Instrument Reconstruction Hints

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Instrument reconstructions and analysis is often very important in determining why an airplane may have crashed. The variety of accident will determine how important instrument condition may have been. Obviously a loss of control accident in instrument flying conditions makes it important to examine all flight instruments. In these cases there are two very helpful clues that should be utilized initially:

A. A radar reconstruction- from this we can determine the aircraft flight path and airspeeds.

B. Radio communications with the F.A.A.

It is noteworthy that Federal Air Regulations require a pilot to announce lost instruments to the F.A.A. if that loss diminishes ability to comply with instrument flight capacity. Thus it was in a General Aviation case I did near Bay Minette, Alabama. The pilot, a high time, instrument pilot radioed "I'm *in the clouds, my attitude indicator just tumbled*"

What a clue! The attitude indicator is the primary instrument used for flying in clouds.

On wreckage review we recovered the indicator and had it torn down. Inside it there is a balance weight known as the trapeze. It was held in place with a screw and the screw was to be secured with a GLYPTOL no back glue. It appeared that there never was any glyptol, the screw had backed out, and the trapeze was loose. Without the trapeze the attitude would fail or at least be incorrect.

Another real clue from which to compare instruments to is the aircrafts first impact with the ground. A lot can be learned from the wreckage and the hole in the ground. Steep or shallow dive the laws of physics remain the same. Wreckage scatter will continue in the direction of flight. Thus from the hole and a compass you may determine azimuth. If the aircraft was other than level you may find wing gouges that tell you angle of bank at impact. The dimensions of the hole and destruction of aircraft structure gives a clue as to speed at impact. So does the length of a wreckage distribution path subsequent to the ground impact. From the ground and scatter pattern we can approximate, angle of bank, yaw if any, dive angle, and speed.

A RULE: THE STEEPER THE DIVE,THE HIGHER THE SPEED,THE MORE LIKELY IMPACT MARKS ON AIRCRAFT COMPONENTS ARE GIVING VALID INDICATIONS OF WHAT THEY WERE DOING at impact

If a man jumps off the Empire State building and his watch crushes you have a good idea of the time of death. The idea is that ground impact produces impact marks-called

witness or capture marks by those in the business. Capture marks are those indentations made on a component such that the component is frozen and can not move from that position. Impact or witness marks are indentations made on components as a result of impact, but the component is not frozen and so they are indicative of a condition during impact or subsequent secondary impacts.

In a high speed steep dive it is likely that there is little subsequent motion and the impact marks are likely capture marks and therefore indicative of the condition at impact.

Since the most important flight instrument is the A.D.I. (Attitude and Direction Indicator) I will direct my discussion to the investigation of this instrument. This instrument gives the pilot his dive or climb indication as well as his wing roll condition.

The instrument is a movable globe or roll painted blue for sky and black for ground. On this globe every 10 degrees there are lines for dive or climb angles. Stationery around the face of the instrument are gradations in 10 degree increments that depict roll angles of the wings. A small airplane like device is held stationery in front of the globe. The globe is free (because of gimbals) to move in roll and pitch axis so the display that the pilot sees is his airplane relative to the movable horizon.

All varieties of A.D.I. instruments are delicate watch like instruments. All varieties of A.D.I. instruments rely on high speed gyroscopic devices for alignment of the instrument's globe to the earths horizon. You remember that a top is stable in space because of its high speed rotation. That is the gyroscopic principle.

As part of all mechanical gyros there are two rapidly spinning gyros aligned vertically and the other horizontally at start up. Once these gyros are started they will remain stationery relative to the original start up directions. This is made possible since they too have virtually friction free gimbals that allow three degrees of freedom.

An investigator then has three pieces of evidence to correlate. The indications derived from the hole in the ground and wreckage should be the same as the impact marks associated with the A.D.I. face and globe, and these in turn should be the same as the capture marks on the gyro system at the gimbals if all systems were working at impact. When the impact angles are shallow and there are multiple impacts it is incumbent for the investigator to determine which witness mark of the many was made first. This is analogous to determining the first break in the midair separation scenario.

There are a couple of rules for the A.D.I. globe that aid in this determination.

A. If the instrument is captured or frozen or damage is severe enough to have captured an intact instrument at some reading and there are other witness marks, THEN THE OTHER WITNESS MARKS HAD TO HAVE OCCURRED EARLIER. If those earlier witness marks are sequential toward the final capture mark then probably the farthest away is the valid first mark.

B. If a witness mark shows scraping or tailing that shows direction of movement then one should look upstream of this mark for an earlier mark downstream occurs later

Let it be said that there are at least four general variants of the A.D.I. instruments that

are in use commonly.

a. A vacuum driven self contained gyro instrument
b. An Electric driven self contained gyro instrument
c. An electric driven remote gyro instrument
d. An electric driven remote inertial gyro platform instrument

An A.D.I. instrument may be fully acrobatic or it may be incapable of such maneuvers. If it is non acrobatic and the airplane was tumbling it would be expected to have an erroneous indication at impact. Before continuing let it be said that an investigator need have the appropriate manuals for the type and variety of instruments he is attempting to analyze. Further he must understand the workings of the instrument within the aircraft he is investigating.

Most electrical gyros have two separate failure flags that are supposed to come into view with failure modes. They are a "power flag" and an" OFF" flag. One displays if the signal has been lost to the instrument. The other displays when there has been a loss of electricity to power the instrument.

Indications that either flag was in view at time of impact was a clue that there was a failure.

Clues an investigator should look for in any A.D.I. investigation

1. Flags in view
2. Capture position of the globe
3. Capture position of the gimbals and bearings
4. Witness marks of the aircraft symbol on the face of the globe
5. Glass shards imbedded in the globe
6. Identifiable witness marks from support frames of instrument to movable globe.
7. Human matter on face of globe. This occurred early in break up
8. Puncture marks in back of globe
9 Other marks identifiably made from contact of the globe with the frame of instrument.

Clues an investigator looks for in the tear down of the gyro system if it is self contained, remote or an inertial navigational gyro platform.

a. Capture marks of the gimbal angles
b. Capture of mechanical devices used to power the repeaters
c. Rotational scoring between gimbals and rotating gyros
d. Bluing of metal due to rotational friction
e. Torque breaks
f. Brake positions (support of gyro when not running-some models)

Note: on the very sophisticated gyros and inertial units the speed of rotation of the gyro is about 25,000 R.P.M. Even though the gyros are small the edge of the gyro is

moving at about 500 feet a second. This is very high energy. If the case for the gyro breaks on impact the delicate gimbals release and the gyro energy is freed uncontrolled. The container is literally exploded by the gyro trying to escape. It is the rule not the exception to find a gyro platform that has its case crushed spread all over the accident scene because of the release of the gyros. If this is not the case then you can assume that the gyro was not running at the time of impact. If the gyro wasn't running then the A.D.I. had necessarily failed pre impact.

In the somewhat infamous legal case Harduvel vs. General Dynamics, later made the basis for the H.B.O. film "AFTERBURN ", this was the most cogent part of the proof that TED HARDUVEL had lost his instruments. The Inertial gyro case had been found crushed but otherwise intact. Internal investigation showed that the gyros had captured differently than the ground impact, differently from the standby or back up indicator, different from the cockpit instrument. It was said that if the gyros had been rotating that the instrument would have exploded like a hand grenade because of the release of internal gyro energy.

Notably the manufacturer admitted that although the same or similar gyro platform was installed in F-4, A-7, F-11, and F-16 airplanes that the Harduvel accident was only the second time that they had received an intact Inertial Platform for tear down subsequent to an accident! More noteworthy was there admission that the only score mark found on the gyro itself was a gouge progressing opposite the direction of normal expected rotation.

The attorney should be advised that teardown and analysis of these instruments ranges from simple logic to sophisticated metallurgical microscopic examinations. These guidelines are sufficient to help you determine the depth of investigation required. The most important facet is to determine the first impact marks. (The later marks only tell what happened subsequent to ground impact.)

Another primary instrument that is often implicated in investigations is the altimeter. Usually the instrument is a three pointer dial with gradations for 10,000 feet, 1,000 feet and feet. There are variants of pointers and digital readouts. Most have pointers and all have a place for the pilot to set the appropriate altimeter setting. A normal altimeter (standard day is 29.92 inches of pressure.)

A failure to set the appropriate -current altimeter will result in a 100 foot altitude error for every 0.10 inch not set correctly. Thus there is the first thing an investigator looks for when investigating the barometric altimeter. WAS IT SET CORRECTLY?

Next the investigator wants to know if it was reading correctly at impact.

1. If it is crushed and frozen that is some indication that it was reading the same at impact.

2. Since the impact forces may be great the investigator looks for "needle slap" against the face. This is simply a witness mark of needle impact with the dial.

3. Sometimes" needle slap" is not visible to the human eye. There may have

been minute paint transfer of luminous paint to the dial.
Then BLACK LIGHT may be utilized to see the indications.
4. Often the face and needles are broken and missing. There may be probative evidence derived from capture of the internal gear trains and bellows armatures. This takes a real expert investigator.

Investigation of other instruments other instruments utilize the same techniques as described above. When dealing with electrical instruments some retain the last reading at loss of electric power, others attempt to return to zero on loss of power. Generally a D.C. powered instrument will return to zero an A.C. Powered instrument will retain its last reading.

Obviously this is a technical and sophisticated business and you require a real experienced investigator.