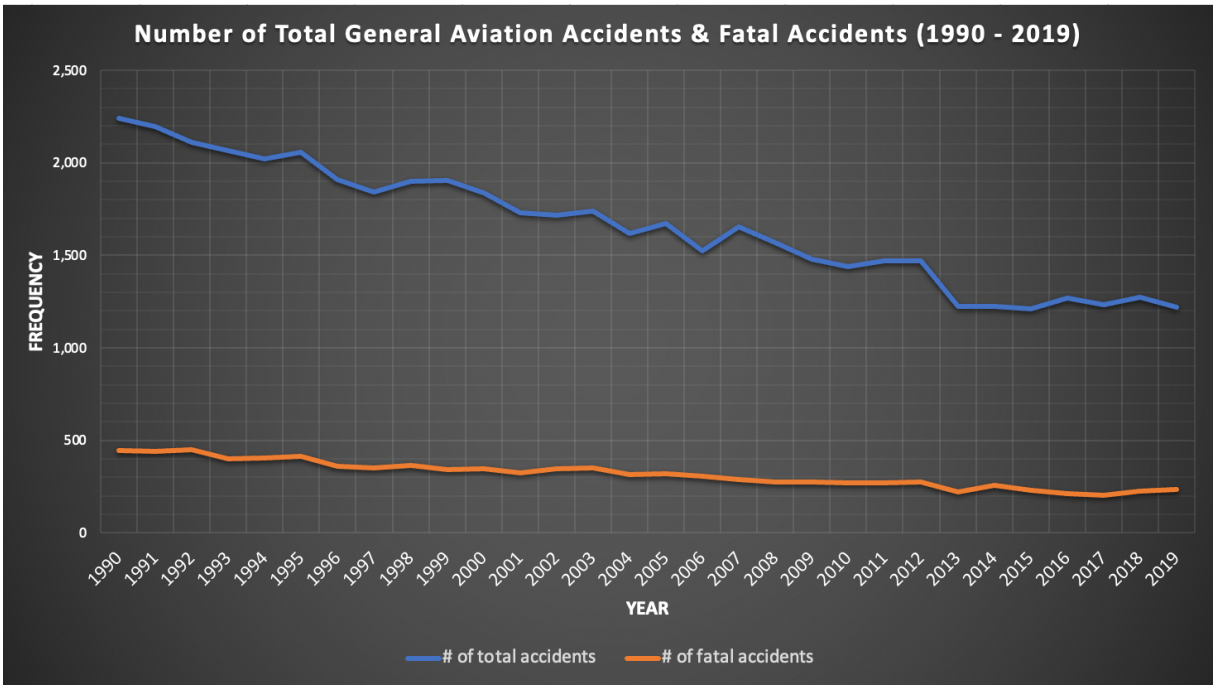


Figure 1. The total number of GA accidents compared to fatal GA accidents. The total number shows a 46% decline over the past three decades, and the number of fatal accidents shows a 47% decline. In 2019, 19% of GA flights were fatal. (Source: Bureau of Transportation Statistics).

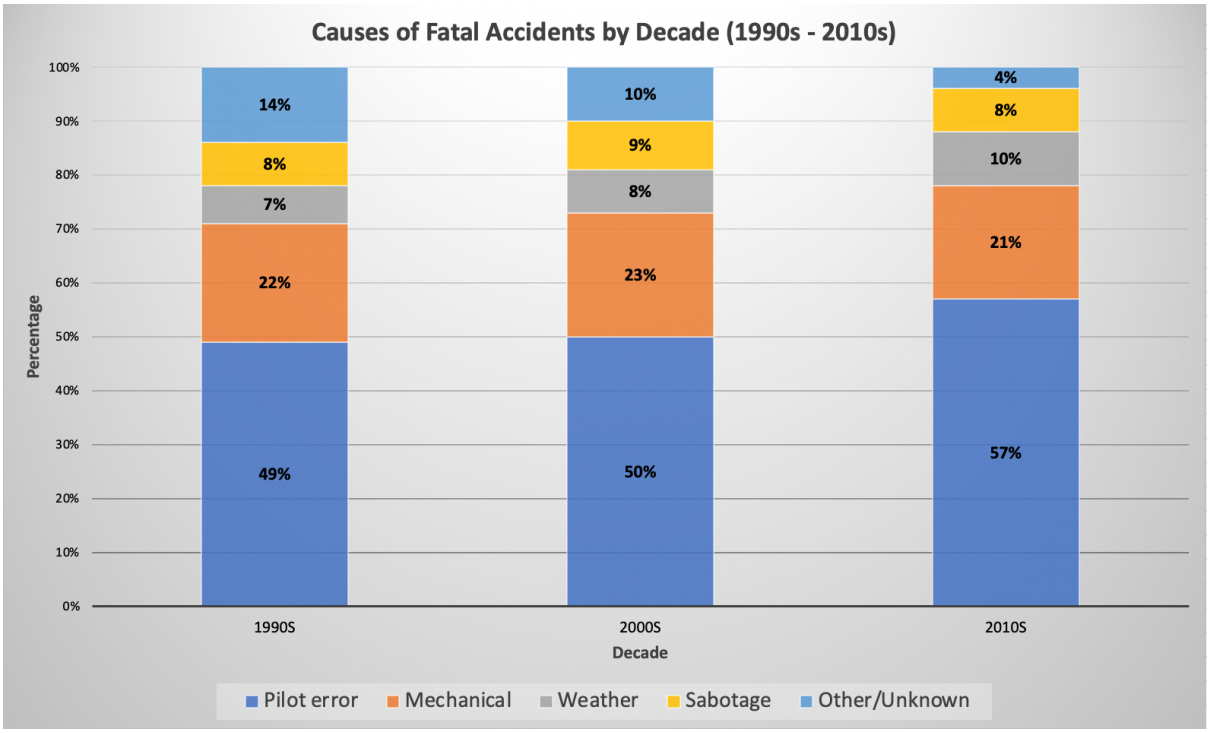


Figure 2. The 5 causes of fatal accidents in the past three decades. (Source: planecrashinfo.com)

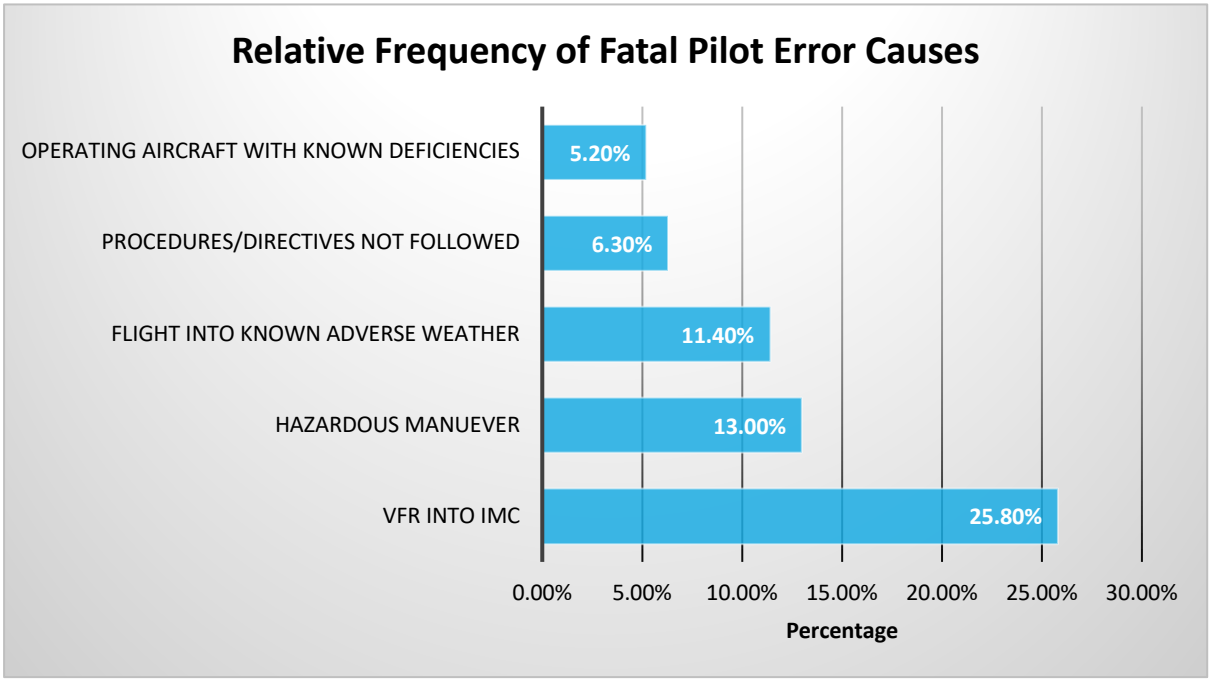


Figure 3. The relative frequencies for the top 5 pilot error causes that lead to fatal accidents. VFR into IMC accounted for 25.8%. (Source: FAA)

## ACS (Airman Certification Standards) Breakdown for PPL, IR, CPL, and ATP

The ACS is the guide for flight students, instructors, and FAA examiners to understand the applicant's knowledge requirements for the FAA Knowledge Exam and the practical checkride, in order to obtain a certificate or a rating. This section compares the PPL, IR, CPL, and ATP requirements with each other. Every pilot must be proficient in each of these items to earn his or her certificate.

**Note**: The same requirement in PPL can be different in CPL or ATP, depending on the certificate/rating the applicant plans to obtain. For full explanations of each section, please refer to the FAA website.

ASEL - Airplane, Single Engine Land
ASES - Airplane, Single-Engine Sea
AMEL - Airplane, Multi-Engine Land
AMES - Airplanes, Multi-Engine Sea

Criteria for PPL, IR, CPL, ATP: (Are you 100% proficient?)

I. Preflight Preparation

1. Pilot Qualifications **(PPL, IR, CPL )**
2. Airworthiness Requirements **(PPL, CPL )**
3. Weather Information **(PPL, IR, CPL, ATP)**
4. Cross-Country Flight Planning **(PPL, IR, CPL )**
5. National Airspace System **(PPL, , CPL )**
6. Performance and Limitations **(PPL, , CPL, ATP)**
7. Operation of Systems **(PPL, , CPL, ATP)**
8. Human Factors **(PPL, , CPL, ATP)**

9. Water and Seaplane Characteristics, Seaplane Bases, Maritime Rules, and Aids to Marine Navigation (ASES, AMES) **(PPL, , CPL, ATP)**
10. High Altitude Aerodynamics (AMEL, AMES) **( ATP)**
11. Air Carrier Operations (AMEL, AMES) **( ATP)**
12. The Code of Federal Regulations **( ATP)**

II. Preflight Procedures

1. Preflight Assessment **(PPL, , CPL, ATP)**
2. Flight Deck Management **(PPL, , CPL )**
3. Engine Starting **(PPL, , CPL )**
4. Powerplant Start **( ATP)**
5. Taxiing (ASEL, AMEL) **(PPL, , CPL, ATP)**
6. Taxiing and Sailing (ASES, AMES) **(PPL, , CPL, ATP)**
7. Before Takeoff Check(s) **(PPL, , CPL, ATP)**
8. Airplane Systems Related to IFR Operations **( IR )**
9. Airplane Flight Instruments and Navigation Equipment **(IR )**
10. Instrument Flight Deck Check **( IR )**

III. Airport and Seaplane Base Operations

1. Communications, Light Signals, and Runway Lighting Systems
2. Traffic Patterns

IV. Takeoffs, Landings, and Go-Arounds

1. Normal Takeoff and Climb
2. Normal Approach and Landing
3. Soft-Field Takeoff and Climb (ASEL)
4. Soft-Field Approach and Landing (ASEL)
5. Short-Field Takeoff and Maximum Performance Climb (ASEL, AMEL)
6. Short-Field Approach and Landing (ASEL, AMEL)

7. Confined Area Takeoff and Maximum Performance Climb (ASES, AMES)
8. Confined Area Approach and Landing (ASES, AMES)
9. Glassy Water Takeoff and Climb (ASES, AMES)
10. Glassy Water Approach and Landing (ASES, AMES)
11. Rough Water Takeoff and Climb (ASES, AMES)
12. Rough Water Approach and Landing (ASES, AMES)
13. Forward Slip to a Landing (ASEL, ASES)
14. **(CPL)** Power-Off 180° Accuracy Approach and Landing (ASEL, ASES)
15. Go-Around/Rejected Landing

V. Performance and Ground Reference Maneuvers

1. Steep Turns
2. Ground Reference Maneuvers
3. **(CPL)** Steep Spiral (ASEL, ASES)
4. **(CPL)** Chandelles (ASEL, ASES)
5. **(CPL)** Lazy Eights (ASEL, ASES)
6. **(CPL)** Eights on Pylons (ASEL, ASES)

VI. Navigation

1. Pilotage and Dead Reckoning
2. Navigation Systems and Radar Services
3. Diversion
4. Lost Procedures

VII. Slow Flight and Stalls

1. Maneuvering During Slow Flight
2. Power-Off Stalls
3. Power-On Stalls
4. Spin Awareness

5. **(CPL)** Accelerated Stalls

VIII. Basic Instrument Maneuvers

1. Straight-and-Level Flight
2. Constant Airspeed Climbs
3. Constant Airspeed Descents
4. Turns to Headings
5. Recovery from Unusual Flight Attitudes
6. Radio Communications, Navigation Systems/Facilities, and Radar Services
7. **(CPL)** High Altitude Operations [1]
    I. Supplemental Oxygen
    II. Pressurization

IX. Emergency Operations

1. Emergency Descent
2. Emergency Approach and Landing (Simulated) (ASEL, ASES)
3. Systems and Equipment Malfunctions
4. Emergency Equipment and Survival Gear
5. Engine Failure During Takeoff Before VMC (Simulated) (AMEL, AMES)
6. Engine Failure After Liftoff (Simulated) (AMEL, AMES)
7. Approach and Landing with an Inoperative Engine (Simulated) (AMEL, AMES)

X. Multiengine

1. Maneuvering with One Engine Inoperative (AMEL, AMES)
2. VMC Demonstration (AMEL, AMES)
3. One Engine Inoperative (Simulated) (solely by Reference to Instruments) During Straight-and-Level Flight and Turns (AMEL, AMES)

[1] Commercial Pilot – Airplane Airman Certification Standards [PDF]. (2018, June). U.S. Department of Transportation, Federal Aviation Administration. https://www.faa.gov/training_testing/testing/acs/media/commercial_airplane_acs_change_1.pdf

4. Instrument Approach and Landing with an Inoperative Engine (Simulated) (solely by Reference to Instruments) (AMEL, AMES)

XI. Night Operations

1. Night Preparation

XII. Postflight Procedures

1. After Landing, Parking and Securing (ASEL, AMEL)
2. Seaplane Post-Landing Procedures (ASES, AMES) [2]

[2] Private Pilot – Airplane Airman Certification Standards [PDF]. (2018, June). U.S. Department of Transportation, Federal Aviation Administration. https://www.faa.gov/training_testing/testing/acs/media/private_airplane_acs_change_1.pdf

# Guide to Risk Management

There are two kinds of risk management training: system safety training and setting own personal minimums and alternative plans in different scenarios. The old FAA PTS (Practical Test Standards) emphasizes too much on stick-on-rudder performance, or simply knowing the aircraft system and flying the airplane. That isn't enough when it comes to tricky scenarios such as suddenly having a light headache, facing a passenger medical emergency, or entering unfamiliar terrain or an airport. System safety training mostly comes from training proficiency, but it is equally important to set hard personal minimums before each flight, and be actively looking for subtle indications to change plans during the flight.

**The 7 Strategies:**

1. Know the weather minimums (DIFFERENT from airspace weather minimums)
    a. VFR: >3,000ft AGL **AND** > 5SM
    b. MVFR: 1,000 - 3,000ft AGL **AND/OR** 3-5SM
    c. IFR: 500 - 999ft AGL **AND/OR** 1 – 2.9SM
    d. LIFR: <500ft AGL **AND/OR** < 1SM

2. Evaluate your comfort level & experience
    a. What are the lowest weather conditions you've ever had?
    b. Night-time VFR: e.g. Anything lower than 5,000ft & 7SM should be a warning
    c. Record the **most challenging** weather conditions you've dealt with comfortably in the last 6-12 months. Examples:
        i. Day:
            1. VFR/MVFR: 2,500ft, 4SM
            2. IFR/LIFR: 600ft, 2SM
        ii. Night:
            1. VFR/MVFR: 4,000ft, 6SM
            2. IFR/LIFR: 900ft, 2SM

3. Wind speed, gusts, crosswind
    a. Record the **most challenging** wind conditions you've dealt with comfortably in the last 6-12 months. Examples:
        i. Maximum wind speed (SE/ME): 12kn SE, 17kn ME
        ii. Maximum wind gusts (SE/ME): 5kn SE, 8kn ME
        iii. Maximum calculated crosswind component (SE/ME): 8 SE, 8 ME
    b. Record yours:
        i. Maximum wind speed (SE/ME):
        ii. Maximum wind gusts (SE/ME):
        iii. Maximum calculated crosswind component (SE/ME):

4. Runway length, terrain, density altitude
    a. Record the **most challenging** conditions you've dealt with comfortably in the last 6-12 months. Examples:
        i. Shortest runway length: 2,000ft SE, 4,000 ME
        ii. Highest terrain: 4,000ft SE, 6,000ft ME
        iii. Highest density altitude: 3,500ft SE, 3,500ft ME
    b. Record yours
        i. Shortest runway length:
        ii. Highest terrain:
        iii. Highest density altitude:

5. Practice adjusting personal minimums, but STICK TO THE PLAN BEFORE each flight
    a. **NEVER LOWER** your personal minimums in flight. ALWAYS stick to your preflight plan
        i. That includes lowering the ceiling minimum, wind speed & gusts, etc. There's NO purpose of doing so during the flight.

6. Adjust **Personal** Minimums in **Pre-flight**
    a. Set hard values **before** each flight
    b. Use the PAVE checklist:
        i. **P**ilot: (Key: Pilot currency & physical and emotional conditions)

1. Check your physical conditions using the IMSAFE checklist
    a. **I**llness – Am I physically or emotionally ill?
    b. **M**edication – Any medicine that might affect your judgement?
    c. **S**tress – Will stress affect my in-flight performance?
    d. **A**lcohol – Any ingestion of alcohol over the last 8 hours? Set personal minimums depending on your physical conditions
    e. **F**atigue & Food & Water – Lack of food & water can cause fatigue
    f. **E**motion – Think through your state of mind

ii. **A**ircraft (unfamiliar aircraft, avionics, type):
1. Check aircraft limitations & performance numbers
    a. Never push too close to the limits – those numbers are created in test flights, not in yours
2. Check fuel capacity & fuel reserves
3. Check for proper equipment for the flight
    a. e.g. radio, lights, navigation
4. Runways
    a. Can the aircraft perform takeoffs & landings at an airport with adequate margins?

iii. en**V**ironment (weather, terrain, unfamiliar airspace):
1. Weather Conditions
    a. Check ceiling & visibility & winds at airports and aloft
    b. Important: The actual conditions can be different than the forecast → Have alternative plans (e.g. airport diversions, action plans for VFR into IMC)
    c. Are there thunderstorms? Icing in clouds?
2. Terrain
    a. Have proper altitudes for terrain clearance
    b. Are you flying over water / unpopulated areas? If so, what is the backup plan?

c. Flying into remote areas? Bring survival gear.

3. Airspace
    a. Check NOTAMS
    b. SUA (special use airspace) or TFRs (temporary flight restrictions) to avoid?
4. Flying at Night
    a. considered as IFR flight

iv. **E**xternal Pressure (pressure from passengers, upcoming meetings):

1. Have your own SOP
    a. e.g. have alternative plans
2. Allow extra time
    a. Inform passengers / family members / personnel of a LATE arrival

v. The "Compounding Effect"

1. Risk factors are cumulative. If there is more than one unchecked marginal factor in your PAVE checklist, it is a no go.

7. <u>During the Flight</u>
    a. Deal with changes during the flight
    b. Use the CARE checklist:
        i. **C**onsequences
            1. **P**ilot
                a. Look for changes in yourself as the pilot – Fatigued? Stressed?
            2. **A**ircraft
                a. Less fuel as the flight progresses
            3. En**v**ironment
                a. Terrain & weather is ALWAYS changing
            4. **E**xternal Pressures
                a. Goal-oriented behavior will intensify
                    i. e.g. You will be less willing to go missed / divert as the destination comes closer

5. Takeaway: If conditions (yourself, weather, aircraft, pressure) are rapidly changing, get on the ground NOW.

ii. **A**lternatives

1. Have the Murphy's Law mindset – **anything that can go wrong will go wrong.** Things will not go exactly as planned
2. Important: The range of alternatives will become smaller as the flight progresses, thus it is important to think about more alternatives as you fly closer to the destination.
    a. Examples: Runway closures, passenger conditions, bad weather (e.g. turbulence, icing), emergencies
3. Be prepared to make decisions in the air and take action

iii. **R**eality

1. Flying is dynamic – everything changes
2. Accept the reality and change your plan
    a. Example: avoid VFR into IMC/worsening weather by setting VFR minimums before continuing

iv. **E**xternal Pressure

1. Manage your own goal-oriented behavior – do not let it affect your original in-flight performance and decision making

8. Conclusion:

GA aircraft accidents can very often be caused by pilots' bad ADM (aeronautical decision-making) even though they may think they are in compliance with other FAA regulations. Pilots should take note that FAA regulations are revised AFTER the accident or incident, not beforehand. Although practicing ADM may not be something is included in everyday training, the PIC must clearly make his/her action before and during each flight, sticking to his/her personal minimums and changing the course of action up in the air to conduct a safe and smooth flight. [3]

[3] Federal Aviation Administration, Risk Management Handbook (2009). https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/faa-h-8083-2.pdf.

# What We Can Learn from C-FIT (Controlled Flight into Terrain)

Does C-FIT primarily occur at night as pilots sometimes have more trouble in unfamiliar locations? It may be logical to think that C-FIT involves inexperienced pilots flying in the dark where they do not have visual reference to the outside. But surprisingly, the first statement is false. The General Aviation Joint Steering Committee (GAJSC) reported that a vast majority of C-FIT accidents occur in daylight, but more interestingly, in visual conditions as well. And according to FAA, C-FIT accidents account for 17% of all fatalities in general aviation. So how could pilots control their flights into terrain where they could've seen the obstacles ahead – in daylight and in visual conditions?

Top causes of C-FIT (in no particular order):

Note: This is not an exhaustive list.

1. Wire strikes
2. Setting unrealistic aircraft performance expectations
3. IFR procedural mistakes
4. VFR into IMC
5. Loss of situational awareness

Solutions:

**Solutions to Wire Strikes** (Key: Add extra altitude)

- Cause: This can happen when the aircraft is flying over highways at a low altitude
- Add extra altitude when flying low, as most wire strikes occur <200ft AGL

**Solutions to setting unrealistic aircraft performance expectations**

- Cause: Reaction time is reduced when the aircraft suffers from a mechanical failure, leading to impact
- Solution: Add extra altitude

**Solutions to IFR procedural mistakes**

- Carefully read the missed approach procedure. "Climb to 2000 then climbing left turn to 3000 direct GANSE" is **different** than "Climbing left turn to 2000 then climb to 3000 direct GANSE".

- Go missed **immediately** at the missed approach point. Remember to suppress your goal-oriented behavior and don't cut corners.
- Do not descend below the minimum descent altitude (MDA). Only do so if:
    - The aircraft is at a position from which a descent to landing on the intended runway can be made at a normal rate of descent with normal maneuvers.
    - The flight visibility meet/exceeds the minimums prescribed in the standard minimum approach
    - At least one of the visual reference can be distinctly identified: The approach light system (with exceptions[4]), threshold markings, threshold lights, runway end identifier lights, visual glideslope indicator, touchdown zone / its markings or lights, runway or runway markings, runway lights
- Have adequate IFR equipment.[5]
- Build experience during flight training. The minimum is 40 hours to obtain a IR certificate, but allow more time to be comfortable flying through instrument conditions.
- Focus on the instruments. Do NOT trust your physical senses.

**Solutions to VFR into IMC** (Key: Do NOT trust your physical senses in IMC conditions)

- Avoiding IMC:
    - Have a thorough preflight briefing. Always have alternative plans on the ground
    - Be ready to change/execute your plan at ANYTIME the air if weather starts to deteriorate
- If Inadvertently entered IMC:
    - Make a **slow, coordinated** 180˚ turn can often quickly get you out of IMC conditions. Always follow your instruments during the turn to avoid spatial disorientation and dizziness. Keep an eye on the bank angle to avoid loss of control.

[4] See FAR 91.175(c) for more information. https://www.ecfr.gov/cgi-bin/text-idx?&rgn=div5&node=14%3A2.0.1.3.10#se14.2.91_1175.

[5] See FAR Part 91.205 for a complete list of equipment required for IFR flight. *Electronic Code of Federal Regulations*. Electronic Code of Federal Regulations (eCFR). (n.d.). https://www.ecfr.gov/cgi-bin/text-idx?pitd=20170830&node=se14.1.91_1205&rgn=div8.

    - Having equipment such as an ADS-B receiver can help – make sure to check your instruments & equipment on the ground

**Solutions to Loss of Situational Awareness**

- This is present in almost all of CFIT accidents. Causes include having cockpit distractions, complacent behaviors, goal-oriented mindsets, heavy workload, and poor experience.
- Solutions:
    - Do not trust your expectations. Constantly be aware of updated information and actively scan for new data.
    - Think ahead – use PAVE checklist on the ground, use CARE checklist in the air, and **always** have alternative plans on the ground & in the air. Remember, anything that can go wrong will go wrong.
        - Fatigue causes poor decision-making and loss of situational awareness. Make sure to check-in with yourself, the pilot-in-command, and your physical and physiological conditions.
    - Trust the instruments in IFR conditions, even if you think it may be faulty.

<u>Conclusion</u>:

In addition to the above, it is important to use SRM (single-pilot resource management). The 5 P's – Plan (route, fuel, weather), Plane (equipment, avionics, abnormal indications), Pilot (the IMSAFE checklist), Passengers (anxiety, discomfort – use the PAVE and CARE checklists), and Programming (electronic instrument displays) – can be used to mitigate risks during the flight.

## What We Can Learn from Loss of Control-Inflight (LOC-I)

Loss of control-inflight is the number one cause of all GA accidents. Most factors can contribute to LOC, but the most common ones are system failures, environmental factors, and pilot errors. According to ICAO, LOC-I accidents represented 3% of all accidents in 2015, but 33% of all fatal accidents. 93% of LOC-I result in hull losses, while 90% involve fatalities. [6] In fact, the FAA states that there is one fatal accident involving LOC every four days. [7]

Excluding some systems failures, LOC accidents can be reduced using similar strategies discussed earlier in the document.

Solutions (non-exhaustive):

- CRM (crew resource management)
    - Have effective communication and accurate cross-checks
- Plan for emergencies
    - Go through emergency procedures regularly, familiarize / memorize with checklist procedures in order to reduce reaction time
- Vocalize every action in the cockpit, including during takeoff, landing, pre-takeoff, and pre-landing
- PAVE and CARE checklists are very important (refer to pg. 6-10 – Guide to Risk Management)
    - Always be ready to change your course of action during the flight.

[6] Flight Safety Foundation. (n.d.). Loss of Control–In Flight (LOC-I) Archives. https://flightsafety.org/safety-issue/loc-i/.

[7] Federal Aviation Administration. (2015, July 6). Fly Safe: Prevent Loss of Control Accidents. https://www.faa.gov/news/updates/?newsId=83285.

## Other Useful Official Resources

This document only provides analysis and potential solutions to common aviation accident causes. Because this is non-exhaustive, we recommend referring to the official manuals & websites below for further information.

List of all FAA Handbooks & Manuals

General, Comprehensive Manuals:

- Pilot's Handbook of Aeronautical Knowledge
- Airplane Flying Handbook
- Aeronautical Chart Users' Guide
- Federal Aviation Regulations (FAR)
- Aeronautical Information Manual (AIM)

Instrument-related:

- Instrument Flying Handbook
- Instrument Procedures Handbook

Risk Management & Safety-related:

- Risk Management Handbook
- Safety Risk Management
- Aeromedical Safety Brochures
- FAASafety.gov