INVESTIGATIVE CLUES

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An investigator and lawyer should recognize that the following lists of Clues are helpful hints that may come into play in the investigation that is being undertaken. Just as massive portions of the investigators check list are inappropriate to a particular fact situation so are many of these clues inapplicable to a certain fact situation.

Experience and simple logic will tell the investigator and lawyer whether a specific topic listed below is of concern or whether it may be omitted. Let it be said that for each circumstance and component the investigator must understand the component and it's interaction with the system as a whole. Then having schematic, overhaul manuals and blueprints the investigator can derive the operation condition at the time of crash. Once this condition is recorded the investigator can make a valid determination that the part was a player in the cause of the accident.

Alternator: A device similar to a generator. The investigator will see that its drive is connected. That the belt is present. That it shows cooling fin bends opposite normal rotation. That it shows rotational scoring and bluing. That it shows rotational damage.
If it is unhurt it may be bench checked if required. The presence and severity of rotational damage will show that it was connected at impact and will be a secondary clue to engine power at impact.

Accessory Section: Various components exist here that are run by the engine. These are checked to see integrity, rotational damage, and gear chattering. Drive shafts may be broken with torque damage evident due to sudden stoppage. Damage to the accessory section may be used as secondary evidence of engine power at impact.

Air Conditioning Packs: Air Conditioning packs are run from a single source of pneumatic air. During heavy weight take offs they may be turned off. They may be turned off with loss of an engine. Thus the investigator looks to cockpit switch position to make this determination. When a pack is running it is powered by pneumatic air, thus the investigator establishes pneumatic air valve positions when he is able. The main clue to pack operation will be rotational damage, scoring and bluing if the case is crushed into the moving parts.

Air Cycle machines: A component of the air conditioning system. The investigator is looking for rotational damage, scoring and bluing to determine if it was running.

Aircraft Logbook: The investigator should retrieve a copy of the aircraft logbook and engine logbook. He will check the maintenance history of the aircraft and engine maintenance and performance. This may give him clues as to re-occurring gripes and problems.

Afterburners: In military jets the investigator will look for jet nozzle geometry to determine nozzle positions. Witness marks on the nozzle geometry will tell the investigator, whether burner was selected. (Burner can not be selected at less than military power) Secondary clues are the valves supplying fuel to the burner.

Anti Skid Brakes: Most large sophisticated aircraft utilize anti -skid brake systems. The investigator will look to the aircraft switch positions (normally on) .The aircraft logbook to see if it was operable.

The investigator will look at the runway for skid marks. If there is a skid mark from only one tire then the antiskid provision has failed to release for that tire and another. If at touchdown all tires leave skids the anti skid did not work or was not selected. (Or the park brake was set prior to landing-this locks anti skid out)

If before going off the end of the runway there are skid marks on all tires, the investigator should see if the emergency pneumatic air brakes had been applied. Icing conditions or hydroplaning conditions make these determinations more difficult. Other clues, logbook write ups such as: aircraft pulls left or right, check for dragging brakes, anti skid release lights did not cycle.

Anti Icing Valves: Many airplanes utilize hot engine bleed air for anti icing of wings, tails and engine nacelles. The usage of such devices will require certain engine bleed air valves and duct pneumatic valves to open. The investigator should attempt to ascertain cockpit ice switch positions and correlate these to valve positions at the engine and at the pneumatic valves. Some valves are electrically initiated, pneumatically regulated and spring loaded closed. Thus an undamaged valve of this variety (if unhurt) may change position. An investigator should look for impact witness marks to determine condition at impact.

Also most such systems illuminate light bulbs in the cockpit when on. Thus a filament investigation is helpful. Some modern Digital Flight recorders may record valve conditions.

Autopilot components: Autopilots are very complex devices. They are designed to fly the airplane without pilot input. They can climb, dive, level off at assigned altitude, turn, navigate on airways, fly assigned headings, fly assigned altitudes, and fly I.L.S. approaches. Some control the throttles and some even flare land and roll out. When a good autopilot is present a pilot relies on it for many functions. In some very bad fog conditions it must be utilized to make the approach legally.

Naturally the system must have electronic inputs from, altimeter, airspeed, Air data computer, and directional and artificial horizon platforms. It must also have input from navigational radios if that mode of operation is to be selected. The more complex ones need input from engine power and radar altimeter at the wheels. Thus the autopilot needs a sophisticated computer to analyze and input electronic control signals. These electronic signals are amplified and sent to control actuators (electric or hydraulic). There are safety devices known as clutches that will release if the pilot opposes bad inputs. The amount of control wheel force determines whether the clutches will disengage. They are set well below human strength. The newest derive data from satellites as well. The computer: The main computer and air data computer should be preserved if possible. These should be protected from the elements and placed in a static free bag. Investigation of these components should only be attempted in a capable laboratory.

Head: The autopilot head is what the pilot utilizes in the cockpit to select and operate the functions of the autopilot. This is sometimes called the mode control panel or M.C.P. They typically have an on/off switch, an attitude/climb mode switch; an altitude hold mode switch, a heading command mode switch, and a radio nav mode switch an approach mode switch and a sophisticated nav mode switch.

These selector switches are different with differing models. (Some are actual toggle switches, and the more modern are press to latch switches. When the mode selector switches are press to latch they usually have electric light signs that illuminate when selected. Thus when a mode is selected it will illuminate as being armed. Another mode control light panel will show whether the mode is only armed or when it is in command it will annunciate its operation. Thus the investigator can determine switch position from the head and can do a filament analysis of the mode control lights.

Pitch computer and amplifier: This black box analyses the requirements for nose up /nose down flight commands. It then disseminates a signal to the amplifier where it is multiplied and supplied to a control actuator. These boxes should be recovered, protected and returned to a lab.

Pitch trim computer: Whenever an aircraft pitch input is commanded by the autopilot the pitch trim is simultaneously activated through its computer to alleviate the control forces being applied by the pitch controller. The job of the pitch trim computer is to always maintain the aircraft in trimmed flight so that when the autopilot is turned of there will be no noticeable dive or climb input. It should be saved in the similar fashion and returned to a lab.

Roll Computer and Amplifier: The same as the pitch computer except these controls the ailerons and therefore aircraft roll.

Clutches: These devices are the emergency break out forces that allow a pilot to overcome unwanted autopilot input. These should be recovered and taken to a laboratory and tested to see that they were adjusted correctly (often the same clutch is used in differing aircraft and the forces are adjusted for the model aircraft. If these are rusted or miss set the result may be catastrophe.

Auxiliary Power units: Are self contained engines aboard an airplane that can produce electricity and bleed air to run the air conditioning and to start the engines. Some A.P.U.s are routinely run in the air while others are for ground operations only. The A.P.U. motor is simply a small jet engine. Thus an investigator can use the same techniques to determine its operation as he would on a jet engine.

There are cockpit switch positions and cockpit lights for A.P.U. operation and thus light bulb filament testing is in order. Although unusual, there has been A.P.U. failures and fires reported. When an airplane catches fire airborne and it is equipped with an A.P.U. it is imperative to determine if it was running and whether it may be causative.

In airplanes such as the 737 an A.P.U. generator may substitute for a broken engine generator routinely. Thus one can not say that an A.P.U. running in flight is unusual for those aircraft. In a fully operational aircraft it is unusual to run the A.P.U. in flight except to start it in preparation for landing. It takes about a minute for an A.P.U. to start and come up to running speeds.

Battery Acid: Aircraft batteries may be of the car battery variety. These are acid and are only found in old general aviation aircraft. An investigator should realize an old battery may cause acid burns. Further an unhurt battery can provide some clues. If it is fully charged that is some indication that the electrical system or portions thereof was working correctly. The converse is not true since impact may cause a dead short. Batteries provide the potential of sparking and therefore create a fire hazard potential in fuel conditions. An investigator must be careful in such a situation. It is smart to have a fire truck around during any attempt to remove it.

Battery Nicad: These batteries are the newer more common variety and standard in large aircraft. These batteries are susceptible to thermal runaways. The same precautions about fire potential in a fuel environment exist.

Balance weights, flight controls: The movable flight controls panels and sometimes the aircraft flight surfaces often utilize the addition of mass balance weights and dynamic shock dampeners. The addition of these weights changes (dampens and differs the frequencies) of the natural vibration modes of the surface. They are a critical component of the system.

Loss in flight of such a weight will cause unwanted vibration and possibly fatal divergent flutter. An investigator should audit the presence of all such weights at the scene of any midair separation or control vibration accident. Finding a weight miles from the accident and unattached from its associated movable panel is a strong clue that such loss may possible be causative of the accident.

Bearings: Bearings and races exist through out engines and component parts. These should be checked for condition. Pristine lubricated bearings show normal conditions. Spalled or broken bearings show problems. Seizures due to bad bearings show, lack of lubrication, charcoaling of lubricants, metallic overheats and bluing. The bearings may be frozen. Rotation of the shaft at severe impact may result in scoring of the shaft. The direction of impact force upon the shaft may result in race imprinting and damage.

Black light analysis: Many aircraft instruments with pointers and dials have florescent paint on the needles. When the aircraft crashes there may be “needle slap “against the black background. This may not be discernable to the naked eye. Some transfer of paint may occur and this may show up using Ultraviolet light. Thus a reading at impact may be obtained.

Bleed Air Valves: Bleed air valves are located on the jet engines at various locations. Where a bleed air valve is located determines the pressure and temperature ranges of the air removed from the compressor section of a jet engine. The valves are often electrically initiated, but they are of many varieties. Thus an investigator must know the variety of valve and the purpose it serves. An investigator should look for impact witness marks to determine what its position was at impact. The investigator then must correlate what the engine was doing to determine if the valve was operating properly and was in the expected normal range. The investigator must understand the valves functions and what it supplies since they are multi functional and different from aircraft to aircraft. Certain higher stage bleed air will give a clue to the investigator of the power being produced by the engine at time of impact.

Bluing: This is a phenomena seen when frictional forces create overheat conditions in metals rubbing one another. Depending on where it is located (what components) can give the investigator quite a clue. For instance bluing around bearings at a rotating shaft signifies a pre existing overheat condition. If it was supposed to be lubricated it might be a clue to a failure of the lubrication system. When there is bluing on inlet engine shrouds caused by compressor blade rubbing one can say the engine was rotating at impact. (A clue to determining engine power). Bluing is unwanted and an unusual condition. The investigator must determine when it occurred and what significance it has.

Brakes: See the dissertation on anti skid systems. Aircraft Brakes are designed to absorb great amounts of energy. An investigator should look to see that the brakes are in good condition. (Brake pads remaining) Clues that maximum braking was applied may be seen in the skid marks. Also flight data recorder will record airspeeds which in turn can be translated to deceleration and brake effectiveness. Remember of course that the brakes are less effective on ice or standing water.

Brake Fuses: Aircraft brakes absorb huge amounts of Kinetic energy. This in turn creates immense heat that must be dissipated. Sometimes the brakes actually become cherry red because of heat. Later this heat must be dissipated and the rims heat up. Aircraft tire pressure is already extreme and the heat may force the tires to explode hurting ground crewman. To preclude this they are equipped with fuse plugs that melt before the tire explodes. If an investigator finds the fuse plugs blown he will no that there was a maximum braking effort applied.

Burner section: This is also known as the hot section of an engine. It is the place where fuel air mixture is introduced and ignited within burner cans. It is a very hot section and many clues may be derived here. Some times the compressor rubs its shroud during impact. The steel blades scrape aluminum from the shroud and they are ingested to the hot section. There if they are not already molten they will become so (if the engine is powered). This aluminum and sometimes bearing race material is sprayed out the back and deposited like spray paint on parts further downstream. This is a clue that the engine was on and producing high heat. (Aluminum melts at 1100 degrees).

If the compressor section comes apart or is hit by significant Foreign Object Material this may be propelled into the burner section and cause shrapnel damage to the cans. This is another indication of engine power. If the engine hits and ingests shrubs, trees or grass and the engine was under power these will be baked into charcoal residues throughout the compressor and hot section (burner area) also it is usual to find charcoal forced into any open bleed air valves and ducts near the engine. These are all indications of power at impact.

If an individual burner can shows heat and burn through it may be a result of a defective can. If all burner cans show excessive heat it may be as a result of turbine disintegration and resulting over temperatures. When an engine hits at high power and heat and is dramatically deformed at impact the compressors and turbines are broken and shrapnel is shot through the case. The result is that the remnants look like an eaten corn cob (with only a few blades still in place.)

Bus components (electrical): An aircraft supplies power to its various components by powering an electrical buss. This in turn supplies the components. An investigator should determine the condition of the bus and it connecting relay switch. Then the investigator should determine the components associated with that bus. He should audit the components to see if they were operating, if fuses were intact and circuit breakers in place. Some electric faults will fail components of a buss and allow others to function. Blown fuses, blown circuit breakers, bus welding, wire insulation discoloration or burning and wire melting all suggest electrical problems and faults.

Bus tie relays: These are switches that attach aircraft electrical sources to the common aircraft busses. These are cockpit switches that when latched connect the source to a common buss. These relays are equipped with an automatic disconnect feature that trips when it senses bad electricity on the common bus. Thus the switch may be on and the relay open. When this happens it illuminates a warning light. An investigator may compare actual switch (relay condition to switch position and to light bulb filaments)

There are other protective circuit relays called: Load monitoring relays L.M.R., transfer relays T.R. and auto shed relays A.R. These function to remove non essential busses automatically when they sense a failure of one generator. This auto shed feature protects the remaining generators from being overloaded.

Circuit Breakers: Circuit breakers are designed to protect electrical components from overloads. These are designed specifically for the appropriate amount of current and the will pop out when overloaded. They may be reset when the loads are normal.
Consistent maintenance write ups about a particular breaker popping is an indication of

sickness in the component, the wiring or the circuit breaker itself. They do wear out.

Circuit breakers will pop occasionally on ground impact. An investigator should record all circuit breaker conditions as part of his electrical audit. The cause and effect of a breaker popping should be determined when possible. Multiple breakers failed on a single buss warrants further inquiry as to why.

Cables, flight control: Most small General Aviation aircraft are flown by cable. Most major airliners are flown by cables actuating hydraulically boosted flight controls. Most airliners except the newest and wide bodies revert to cable flown manual reversion flight controls. There are now "Fly by wire" systems and these are different.

An investigator should attempt to track all cables for their integrity. Cables will fail as a result of the crash. These failures are of two varieties. Tensile overload (stretch till it breaks and cutting). A stretch to failure cable will break and look like human hair undergoing electric shock (frazzled). The individual strands will bee necked down in tensile failure.

Pre-existing defects may exist that lead to cable failure. They can be corrosion failure, fatigue failure, electrical arcing failure, rubbing or chaffing failure. Also the connector or buckle may fail or become undone do to improper maintenance. Corrosion failure is signaled by strand failures attributable to corrosion. Fatigue failures are old age failures from repeated loading and unloading. These occur in strands near a stress concentration area such as a pulley. Their fingerprints are discernible under microscopy. Electrical arcing failure is easy to identify since it usually occurs near an electrical source or ground and because it has the appearance of melting or welding. Rubbing or chaffing is easy to identify for the rubbed component as well as the wire are marked distinctively. Control cables are stainless steel and act as a saw blade as they rub. A faulty turnbuckle backing off is usually found when safety wire has been forgotten.

Any major flight control cable that fails in flight will cause problems ranging from serious to fatal. Thus it is important for the investigator to audit every control cable whenever possible.

C.A.D.C. The Captains air data computer is a computer that serves many functions related to aircraft flight instrument corrections. Thus the air data computer supplies many functions to flight instruments relating to altitude airspeed temperature and the like. When an air data computer fails it will send out warning signals to the individual instruments it controls. These will then exhibit flags that notify the pilot of the failure. Some instruments will fail partially so that corrections derived from the computer are not displayed but raw data still is. The C.A.D.C. plays a major role in auto flight capabilities.

An investigator should monitor flags and lights for indications that there was a failure. As to the black box itself it should be retrieved and protected in static free weather bag and returned to a lab if testing is thought needed.

Camshaft: The cam shaft of a reciprocating prop engine is important as its position controls the valve and lifter positions of the engine. If it has broken the investigator should determine the mode of failure. A rotational torque failure denotes an engine under power.

Cockpit control positions: Cockpit controls positions are important to the investigator as they give clues to what was being called for in the cockpit. The investigator should correlate what the control position was compared to what had been obtained at the control.

The throttle is a condition of power; in fact some times it is called a thrust lever or power lever. It is usually free to move and may be moved as crash damage. The fuel on/off and mixture switches are usually riding in detents and therefore not as susceptible to crash damage.

Flap handle position is usually configured with detents and thus not susceptible to crash damage. A spoiler speed brake handle is usually detented in the down position and therefore not too susceptible to crash damage. Prop control is free to move except in reverse and in feather and these positions are usually detented so it is unreliable due to crash damage except at feather and reverse. Jet reverse handles are not usually susceptible to crash damage in a movement to reverse, but are in a movement out of reverse. Gear handle position is usually detented and not susceptible to crash damage. The severity of the crash of course mitigates the general rules stated above.

Cockpit switch positions: Cockpit switches are normally of five varieties:

1. Those that are rotated to seek a condition. These are usually fairly accurate and not susceptible to crash damage. Some rotating switches must either be pulled or pushed prior to rotation. These give good indications and are not susceptible to crash damage.
2. Toggle switches that are simply unguarded fore and aft motion switches. These are very susceptible to crash damage.
3. Fore and aft switches that must be lifted over a detent. These are less susceptible to crash damage.
4. Fore and aft covered switches. These covers are placed on critical switches that are not to be inadvertently moved. First the cover must be removed in order to get at the switch. These are not susceptible to crash damage. I believe they are designed to be covered for two reasons first to prevent human factor failures of moving a switch inadvertently and second to aid crash investigators with critical system evaluations.
5. Latch switches .Push in for on, push again to release to off.

These are susceptible to crash damage, but they are almost always equipped with a light signifying in use /on. Thus the investigator may have the ability to do a light filament analysis.

An investigator often must look closely at these switches since he may be able to tell that the switch has moved as a result of crash damage. (Broken or scuffed detents etc)

Cockpit Voice Recorder: Cockpit voice (sound recorders).These very important recorders continuously record the last thirty minutes of

Cockpit noises and radio transmissions. It is an invaluable tool. Today the rules have changed and the N.T.S.B. will not release tapes of the conversations. Instead they take them to their second class facility and do an amateurish job with sound analysis. They only release their transcript of the tapes. However when the investigation is complete they release ownership of the tape to the registered owner/operator of the aircraft. Legal discovery may be attempted to retrieve this data from them. See the dissertation on sound analysis.

Converters: Converters are electrical devices that change ac to dc electrical power. They are similar to the rectifier portion of a transformer rectifier. When one is discovered in the wreckage it should be looked at for general condition --no signs of overheat or short circuit. It can be taken to the lab and checked for function.

Compression check: Sometimes when engine failure is not really suspect a complete teardown may be avoided. One helpful method may be to remove the spark plugs and run a compression check. The numbers obtained from a wrecked engine that appears in good shape should be close to those recorded the last time a check was run. A very schlock test is to simply place a finger over the spark plug hole and rotate the engine. The ability to rotate the engine is in itself some indication that it is alright internally. I prefer to always tear down any engine that was not seemingly producing appropriate power.

Compressor blades: Jet engine compressor blades are made of very tough steel. They act as a suction device as they rotate sucking air into a jet engine and through successive stages compressing the air before it is mixed with fuel in the hot section. Clues an investigator may glean to determine engine powers are:

1. Blades tips bent opposite normal rotation.
2. Blade tips worn and blued from rubbing the surrounding shroud.
3. Shroud scraping in a manner of rotation.
4. Charcoal and debris ingested throughout the compressor section.
5. In some cases all blades missing leaving the core to look like an eaten corn cob. In this case compressor blades are sucked through the engine.
6. If successive stages of compressors have increasing numbers of missing blades. This may be as a result of foreign object being sucked into the engine. As The F.O.M. is sucked through each deeper set of compressor blades is damaged to a greater extent as more blades are sucked through.

Compressor shroud: The compressor shroud is the metal external case that houses the rotating compressor blades and the static stator blades. If there was rotation you should see compressor blade rub in the aluminum.

Compressor stators: For every ring of moving compressor blades there is an adjacent set of permanently stationery stator blades. These stators tend to increase compression while stopping the rotational flow of inlet air caused by the compressors rotation. These blades will be damaged by foreign objects if they are sucked through and they may be missing to a great extent if the corn cob coring takes place.

Cylinders: Cylinders are found in reciprocating and opposed engines. Typically they are made of aluminum and have cooling fins for air cooling on the outside. When there is a failure it typically happens that a wall bulges and simply blows out. This is very easy to see. Also the cylinder is held on the engine with bolts. Some times one or more of these bolts lets go and the cylinder loses compression around its lower gasket. Occasionally a cylinder may lose pressure at the head gasket. In each case these are easy to detect after they have progressed to failure. Discoloration due to heat and oil blow by is a clue if it isn't totally evident to the naked eye.

Crankcase: This is the main body of an aircraft engine .Usually these are not a problem except that they occasionally become slightly misshapen or worse they crack. There is a problem in general aviation currently having to do with cracked cases being repaired by aluminum welding shops. This is a difficult process and often not too successful.

Crankshaft: The rotating portion of a reciprocating engine that attaches to the propeller. If it has failed it should be examined to see if the failure was rotational torque overload from a sudden stop or whether it was from other reasons.

Connecting rods: These rods are components of an engine that attach to the piston. An investigator looks for damage usually found near the bolts or emanating from stress concentration risers.

Constant speed drives. C.S.D.: These devices are part of the electrical generation system of the airplane. They are a device that is driven by the engine and in turn drives the generator. It is simply a fluid drive transmission that governs to constant speed. The C.S.D. is set to run at a speed that will produce 400+ - 8 cps and 115 +-5 volts.
These C.S.D.s can overheat and be disconnected by the flight crew. The investigator looks in the cockpit for signs of disconnect at the switch and light bulb filaments for the associated lights.

At the device itself it is simple to determine if there is a disconnect since a mechanic must be able to reset the disconnect easily. One very common failure of C.S.D. devices is low oil (failure to service properly).In military fighters the servicing of a C.S.D. is more critical because of the high g envelope. What a fighter pilot doesn't need is to lose a generator in the middle of a dogfight.

DATA PLATES: Most airplane components that are aviation equipment come with data plates. These data plates are usually designed so that they can be read even in there installed position. They will usually include descriptive name, Manufacturers name, contract or spec number, part number, serial number and date of manufacture.

When an A.D. change has been incorporated it may be stamped onto this plate or attached as an add on tag, When the part has been overhauled the part may have a tag, data plate or adhesive stamp of the overhaul facility and the date of Overhaul.

Doors: Doors should be examined to determine that they were closed and locked at impact. If they are found closed they were. If they are open or missing a metallurgist should examine the locks. If they are deformed or broken the door was closed at impact.

Electrical harness: The electrical Harness is part of the ignition system of a reciprocating engine. It delivers the spark from the magnetos to the spark plugs. It is a shielded cable. The condition is critical and investigators should look for wear and grounding flaws. A bad harness can cause loss of an engine or more likely a rough runner. It also may be the cause of intermittent engine problems that are hard to detect. (This is true for all electrical chaffing problems.)

Elevator positions: The position of the elevator at time of impact should be determined. As part of the flight control audit the fact it was found and its location relative to the wreckage has been determined. The elevator may move during the crash sequence, therefore it is necessary to determine first impact marks to determine what position it was in at impact.

Metallic impact marks are the best clue. In aircraft where the elevator is moved by hydraulic actuated boosters an examination of them is critical. Within such an actuator there is a power ram that usually protrudes from one end of the actuator as a polished steel rod. This ram moves internally extending or retracting the power rod. The rod attaches to the elevator. Measurement of the rod extension will determine the position of the elevator. Sometimes this rod moves during impact. (This occurs frequently during shallow dive angle impacts where the aircraft first knocks down trees then impacts the ground and then breaks up and skids and tumbles for many yards.) In such a case it is important to look for impact witness marks on the rod as well as internal cylinder impact witness marks caused by the power ram.

Elevator trim or tail slab trim position should also be determined. This can be done relatively easily .Often trim positions can be determined at the surface by determining where that trim is being asked to go. In many cases the trim is moved by a mechanical device that translates rotational movement into liner movement in the form of extension or retraction. Often these trim actuator devices are jack screws. As a general rule a jack screw device will not move during impact and the condition found reflects the condition at impact (not always true)

Often trim position is controlled through a series of cables capstan reels and pulleys actuated in the cockpit and running to the trim actuator at the surface. The linear reel in or reel out of cable at the Capstan rotates the jack screw and this in turn creates an extension or retraction of trim position at the surface.

The trim position can therefore be determined at the capstan by measuring the amount of cable reeled in (trim up) as compared to the amount of cable reeled out (trim down). Additionally some aircraft are equipped with trim position gauges in the cockpit.

This is far too simple an explanation as the variances between aircraft systems is great. Suffice it to say that the investigator needs to know the system and how it operates and is rigged in order to make valid determinations. The investigator needs the maintenance manual portion on flight control rigging to be sure of his findings.

A field investigator may accomplish the task by identifying the component parts, taking appropriate measurements, recording the as found condition and taking a myriad of photographs. Actuators should be tagged for bench testing and later teardown if appropriate. This data may be correlated with the rigging manual back in the office.

Within N.T.S.B. investigations of large planes the manufacturer will have a representative expert in the area of flight controls.

Often in military accidents the service will return the components for testing and teardown. The result is often separate reports that may be obtained F.O.I.A. They are called E.I. engineering investigations in the navy, T.D.R. s in the Air force.

Engine Power at Impact: Generally speaking it is valuable to know engine condition before and at impact. See the chapter on engines. Clues that something is wrong may be obtained from: Cockpit voice recorders, Flight data recorders, radio transmissions, surviving witnesses, aircraft maintenance history, aircraft flight path, cockpit control positions, cockpit instrument conditions, cockpit light bulb conditions, and the wreckage itself.

Jet: rotational damage, corn cob coring, compressor blades bent, compressor blades tip damage, scoring at inlet shroud, Metallic spattering (spray painting) Turbine blade bending rather than brittle breaks, Charcoaling of foreign ingested materials, bearing conditions, Foreign Object Material, shrapnel damage, explosive force damage emanating from the hot section outward, torque damage from sudden stop etc.

Prop: condition of prop, prop gear box, torque damage, rotational damage to spinner and prop hub, External condition of engine and components, internal condition of engine from teardown, condition of accessory section.

Propjet: Condition of prop, spinner, hub, gear box, turbine section, drive shafts and jet engine condition similar to above jet engine clues.

Engine instruments: The standard engine instruments are listed below. An investigator must determine what variety of instrument they are since it makes a difference as how they fail with loss of an engine or loss of electrical power. The list below is general....an investigator must have the maintenance manual for the precise instrument variety to ascertain the validity of readings found on engine instruments.

E.P.R. Exhaust Pressure Ratio is a device that determines jet engine power. Some have flags when electrical power is lost to the instrument. At loss of power it will try to move to zero.

R.P.M. These gauges for propeller aircraft get their power from there own tach generator. Thus they should read at impact.

N1. This is the R.P.M. of the jet engines fan; it is a tach generator and gives valid information with loss of electricity.

N2: This is a jet engine's core rotational speed, it is a tach generator and it gives valid information with loss of electrical power.

E.G.T.: This is an indication of jet engine temperature performance. It is powered by its own thermocouple and will be valid at impact.

Oil temp: This gauge will usually fall to zero with loss of electrical power.

Oil pressure: This instrument will usually maintain its last reading at loss of electrical power.

Fuel flow: Fuel Flow will usually return to zero with loss of electrical power.

Torque: An indication of prop engine performance, it may retain its last reading at loss of electrical power.

B.H.P.: An indication of engine horse power, it will fail to zero at loss of electrical power.

Fuel pressure: A gauge used in prop aircraft. It will fall to zero at loss of electric power.

Manifold pressure: This is a gauge that determines the pressure of air being sucked through the engines carb and manifold system. With loss of an engine it will fail to field barometric pressure if the prop is stopped. With loss of electricity it will fail to zero. It is noteworthy that many general aviation airplanes have takeoff manifold pressures identical to field barometric pressures; the same is true for idle descent pressures and pressures found on wind milling engines. Thus a Manifold pressure gauge should not be used by the pilot as a primary gauge to determine engine operation.

Feathering controls: See the chapter on propellers. Feathering controls differ greatly in type and location within a cockpit. They usually require a positive action to move them and therefore their position at impact is usually valid. A feathering system is utilized with a failed engine in flight. It turns the prop blades to about 90 degrees and streamlines the prop in the wind stream thereby dramatically reducing drag forces. When an investigator finds a prop feathering device actuated in the cockpit and the propeller at other than feather this is a good clue as to a major problem and possibly a cause of the accident. Many light twins will not fly if feather can't be attained upon the failure of an engine. It is a critical feature.

Flight Controls: See the chapter on flight controls. An investigator should attempt to ascertain:

1. Integrity of cables and lines to all flight controls.

2. Inventory all flight control movable surfaces
3. Inventory all mass balance weights
4. Record location of all such parts in a midair separation distribution chart.
5. Determine, elevator, aileron, spoiler, rudder, flight spoiler, ground spoiler, speed brake, flap and L.E.D. positions at impact.
6. Determine trim positions for elevator, aileron and rudder.
7. Determine hydraulic system condition.
8. Determine manual reversion condition.
9. Determine auto flight condition
10. Determine yaw damp condition
11. Determine Pitch Trim compensator utilization.

Flight Recorder: In both N.T.S.B. and military investigations one of the primary jobs is to recover these recorders. In the Military they are sophisticated enough to recover all computer memories from all recording devices while the N.T.S.B. only worries about The C.V.R. and the flight data recorder. An investigator for a plaintiff's attorney will not be allowed to participate in their analysis. Thus only data and transcriptions will be readily available. If an investigator is to do independent lab analysis it must be ordered through court discovery.

Flight data recorders are of two varieties. The old metal tape that records five parameters, Heading, altitude, airspeed, g forces, time hack, and marks radio transmission initiation. The new digital recorders record about 62 parameters. These recorders constantly monitor the parameters and record them either continuously or every so many seconds. It takes an expert and a lab to interpret the raw data. Newer recorders now record over 130 channels.

Flight Management systems: These are of many varieties and as a result are of varying usages and complexities. They all have a computer memory and as such are amenable to laboratory retrieval of data. These should be retrieved and protected in static free bags. A Genius computer technician is required since this technology is new and ever changing. Often you must rely on the manufacturer.

Gearboxes: Gear boxes are used to change the speed of rotational motion, do change the direction of rotational motion and to provide mechanical advantage. In aircraft gear boxes are typical between engine and propeller and at the accessory section. In helicopters they are used as transmissions for the rotor, tail rotors and to change direction of rotation at the 90 degree gear box.

These should be torn down and internally examined. There you may find either sudden stop damage in the form of torque overload failures, or evidence of preexisting failures. You may find gear failures, bearing failures or lubrication failures. When you have bearing or lubrication failures there will be evidence of overheat.

Most transmissions and large gearboxes have chip detectors that are to warn of transmission impending failures. Chip detectors should be pulled and examined as well as the associated warning light filament checked.

Gimbals, instrument: Flight instruments that have multi degrees of motion such as attitude indicators, gyros, and inertial platforms obtain the freedom of motion through gimbals. When such a device impacts the gimbals usually break, capture or leave witness marks on the gimbals and surrounding structures. A qualified investigator can determine instrument position and condition at impact by determining this capture or witness marks internal to the instrument.

Gyro platforms: Gyro platforms have two rotating gyros that spin at high speed. These gyros are usually stainless steel and rotate at about 25, 000 rpm. They are gimbaled to allow freedom of motion of the aircraft around the stable spinning gyros. Gyros that are spinning tend to be stable and remain erected exactly in the position they were in at spin up. This is the principle of a child's top. (It remains erect as long as the spinning continues.)

When a gyro platform crashes and the case is crushed the gyros typically disintegrate the internal mechanisms and almost explode due to the kinetic energy of rotating steel gyros. Even though the gyros are small they are heavy (2 to 3 lbs) and they outer diameters at 25, 000R.P.M are moving about 300 miles per hour. These steel gyros will not be simply captured in place easily. Sam Taylor has said that he has only seen two crushed platforms of this variety with the gyros still in place. In both cases the gyros were not running at the time of impact. Sam has said that they scatter like they were an exploding hand grenade because of the internal energies.

A gyro platforms gimbals, and the instruments it controls such as the A.D.I. and H.S.I. and the aircraft attitude of dive, roll, and heading should all be identical if the instruments were working properly. This means the hole in the ground, the pilots' instruments and the gyro platform should produce identical readings if the systems were working at impact.

Clues an investigator has to work with:

1. If the gyro platform case is deformed the gyros should have done terrific internal damage and more likely than not escaped from the case due to the kinetic energy release at impact. (If the gyro was operating) If the gyros are in place this is a good hint that the platform was not running at impact.

2. The gyros will have smear marks from the softer gimbals material if they were rotating at impact.

3. The gimbals will capture at the position where the gyros broke free at impact. From these capture or witness marks one can determine aircraft attitude.

4. Should the gyros be running and capture inside the case at impact there will be much, destruction, smearing and bluing. More likely than not the gyros will have broken free of the case. Sam has said he has found spinning gyro parts two hundred yards from the impact because of their rotational energy. In the Harduvel F-16 case the Inertial Gyro Platform manufacturer's expert said that in all the wreck teardowns that it had done only one other intact gyro was brought in to them and it was determined that the gyro was not running at impact.

Fire Protection: Most multi engine large aircraft have fire protection installed. These devices usually include a single handle that when pulled will disable all functions to a burning or overheated engine. These functions include closing fuel valves to the engine, shutting oil to the engine, shutting hydraulics to the engine, killing the associated generators field and closing all bleed and pneumatic air to and from the engine. Pulling the "T" handle also arms all fire protection systems to that engine. Fire protection consists of fire extinguishing agent bottles that can be directed to fight an engine fire.

Clues an investigator has is the position of the cockpit "T" handle. Warning lights associated with the "T" handle. Fire bottles discharge blow out tabs for normal discharge or thermal blowouts. Naturally the investigator has all clues from an actual fire or overheat. (See section on airborne and ground fires). Further the investigator should check the appropriate oil, hydraulic, bleed air and fuel shutoff valve positions.

Fire detection: Fire detection systems are usually provided in multi engine aircraft and military aircraft. The devices are located around engines, nacelles and A.P.U.s. Single engine general aviation may not have such equipment. These devices sense heat and hotter heat (fire) around engines and bleed air ducting. Overheat condition in ducting is usually signified by lights alone.

Fire detection is often displayed as a flashing red master caution light, aural warnings and associated equipment fire lights. The investigator should check the C.V.R. for aural warnings, light bulbs for visual warnings. T handle position and fire bottle switches to see if the fire was fought. The obvious is for the inspector to check the aircraft at the fire source to see if there indeed was a fire or overheat condition. This investigator has done one F-111 crash that was caused in part by shutting down a good engine due to a false alarm overheat !

Fire Investigation: See chapter on aircraft fires. Investigator should look for signs of fire and overheat. (Sooting, discoloration, Aluminum crimping, smoke patterns, burn patterns, melting points of metals, flight path spatters and burned off components. Explosion clues fuel vapor results in aluminum bulging outward, sabotage explosives have their own more distinct and localized patterns that include curled back aluminum edges.

Fires in Flight: Clues include C.V.R. tapes, radio transmissions, witnesses who see smoke or fire, flight path spatter and burned components, horizontal smoke patterns, hotter temperatures` evident due to air stream. Fire on Ground: Clues the investigator looks for. C.V.R. tape sometimes, vertical patterns of burn and smoke/sooting. Cooler temperatures relative to airborne fires, adjacent component parts burned differently since at crash they were scattered before the fire engulfed them.

Flags instrument: Many aircraft instruments are equipped with small red flags to annunciate their condition. Each instrument so equipped has flags that may signify loss of power or loss of some capability. The investigator needs an instrument manual to determine the flags present and there function and failure modes.

These flags usually are biased out of sight electrically and they gravity fall into view with either loss of power or loss of function. When an airplane crashes and instruments are crushed the flags often are captured at the position they were in at impact. Sometimes the flags are broken and missing. In such cases the investigator may see indentations, scratches that witness to flag condition at impact.

Flap positions: Determining flap positions at impact are a very important function of an investigator. Flaps positions give a clue to aircrafts flight speed regime. A flap down signifies slow flight.

On many sophisticated aircraft the flap position also regulates many other facets of aircraft system operation. For instance flap position may regulate the amount of Aileron and Spoiler authority available, the amount of Rudder authority available, the hydraulic pressure available.

Flaps are always supposed to deployed equally on both sides of an airplane. If one side deploys and the other does not the aircraft will roll violently out of control. To protect against such a problem sophisticated aircraft have asymmetric flap sensors that stop flap movement if one is operable and the other stuck. The investigator must have an overhaul or maintenance manual associated with flight control rigging to understand all functions of flap deployment.

Flap deployment clues are found in the cockpit: they are handle position and cockpit dial positions. The flaps themselves give many clues. Flaps are almost always deployed by actuators. Most are of the Jackscrew variety. These do not usually move on ground impact. Thus an examination of the jackscrew thread lengths will often tell the story. General condition, stowed or deployed may be evident. There may be witness marks on structure and guide rails as well.

Flutter clues: See the chapter on flutter. Flutter is the most difficult event for an investigator to determine. Flutter is a self sustaining exacerbation of a natural aircraft vibratory mode. It is exacerbated because of aerodynamic forces caused by airspeed. Divergent flutter causes destruction of the surface and usually the aircraft.

All airplanes will flutter if they are flown fast enough! There in lies the problem. Suffice it to say that flutter is designed out and no aircraft should flutter within the design flight envelope. Flutter speeds of an aircraft may change with old age, rigging, loss of rigidity and stiffness, loss of mass balance weights.

Clues that there was flutter may be detected on a C.V.R. as vibratory noise associated with a known vibration mode frequency.

Other clues are:

1. There was a midair separation.
2. There are missing flight controls or mass balance weights.
3. The structures` show up and down bending
4. Some structures show rotational bending in two directions.
5. Aircraft skin shows wrinkling in two directions.
6. Rivets show vibratory enlargement or tearing out.
7. Flight controls show stop damage in both directions. (This is only a clue since many modes of flutter can occur without either stop being in contact with the

control that is in flutter.) The N.T.S.B. wrongly teaches that stop damage is the best clue!

8. Engine mounts show rotational damage often in two directions.

Once the fingerprints of flutter are found the investigator must determine whether the flutter occurred within the design envelope or for other reasons .When possible a radar track is needed to show that the aircraft came apart within the design envelopes speeds. Once this is established it must be shown that the pilot did not overstress the aircraft. Once this is accomplished the investigator should look to structure failures due to fatigue or the loss of a mass balance. If all of these possible causes are eliminated then you may have a real case of flutter within the design envelope.

To make evaluations of engineering certifications testing you need an investigator that is an aero elastic expert. There are very few qualified people in the United States. The N.T.S.B. almost never finds flutter and when they do they do not question the manufacturer since that would automatically put into question the governments' certification procedures for the aircraft.

Fuel Bypass Valves: These devices simply bypass fuel around a contaminated or clogged fuel filter. When an investigator finds witness marks that a bypass was in effect, he will almost always find a dirty or contaminated filter. However Ice in the filter may cause a bypass as well. The cockpit is usually equipped with a bypass light that is amenable to filament testing.

Fuel Injectors: Fuel injectors are complex devices with internal critical parts and tolerances. When such a device is found intact in the field and it is suspect it should not be dismantled in the field. It should instead be returned and bench checked, flow checked, pressure checked and then dismantled, especially if it fails the bench testing. This should only be done by experts. Once inside the injector the parts serial numbers should be checked for A.D. compliance.

Fuel Carburetors: These should be checked for integrity of parts and linkages. The air heat function should be checked for position to see if carb heat was employed.

Fuel Contamination: Fuel Contamination can come from many sources. The investigator should take fuel samples from each tank and filters (low system collect points) these should be returned to a fuels lab for analysis when fuel is a suspect.

Contamination may be a suspect when there is engine failure or power loss or rough runners. It may be in the form of Water, wrong fuel for aircraft, paraffin's in old fuel, algae in old fuel, Rubber deterioration from the tanks, tools and rags from maintenance, sabotage such as sand or sugar. There may have been fuel ice or filter ice (here the contaminant was water. There may be the contaminants from pump exfoliation trapped in filters. Dirty Filters are a possibility. Crimped fuel lines are a possible cause as well. Fuel line internal rubber delamination and improper fuel soluble rubber hoses are also possible.

Fuel Control Units: Fuel control units are the most sophisticated jet engine supply for fuel. These devices are electronically regulated by computers that sense fuel requirements. These units fail to a manual operation should the electronic portion fail.

They typically get input from Inlet guide vain position, engine R.P.M., altitude, temperature, throttle position, acceleration or deceleration requirements, and afterburner requirements. The systems integrate the inputs and determine appropriate fuel flow to be delivered to the engine. It is always a very sophisticated device and it should be returned to the lab for testing. Internally the device moves valves for fuel delivery schedules as required.

An investigator needs the fuel unit overhaul manual and rigging manual as there are many varieties. When the unit is damaged it may be disassembled and witness marks and capture marks will tell the condition of the unit at impact.

The investigator has other clues external to the unit. In the cockpit the investigator should determine switch position. (Automatic or manual). If it is in manual there is usually an illuminated light associated with that position. Actually it is a warning light showing fuel unit failure in automatic and the necessity to switch to manual.

External to the unit there is a linkage or switch that will tell whether the unit is in automatic or manual. A system that is being run in manual suggests a fuel control unit failure.

FADEC is a fuel control unit. FADEC stands for "Full authority digital electronic control" The systems have a computer, often called EEC or ECU that is supposed to control all aspects of aircraft engine performance. FADEC are used in both piston and jet engines. The good and the bad. They have no manual override so failure of the FADEC and the engine fails. It is a good way to control fuel efficiently but often the system needs two such systems for redundancy. From an investigative standpoint after an accident ….the line replaceable unit need return to a computer forensic shop. Typically back at the manufacturer. Luckily there are Non Volatile chips with memory so investigation is often possible.

FADEC works by receiving multiple input variables of the current flight conditions. Digital inputs are received a 100 times a second or more and the programs software makes over-exceedences are impossible when FADEC is working.

Fuel Dump: The purpose of fuel dumping is to lighten the fuel load by dumping fuel into the airstream. Fuel dumping is almost always an emergency condition. (The military used to dump fuel routinely to get down to landing weights.) Fuel is dumped either to lower weights so the airplane can continue flight because of loss of power or more likely so the airplane will be reduced to a suitable landing weight in an emergency. The usage of fuel dump suggests an emergency to an investigator.

Fuel dump can be ascertained by checking fuel dump switch positions in the cockpit and dump valve positions in the wing or tanks. Witnesses can often see dumping and may call it white smoke stream.

Fuel Filters: These should be checked for condition and contaminants. They may be clogged with hard to see paraffin's.

Fuel Lines: Should be checked for integrity and leaks. Leaking fuel lines are often easily detected as the fuel often cleans away oily residues from the engine. Fuel lines should be checked to see they are appropriate for the engine involved. Often fuel lines are replaced at checks and overhauls.

Fuel Pumps: Fuel pumps should be tested in a lab for condition and operation. They should be flow and pressure checked. When the fuel pump is engine driven it should be ascertained that its drive shaft was intact. If the pump is torn down its internal condition should be noted. The investigator is looking for evidence of rotation and sudden stoppage due to impact. The pump should not have failed internally. In jet operations the loss of the main engine driven fuel pump will always result in engine failure.

Some fuel pumps are chrome plated within. This plating can exfoliate especially with high sulphur fuels. This is easy to detect. Piston displacement pumps may exfoliate and be damaged if they pump fuel with a high content of water. This is true since lubrication is supplied by the fuel the pump is pumping.

Fuel Pumps auxiliary: Most aircraft have fuel boost pumps that are located in the wings. These are electric driven submersible pumps that pressurize fuel lines. Most aircraft are certified to fly without boost pump usage. Boost pumps have been known to overheat and ignite fuel air vapors in dry aircraft tanks.

These fuel pumps may overheat if they are clogged with foreign material, if they have a dragging bearing, or if they self destruct internally. These devices have auto shut down features that are supposed to prevent disaster. For instance if the tank is empty the cockpit light will illuminate and the pilot is to turn off the pump. The pump should be shut down. If the pump drags the current should increase and a c/b should pop. If the bearing overheats the case temp should rise and a thermocouple should shut it off.

Even with all of these protective features boost pumps have caused explosions and fire both airborne and on the ground.

When an investigator has a fuel tank fire or explosion he must suspect fuel boost pumps in a vapor environment. This is true since there are only a few ignition sources available. (The others are fuel probe pick offs and transfer valves) Neither of these are likely sources of ignition. He should check switch positions, circuit breaker positions and the pump itself.

A bearing drag will result in bluing and carbon bearing transfer to the shaft.

Foreign object drag will be evident as scoring at the centrifugal impeller. Pump internal destruction will be evident as rotational scoring and broken satellite bearings as well as overheat conditions. The case thermocouple should be checked to see if they have tripped.

Fuel aux pump problems and transfer pump problems have resulted in the loss of at least 3 Air Force B-52 aircraft, at least two Kc-135 tanker losses and one known civilian ground fire.

Fuel selectors: Often aircraft have multiple fuel tanks. The investigator must have a fuel schematic for his accident aircraft. Fuel selector valves determine which tank the pilot is using. There have been accidents reported where the pilot has run an engine dry and not switched to a tank full of gas. The selector controls are located in the cockpit. The valves are located remote places. The investigator should obtain fuel loaded aboard records, calculate fuel burn and determine selector valve positions. If the tanks are intact the fuel available may be determined.

The design of some selector valves induces some pilot errors from a human factors standpoint. Check to see that valves position completely to the tank or off position. Often some intermediate position has been found in those designed that allow mid positions.

Fuel shutoff controls: There are usually several ways to shut fuel off from an engine. There are the usual jet fuel levers with on and off. The prop engine mixture control with off, normal and rich positions. There is the fuel tank selector valve. There is the engineers' panel on /off valve, and there are valves associated with the Fire "T" handle. To ascertain whether there was fuel selected for engine operation the investigator must determine the status of all such valves and systems.

Fuel Starvation: Fuel starvation is a condition that exists when an engine is not receiving fuel. It can result from a valve being inadvertently shut, from an icing in fuel or fuel filters, from fuel lines clogging, from fuel filters clogging, from the tank being run empty, from fuel line leakage. The investigator can easily determine this by checking to see if there is fuel in lines closest to the carb, injector or fuel control unit.

Obviously if there was no fuel delivered to the engine the investigator would find that engine shut down. When all engines are failed it is almost always a fuel problem-starvation or contamination.

Fuel Tank Condition: Fuel tanks crash differently depending upon whether they are full or empty. Empty tanks crush, full tanks rupture outward due to hydrostatic pressure. This is a distinct and easily recognizable clue.

The question whether or not a tank had fuel can often be settled by witnesses who may see a massive vapor ball drift in the wind after impact. If this occurs there may be a massive grass kill. The N.T.S.B. almost never sticks around long enough to plot the grass kill (this often takes a couple of weeks) In general Aviation accidents the wreckage is often moved in a couple of days.

Good investigators can survey grass kill and take sod and root samples to lab and determine what variety of gas killed them by adsorption of fuel additives such as lead tetraethyl etc.

Fuel Vapor lock: Fuel will turn to vapor as a direct result of the variety of fuel and its temperature and pressure. If the pressure is low for a certain temperature it will vaporize. If this is allowed to happen in a fuel line a gas bubble will result. This bubble will effect the pumps and they will cavitate and fuel will not be drawn into the engine. When double engine failures occur in hot weather with fuel available this phenomena must always be suspect. It is more likely to occur with low fuel remaining, boost pumps off and system fuel switches in cross feed.

Fuel Types: Specific engines require specific fuels. Reciprocating engines can only burn gasoline. Various octane ratings are called for and they are color coded. Jet engines require kerosene of differing varieties, but most can burn gasoline. The investigator should take fuel samples from the aircraft and from the delivery truck. The investigator should check fueling paperwork for type, amount and distribution of fuel.

Fuses: Are electrical protective devices that melt when overloaded. They can not be reset. If an investigator finds blown fuses he can feel certain there was an electric fault of some nature. Checking fusses should be a routine part of an electrical audit.

Gear train continuity: Gear train continuity should be examined. The investigator is looking for sudden rotational stop damage, pre-existing gear failures, bearing spalling or failures, lubrication failures, overheated areas at bearings and teeth chattering.
Generators:

G.P.W.S.: Ground proximity warning systems give the pilot multiple warnings of unwanted and dangerous flight path deviations. It annunciates by word and flashing light the problem. On an I.L.S. approach it will tell the pilot if he is low. It will announce “Glide Slope" All other word warnings simply say "Pull Up" some say "Pull up terrain. It will announce pull up with a descent into the ground with gear not down. It will announce rapidly rising terrain and it will announce a settling back toward ground immediately after takeoff. This device uses` the radar altimeter and the I.L.S. glides lope as well as its own computer for data. If the radar altimeter is broken so is the G.P.W.S. Cockpit voice recorders CVRs are a good clue as to whether the G.P.W.S. sounded. A flight path reconstruction is advisable to determine if there should have been a warning from the G.P.W.S. Also the investigator should check switch positions because some pilots disarm them because of false alarms especially in mountain area approaches.

Inverters: Inverters are electrical devices that change direct current into alternating current. These should be checked for condition, arcing, welding and they may be tested at a lab if suspect.

Instruments flight: Flight instruments are those utilized by the pilot to navigate and pinpoint himself in space. These instruments may fail. It is often possible to tell what the instruments were displaying at the time of impact. First if the instrument has crushed in a steep dive accident usually the face readings are captured in place. On the other hand if it is a shallow dive with multiple impacts the instrument may change position from first impact to final capture impact. Thus an investigator must tear down the instrument and make determinations from the first witness marks. It is intricate business but not nearly as difficult as it seems. Much of this work must be done in a lab under magnification.

For instance a dial pointer may be missing. The reading may be taken from the broken stem and internal conditions of the instrument. Some times the pointers are missing and their “needle slap" can be read on the dial surface. Often Black light will show needle slaps which were not visible to the naked eye. Witness marks internal to the instrument may both show original condition and direction of movement in the crash sequence.

A.D.I.: Attitude and direction indicator is an instrument that shows aircraft attitudes of roll and pitch. It usually consists of a movable globe painted blue for sky and black for ground. This instrument is also called an artificial horizon. The globe is free to move on gimbals. When it fails it flags. When it fails it fails to a particular condition of nose down wing down.

When it is working it should be doing exactly what the airplane is doing with respect to nose position and roll configuration. If the capture on the instrument is grossly different than that of the impact crater the investigator suspects a failed instrument.

H.S.I.: The horizontal situation indicator is an instrument that displays aircraft heading around the rotating compass card at the periphery. It is a repeater from the gyro platform. An aircraft that has` crashed should show the same heading on the wreckage scatter pattern, on the H, S, I. And on the gyro teardown, if this is not the case then there is a chance of pre existing instrument failure.

I.N.S. The inertial navigation system is a system consisting of a gyro platform, a set of accelerometers, a cockpit head and a black box computer.

Once the gyros have been started and have reached speed the system may be initialized. This means that the pilot types in the lat and long of his exact position in degrees, minutes and seconds. Once this is memorized the pilot can type in any number of other positions called waypoints. These are sequentially numbered and then memorized.

Once This is accomplished the accelerometers that sense accelerations can continually (through the computer update the pilot as to his current position and how to get to any of the waypoints or back to the initialized home base,

Additionally through the computer the pilot is told airspeed groundspeed track, track angle, displacement from track, distance and time to the next selected point. The instrument also checks itself for drift errors and annunciates mode failures, if the computer portion fails the gyro platform will continue to feed raw data to the flight instruments such as A.D.I. and H.S.I.

The computer should be retrieved and data retrieved from the memory when possible. Again the military does this the N.T.S.B. doesn't. Some I.N.S. record digital code failure modes. These can be retrieved. The cockpit head and enunciator should be retrieved and a light bulb analysis conducted.

Altimeter: Altimeters are of many makes and styles. They display altitude information. There are many varieties of face dials. There are three main varieties of altimeters. T here are radar altimeters that readout altitude in feet above terrain. There are pressure altimeters that read out altitude above mean sea level -these are only corrected for barometric pressure, and there are corrected altimeters that use C.A.D.C. to correct for temperatures and other variables. If the C.A.D.C. fails it will show a standby flag and will revert to operating as a pressure altimeter.

The investigator has many clues. The first is to determine that the pilot has` dialed in the current altimeter setting equal to the current barometer reading. A failure to install the appropriate barometer will give a false reading. Suppose the altimeter is 30.30 inches and the pilot has left 29.92 inches installed the altimeter will be in error by an amount of 380 feet. (Each 0.1 error equals 100 feet in error.)

The investigator should attempt to read the face of the instrument, the "needle slap" reading or black light "needle slap". If the dials are missing the internal gearing and stem position may tell the altimeter setting. The investigator should know that sometimes an internal spring breaks free and drives the altimeter to erroneous readings due to ground impact. The instrument should be taken to qualified instrument lab for teardown and analysis when appropriate.

Landing GEAR: Landing gear come in two varieties, fixed and retractable. The investigator should check the position of he retractable gear to see if it was up or down. If it is down and broken off then both the up locks and door locks should be intact. On the other hand if the gear was up at impact and is now strewn around the up locks and door locks should be broken.

When landing gear collapse on landings the investigator should call upon a metallurgist, some of the strut materials used in landing gear are susceptible to stress corrosion and hydrogen embrittlement.

Hot section: The hot section is covered in the engine chapter and in the title Burner section (above)

Hydraulic accumulators: Hydraulic accumulators are devices that hold and disperse hydraulic fluids. Typically the accumulator fluid is under some pressure often provided as an inert gas pre charge, an accumulator of this variety tends to keep a constant hydraulic pressure applied and it counteracts any tendency for a hydraulic surge. An investigator should check the condition and whether there is a pre-charge still remaining. An investigator should be very careful around such devices because hydraulic pressures can be dangerous and hydraulic fluid can be very toxic. Hydraulic actuators: Hydraulic actuators are often used to operate primary flight controls, spoilers, speed brakes, and landing gear and gear doors as well as flaps and yaw dampers. Commonly these systems are of two general varieties. They are pure actuators where hydraulic fluid is ported to and from opposite sides of a power ram by moving a sliding metering valve.

The other is really a hydraulic motor that is forced to rotated in a particular direction, this in turn runs a screw jack device that changes rotational motion to extend or retract linear motions.

When a hydraulic device is suspect an investigator should: Photograph it in the as found condition. Take appropriated data measurements of ram extension or screw jack condition. Actuators the more complex they are the more susceptible they are to contamination clogging and restrictions. Thus the filters should be checked. The design of some complex servo actuators is such that they generate contamination internally.

When this is suspect the servo actuator should be removed and X ray examined before any attempted movement of parts. The next step is to see if the part will function appropriately in bench testing and A.T.P. testing (acceptance test procedure). Only then should the component be dismantled. Position can be determined externally from the ram extension length. Internally the part may leave witness marks at the ram piston- cylinder wall interface.

Jack screws are easier and less prone to movement. The investigator takes measurement of the threads exposed on both sides of the screw device and correlates that to rigging diagrams to determine extension or retraction.

Hydraulic filters: Hydraulic filters are to be examined for contamination. This is a clue to general condition of the hydraulic system and the fact that components may be creating contaminants some where in the system.

Hydraulic delta: These are little poppet's that blow and bypass fluid around clogged filters. They signify that fluid has bypassed the filter usually because the filter will not pass enough fluid on demand.

Hydraulic lines: Hydraulic lines should be checked for integrity at connections and to see that they had not ruptured pre impact. These lines are usually bent steel. Hydraulic aircraft systems are usually run at 3, 000 psi or 1, 500 psi. Thus a ruptured line will vent all reservoir fluid overboard in a matter of seconds. When there is a line leak the fluid may atomize into a mist.

Hydraulic pumps: Hydraulic pumps are of two varieties generally. They either get their power from the engine through the accessory section drive or they are electric driven. The investigator is looking for crash damage that would show they were operating at impact. Thus cockpit switches hydraulic pressure gauges and warning lights should be examined. At the Pump you are looking for rotational damage, overheating and internal damage. If the pump is intact it can be taken to a lab and pressure and flow tested.

An investigator must have both overhaul and flight manuals for the aircraft in order to determine what the status of the hydraulic system should be during a particular phase of flight. (It differs on the ground, takeoff and landing and in cruise)

Hydraulic Reservoirs: Hydraulic reservoirs are storage tanks for supply hydraulic fluid. They are not pressurized to system pressure. If they are intact post crash they should have fluid present, if they are intact -upright and empty the investigator may suspect a problem that may have pre existed the crash (remember however it doesn't take long for a working system to evacuate the fluid overboard.

Hydroplaning: Hydroplaning is a condition of wheel to runway status that results in a skid as brakes are applied. There are three varieties. Deep water hydroplaning where the tire tread rides on a cushion of water. Viscous hydroplaning where the tire tread rides on a thin layer of water grease emulsion, and reverted rubber hydroplaning where the tire friction and heat turns the water to steam and the tire tread rides on a cushion of steam. Any variety of hydroplaning destroys brake effectiveness. Deep water hydroplaning is expected to occur at 7-9 times the square root of tire pressure.

ICING: See the chapter on icing. Icing kills. It forms on aircraft at temperatures of plus and minus 10 degrees Celsius in visible moisture and airframe ice is in the form of rime ice (white build ups with air bubbles throughout), or clear icing (clear like an ice skating rink)Airframe ice increases stall speeds, destroys airfoil aerodynamic shapes, increase aircraft weight, increases aircraft drag. It can affect engines and propellers deleteriously.

Clues the investigator has of airframe icing: C.V.R. tapes, Radio tapes, Switch and anti ice valve positions, warning and status lights, decreased aircraft performance and speed. Weather reconstructions, pilot reports. Pireps in the area.

On the wreckage itself sometimes ice will be knocked free at impact. If this occurs and the aircraft paint was dirty then the area that was covered with ice will be clean if the ice is jarred loose.

Engines may ice and quit. There are several varieties of icing problems associated with ice. A fuel filter may ice, carburetors or injector venturis may ice. Jet engines may be hurt by ingestion of hunks of ice. Jet engines may flame out because of ingestion of ice. Carburetor icing may occur in ambient temperatures well above the normal icing range because internal to the Venturi potions of the device pressure and temperature is lower than ambient.

A problem for the investigator is that often the ice that caused the problem is dislodged or has melted because of higher ground temperatures or fire. Icing must often be proved by circumstantial evidence and by scientific and demonstrative testing by simulating flight conditions, that and through expert testimony.

Icing, slush, snow and water effect braking efficiency as well.

Instrument approach accidents: When an aircraft crashes doing an instrument approach the investigator must not only examine the aircraft instruments and radios, he must also check the ground facilities for there operational status. The facility log will show equipment status at the time of the accident. There are other records relating to the specific navigational aids. When they were first installed they underwent a site evaluation check, then a commissioning flight check. In the interim they may have had several periodic flight checks, and after a crash there may have been a special post accident flight check. The investigators should obtain all of these records.

Jackscrews: Jackscrews are devices that translate rotational forces to linear extensions and retractions often providing mechanical advantage as well. A jackscrew is a Godsend to an investigator for they almost never are moved as a result of impact damage. Thus the reading found at impact is usually valid.

Light Bulb Analysis: If there has been an impact and the glass of a light bulb is intact then if the filament is stretched it was hot and on. If the filament is not stretched or broken in a brittle condition it was not on. If the bulb is broken and there is tungsten oxide residue found by S.E.M. scanning electron microscope. Then the bulb was on

Locks: Gear locks up and down should be examined as should all door locks. If the gear is broken or doors open or missing the locks will be broken or deformed if it happened as a result of crash damage. If the locks are not deformed or broken the doors or gear were released pre impact.

Magnetos: Magnetos are part of a reciprocating engines electrical ignition system. They create the high voltage spark that is delivered to the spark plugs by the ignition harness. The investigator should ascertain that they were connected and rotating at impact through its drive shaft. If they are unhurt they may be bench checked.

M.C.O: Maintenance Carry Over items are systems and components that are found to be inoperative but the aircraft can legally be flown without them. In the log these are listed as M.C.O.s. In large aircraft there may be a restriction to how long an item is allowed to exist before it is fixed.

Minimum Equipment List: The Minimum equipment List for an airplane lists all components that may be inoperative and restrictions placed on the airplane while it is still being flown.

Mixture controls: These are the controls for a prop airplane. It determines whether gas is on or off and whether the mixture is lean, normal or rich. The on /off function usually has a detent and that is not damaged by crash.

Needle slap: Needle slap is a phenomenon that often happens when an instrument impacts the ground and the pointers and needles slap against the face of the dial. Often these slaps leave marks or paint flecks called "needle slap ".

Ninety degree gearbox: A ninety degree gear box is found in the tail rotor area of a helicopter. A 90 degree gear box changes the rotational direction by 90 degrees and may also change speed ratios or mechanical advantages. An investigator looks to see the signs that it was rotating at impact: rotational damage, torque failures due to sudden stoppage, heat and bearing failure, internal failure clues etc.

Oil Pressure: Oil pressure is very important to the normal operation of engines and gear boxes. Oil pressure gauges usually are accurate and reflect the reading at impact. Lack of oil quantity results in the same oil heat problems as does lack of oil pressure. The clues are oil leaks, oil starvation, heated bearings, spalling bearings, sized rotating parts, blued areas due to heat.

Oil starvation: Oil starvation is identifiable by no oil present, low oil pressure readings, seized parts, failed bearings, overheated metal discolorations etc.

Oxygen systems: High altitude aircraft carry O2 systems. In American certified aircraft each passenger is supplied a mask. A high altitude warning occurs at 10, 000 foot cabin altitude. At 14, 000 feet the masks deploy automatically. The pilot can pull a handle and deploy passenger O2 at any time.

The pilots have a separate system from passengers. Any time an aircraft is above 25, 000 feet and a crew member leaves the cockpit the pilot remaining is supposed to don his O2 mask. O2 tanks can leak and may cause fires to erupt .A clue that there was a serious aircraft problem may be that the masks were deployed or that the crew had donned masks. If all masks are deployed the aircraft had lost pressurization. If the crew is wearing O2 masks the plane lost pressurization or there was an onboard source of serious smoke or fire. If the crew has donned onboard smoke goggles or the air breathers there was serious smoke or onboard fire.

The investigator can listen to the C.V.R. for the cabin high altitude alert horn and conversations. The altitude warning sets off a light and thus there may be light bulb analysis.

Pistons: Pistons move up and down in engines. In reciprocating engines the volume of air a piston compresses is its diameter (bore) multiplied by it's stroke (distance the piston moves).The displacement of the engine is that volume multiplied by the number of pistons. The compression ratio of the engine is the ratio of the volume of air entrapped in a cylinder at top dead center to the volume of air trapped in the cylinder at bottom dead center. Typical compression ratios are 10 to one. In more modern engines higher compression ratios and faster R.P.M. produce greater power.

Pistons should be examined. An investigator can tell if they have been subjected to detonation and backfiring. Also they often fail where they are attached to the connecting rods.

Pitot Static systems: Aircraft pitot static systems are of many varieties and complexities. They provide ram and static air pressures sufficient to provide altitude and airspeed data. Pitot tubes face directly into the ram air and static ports are flush with the fuselage in areas where they will not receive ram air effects. These ports can ice over and cause bad readings. Many are equipped with electrical heating elements to prevent icing. An investigator should check whether these were on and operable when icing is a possibility. Static and pitot ports are invitations to wasps and insects. Dirt daubers have killed a few airplanes.

Pneumatic air valves: Pneumatic air is used for air conditioning, starting engines and for anti icing wings and nacelles as well as windshield rain hot air. There are many valves. The investigator should determine what systems were in usage, switch positions, warning lights and status light condition and valve positions consistent with desires.

Pneumatic ducting: Pneumatic ducting carries hot high pressure bleed air from the engine to the point it is needed to do its job. Often these ducts can overheat or rupture. When possible the investigator should audit those ducts. Overheats usually annunciate with warning light illumination. Ruptured ducts may result in aircraft system loss all the way to aircraft over pressurization. The investigator must understand the aircraft and the pneumatic system to analyze for duct loss consequences.

Preserving evidence: An investigator must recognize the need to be able to document the condition of evidence at the time of impact. Thus the first stage is to document, photograph and video all parts as they lay (the as found condition) Once this investigator retrieved photos from a fire department that showed a gust lock pin in place, by the time the feds got there somebody had removed the pin!

Once parts are disturbed they may acquire new scratches that obliterate or create new witness marks. Often to get to a part or component the aircraft must be dismantled by sawing, cutting and/or cutting torch. These cuts should be logged and care must be taken to insure that probative evidence is not destroyed and that false evidence is not introduced.

The military usually preserves parts and components thought causative as well as keeping the wreckage for about two years. (Coincidently about the average statute of limitations time)

The N.T.S.B. does not usually undertake to store or preserve wreckage. After the accident investigation is complete they release the wreckage to the owner or the owner by right of salvage due to hull insurance. These enlightened insurers often keep the wreckage.

Every investigator realizes that the more often the wreckage is moved, lifted transported and examined the more likely evidence is lost or false evidence may be introduced. The salvage dealer is more concerned with getting it on his truck than he is about preserving witness marks. Salvage yard examinations by experts always include time sorting out which marks and scratches were as a result of salvage and which happened at impact. As found photos are often the key. See the chapter on spoliation of evidence.

Pressurization valves: Aircraft pressurization valves or outflow valves regulate and maintain appropriate pressure within the airplane. Think of an airplane as a football that is constantly being inflated with new clean air conditioned air. To keep from over pressurizing the football you must let some old breathed air out. This used air (excess) is vented over the side through several regulating outflow pressurization valves.

If these valves should regulated shut then the airplane would over pressurize. On the other hand if they went full open the airplane would lose all its pressure and that would cause problems at high altitude. When there is weight on the landing gear the outflow valves should de pressurize. You cannot open the aircraft plug type doors on a pressurized airplane.

Prop Condition: See section on propellers. An investigator can tell many things from prop condition. First he determines that all prop blades are present. A slung blade is often fatal.

If all blades are present the investigator should examine them for signs of rotational power:

1. Tree limbs cut down
2. Chord wise scratching
3. Leading edge damage
4. Blade tip twist
5. Bends opposite rotation.
6. Spinner rotation damage evident.
7. Prop broken of by torque overload.

If a teardown is performed look for Blade angles:

1. Force angle semi circles at hub and butt.
2. Look for indentation transfers between butt and hub.
3. Look for fatigue failures in hub
4. Look for witness marks internal to prop cylinder and piston.

Prop controls: Prop controls may have three positions, feather, normal range and reverse range. Usually the pilot must pass some detent to get to feather and reverse. Thus prop controls found in this condition in the cockpit suggest some pilot action. Props found in feather and reverse without identical prop control configuration is indicative and a clue to a problem.

Pulleys: Aircraft that use cables for controls also invariably use some pulleys for routing the cable and changing cable direction. Cable pulleys should be examined. If they are torn out from their mounts of bolts or rivets in tension overload the investigator has a clue that the pulleys were in place and the cable was taught at impact (under tension). Sometimes such pulleys simply fatigue fail and then the control cable is lose and inoperative. Pulley side walls are often broken off and this is clearly indicative that the cable was in the pulley at ground impact.

On a related area, aircraft control systems often utilize capstan devices that reel in cable on one side while reeling out cable on the opposite side. At crash the investigator may count rolls of cable on each side of the capstan and thereby determine
whether the control was up down or neutral. Often if the system undergoes great cable tension during impact breakup the tension forces will actually stamp an imprint of the cable strands on the reel in /reel out capstan and this will tell the investigator exactly how many evolutions were present on which side at impact.

Radar: On board weather radar and T.C.A.S. displays. The investigator should determine that these items were operable and installed from the aircraft logbook. A C.V.R. tape is helpful because usually if there is bad weather the flight crew will be discussing the weather depiction shown on the radar.

An investigator should order a weather reconstruction and retrieve weather radar photos from the National weather service. In the aircraft there are the components switch positions to show what mode he was operating in and what mileage scale was being depicted.

T.C.A.S. is a display that utilizes the same radar screen. It displays all other air traffic with a code and it's altitude. (It only displays traffic with altitude encoding altimeters turned on)T.C.A.S. also gives visual alert and aural verbal instructions to the pilot if a traffic alert and potential conflict or collision is sensed as a potential. The T.C.A.S. alerts may be obtained from the C.V.R. whenever there has been an air collision or a near miss or a midair aircraft separation the investigator should freeze and then retrieve all ground radar tapes that might be painting the aircraft flight. This includes not only those radars that are controlling the airplanes but those that may be ancillary but may have data.

For instance in the San Diego P.S.A. mid air accident the flight crew saw the wrong aircraft. In another case the controller warned of an aircraft but told the pilots to look left rather than right. (Ten o'clock rather than two o'clock)

Radar altimeters: Radar altimeters read aircraft height above the ground usually at the wheels. A pilot may set an altitude alert at a selected position. (Usually approach decision height).The investigator should note the logbook to see it is operating, the face of the instrument for flags, the decision height set in. An operable radar altimeter is required for the Ground Proximity Warning Alert System to be operating.

Radios Vhf Comm.: The investigator should record frequencies selected, on /off position and radio volume. If these are unhurt they may be bench tested or even tested in the field.

Radios Navigation: All radio navigation equipment should be audited and recorded for:
F.M.S. on /off, waypoints and loading, lab retrieval
I.N.S. on/ off, way points and loading, modes selected, warning lights, lab retrieval
RNav, on /off, waypoints, mode selected.
Omega, Loran, Loran C, on /off, waypoints, mode selected.
Satellite System Navigation Units (military) on /off, modes.
Civilian GPS Nav, on /off, modes.
H.S.I., course selected on heading bugs, course selected to display radial.
Nav radios, frequency selected, on /off
H.F. frequency and on /off
A.D.F. frequency selected, on /off, mode selected.
R.M.I. mode selected for needles, Vor, ADF, or other.
H.U.D. (military) on /off display selected.
Tacan, (military (navy) on /off, course selected
D.M.E. on/off, read out recorded.
Altimeter, corrected or standby, barometric setting, reading, M.D.A. setting
Radar Altimeter, flags, reading, decision height setting.
Flight Directors, mode of operation, flags, mode panel lights, needle captures.

Mode control display lights, light bulb analysis.

[ALL of these are amenable to laboratory analysis]

Rain Repellant: Rain repellant is sprayed on windshields by pilots during rain approaches. It makes the windshield slippery and the visibility improves. C.V.R. will tell if it is asked for, switch position and bottle condition will tell if in use. It is Toxic.

Ram Air Doors: Ram Air Doors regulate from open to slightly open. Ram Air is used for air conditioning and pressurization. They regulate automatically. Usually they are full open on the ground and at low altitudes especially in hot weather. At cruise they are usually as far closed as they go. An investigator should record these especially if there is a suspected problem with air conditioning or pressurization. You must understand the systems operation in order to correlate door position to cabin operation.

For instance if one air conditioning pack overheats the ram air door will go full open to provide additional cooling. In the cockpit there are switches for automatic door control and manual override. There are warning lights for air conditioning and pack overheats (these open the door automatically)

Rotor blades: Rotor blades are the propeller for a helicopter. They are mass balanced. An investigator should audit all mass balances. All rotor blades should be found near the accident. They may be slung quite a distance after impact.

The investigator looks for condition, leading edge damage and rotational overload from sudden stoppage. Dramatic up ward bending suggests that the rotor blade had been under speed. The investigator should ascertain whether the rotor was powered or in an autorotation mode (in freewheeling neutral)

If it is determined that a blade has come off in flight it is almost a sure thing that others will vibrate off after loss of the first blade. The investigator must determine which blade is first and then why it was shed.

Common reasons are:

1. Blade struck something.
2. Blade shed mass balance weights or structure.
3. Fatigue of blade or blade hub.
4. Failure of blade restraining system and clamps for several reasons.

Rudder position: The investigator should determine the rudder position at impact. He may have clues as to position from rudder hinge tear out direction and stop damage. (If a rudder is off center to one side it will want to continue off center at impact.
If at the time of impact it is powered hydraulically then the rudder power actuator is a very good indication of rudder position (see hydraulic actuators above and chapter on hydraulic systems)

Rudder trim positions are a very good clue as to rudder applications and problems at time of impact. In airplanes operating normally the rudder trim should be zero or very close. Rudder trim is provided to counteract asymmetric thrust (loss of power in an engine) and unusual drag or uncommanded flight control inputs. In Manual reversion, failure of hydraulic boosting, the power pack actuator is disabled and flight control tabs are released to operate the rudder in manual. This is a very substantial clue for the investigator.

SAMPLES, Oil, Gas:
Oil should be collected into sterile containers and capped. The source should be well documented (# 1 engine supply, #2 C.S.D. supply, # 2 prop dome, etc.) This should be returned to a lab and analyzed for contaminants. Fuel Samples should be obtained from as many sources as possible and examined for contaminants and type of fuel. Each tank should be tested as well as samples from sumps, filters and lines.

Skid marks: Skid marks are a clue to the investigator. On takeoff accidents if one or more skid marks are found from the beginning of takeoff roll then there was a dragging brake or brakes. If skid marks appear down the runway there was an attempt at maximum braking in an abort situation.

On landing a single skid mark shows anti skid failure and a dragging brake. All skid marks show locked brakes, pneumatic brake application or landing with the park brake on. In wet weather black skid marks show viscous hydroplaning and white clean tire marks show reverted rubber steam cleaning hydroplaning. In most cases they show a pilot attempting to stop the aircraft.

Spark plugs: Spark plug condition tells an investigator about engine condition. Spark plugs are easy to remove in the field and they should be observed. They can be tested for spark and shorting later. When they are removed they should be labeled so to preserve evidence of which cylinder they came from.

Before removing them check the leads integrity and that the plug was torqued properly (not lose)

Check for:

1. Clean plugs, no lead or oil fouling
2. Electrode condition
3. Metal deposits (melted)
4. Melted copper rivulets.

Speed brake positions: Speed brake conditions should be considered and recorded. Speed brakes are used to slow an aircraft in flight and on the ground. Jet airliners use a dual purpose device for the speed brake function. These are spoilers that deploy from the wings. They are used as a flight control to aid turning and in this capacity they are deployed on individual wings. When they are used as a speed brake they are deployed simultaneously on both wings. Their deployment accomplishes two things: One they spoil lift on that wing -thus on landing their deployment gets aircraft weight on the wheels to aid the friction of braking. Additionally their deployment causes aerodynamic drag that aids in slowing the aircraft.

In the cockpit speed brakes are deployed by a handle or in some aircraft an electrical switch.

On jetliners the speed brakes (called ground spoilers should be deployed as soon as there is weight on the wheels). Some jetliners have automatic speed brake deployment on landing when there is weight on the wheels and there is wheel spin up. If the system is automatic it must be in the armed condition. Some are always armed and it can be disarmed. Others must be armed. The investigator must know his particular system. Regardless the spoiler speed brakes are normally to be deployed on landing. If they are not there is either a system failure or a pilot failure.

In flight the spoilers-speed brakes must be manually applied. Sometimes on go around and in some flight accidents the spoilers have been found deployed when there is no reason for them to be in use. Here you have a system failure or pilot error.

Most speed brakes are hydraulically actuated and operated, thus the actuators at the wing are the best clue as to actual speed brake deployment condition. See chapter on hydraulic actuators.

Some aircraft, Military and Fokker have fuselage mounted speed brakes. Some military speedbrakes are mounted both on top and below the wings. If this is the case they are complex systems since the bottom of the wing speedbrakes will not deploy if flaps are down. Again the investigator must understand the operation of the particular system he is investigating.

Springs: Springs are used in aircraft for many diverse purposes. They may operate within complex and sophisticated metering systems; they may operate to regulate tensions in flight controls. They may be the actuating force for latching mechanisms. They may be the moving force in valve positioning devices. I can't tell you the number of aircraft devices that the best systems instructor in the world (MARK WILLIS) describes as “electrically initiated- pneumatically or hydraulically operated - spring loaded closed”. Springs are every where and they do fail. They may disconnect, they wear out, and they sometimes fatigue fail. Occasionally maintenance may install an improper spring during overhaul.

Spoiler positions: See speedbrake above. Spoilers are used as part of the roll control of airplanes. When they are used in this capacity they deploy one wing at a time and they act to destroy a portion of lift on the wing and they add some drag to that wing. The result is that the wing drops and a rolling turn is initiated. A spoiler deployment in flight can only be initiated by a failed system or pilot input. If an investigator finds spoilers on one wing deployed at the impact site the pilot could have been attempting to roll the aircraft in a futile attempt to correct the situation or that deployment could be part of the cause.

Starters and starter valves: Engine starters are usually electric motors in prop airplanes and pneumatic in jet aircraft. Usually starters that don't work on the ground do not cause aircraft flight accidents. I have investigated one take off accident where a pilot said, “I thought I would take off with the good engine and get an air start."

Jet engines may fail if a starter valve opens in flight. If such an occurrence happens the pilot must quickly shut down all sources of air to the starter. Depending on the aircraft he may have to shut down the engine to protect it for starter seizure or disintegration can cause serious problems.

C.V.R. tapes, switch positions, starter condition and engine condition and operating status are the best clues to this variety of problem. Light bulb analysis of starter valve light is possible.

Stop damage: Stop damage generally relates to damage done to control stops when the control surface has slammed full against one or both movement stops. These stops are to prevent over travel of the control surfaces and set up the correct rigging travel limits. Stop deformation on both sides suggests hammering or cyclic movements in excess of those expected. Stop damage on both directions does not mean flutter; all it means is that the control surface has hit both stops. In normal operation there should be know stop damage.

From a metals standpoint there are numerous devices that have travel limit stops. Any time one is deformed or hammered the investigator should examine further to determine what the cause was and what the result means.

Tachometers: Tachometers are self contained generators that sense rotational R.P.M. These are usually accurate at impact and will retain the last reading at impact.

Tail rotor blades: Tail rotor blades are found on helicopters. Their purpose is to counteract yaw and provide directional control. They are very delicate and since they rotate so fast they must be perfectly balanced. Throwing balance tip weights or honeycomb structures or icing may unbalance them. An unbalanced tail rotor may shed a part of a blade, a whole blade or the whole rotor may come off due to vibration failures. An investigator should inventory all blades, tip weights at the scene.

Additionally he should ascertain it was rotating under power at impact he does this by:

1. Seeking rotational damage
2. Torque failures at the 90 degree gear box
3. Torque failure at the torque tube.
4. Broken blades due to rotation
5. Bending opposite rotation.
6. Leading edge damage.

Testing: Testing is done by the N.T.S.B. and the military. Their results, data and photography may be obtained. When you as an attorney undertake testing you must be aware of spoliation guidelines. It is appropriate to do any non destructive testing you wish on components that you possess legitimately. Since there is the consideration that you may be doing these tests for the purpose of litigation you must be cautious to not violate spoliation laws that are rapidly expanding and changing.

It is always best to utilize scientifically recognized protocol at certified testing laboratories when possible. Once involved with litigation the lawyer should work with the opposition when destructive testing is contemplated. To this extent mutually agreed upon criteria and protocol as well as mutual viewing is sometimes possible.

Throttles: Throttles are the gas foot feed for a reciprocating engine. They very often move during the crash sequence. The investigator should note their position and then correlate that position to other engine performance criteria and status.

Thrust levers: Thrust levers are the fuel foot feed for a jet engine. They are susceptible to movement during crash sequence. An investigator should correlate their positions to other engine criteria and status.

Tires: Aircraft take special tires. The investigator should ascertain that the ones installed are appropriate. Many jets require special chine nose tires and mud flaps to suppress ice and water ingestion in rear mounted engines. If an accident is caused by multiple blown tires the investigator should return all the rubber to a tire lab and ascertain why they blew. Many aviation tires are second hand retreads.

Torque tubes: A torque tube is the name given a drive shaft to a tail rotor of a helicopter. It is usually a long thin metal tube. The investigator should look for integrity or torque failure due to a sudden stop.

Trim Positions: All aircraft trim tab positions should be determined at the tab itself by measuring the actuator or the jackscrew position. The trim position should be verified in the cockpit at cable take up reels or capstans and at the cockpit indicator. The meaning of each trim position should be analyzed as to meaning in the expected flight envelope before impact. (Ergo : full nose down trim might mean the pilot would have to pull back with 50 lbs force at cruise or 100 lbs force at high speed in order to fly level.)

Turbine Blades: Turbine Blades are jet engine blades that recover rotational energy from the expanding hot jet exhaust in the turbine section. The operating temperatures in a working turbine section are extreme. Therefore the metallurgy of the blades is so sophisticated that the blades are very brittle (almost ceramic) at room temperature and they become softer at the operating temperatures. This becomes a very good clue to operating power of jet engines at impact. If the turbine blades broke brittle it was relatively cool. If the turbine blades broke hot then they will bend opposite the direction of rotation.

Turbine Spatter: Molten metal may be spattered around the turbine section of a jet engine. If this occurs the metallic spatter shows that the engine was hot at the time the metal was being melted. The metal that spatters is usually aluminum from a scraped shroud.

Valves: Valves are engine parts on a reciprocating engine. These should be examined if the engine is torn down. Here you are looking for condition of valves, valve stems and rocker arms. The valve should not show localized overheat.

Vacuum pumps: Vacuum pumps are aviation air suction pumps that are used to power some instruments. They should be checked for condition, rotation and in particular connections and air tight integrity.

Weather accidents: When weather is suspect the investigator should retrieve data from some or all of the following sources. Witness statements (tower and other pilots). Weather radar, radar photographs, Aviation weather sequences, Surface observations at towers and weather facilities, Pireps, Airmets, Sigmets, Winds aloft, Adiabatic Charts, R.V.R. reports, A.T.I.S. reports, Braking reports, Weather satellite reports, area forecasts, Terminal forecasts, Severe weather reports, and local T.V. weather from independent sources.

Windows: Windows should be checked for integrity pre impact and for bird strikes. They also may be dirty from oil leaks in single engine machines.

Windshield Wipers: Windshield wipers are usually stowed. Finding them deployed is a clue they were in use. The cockpit switch position and the motor are the other clues for operation.

Wires: Aviation wire is and insulation is a specialty field. The investigator should check to see that the wire is the appropriate variety for use in the aircraft. Hot section insulation requirements are different from other areas and insulation is rated by its heat resistant capabilities. Maintenance facilities do not always utilize correct wiring.
Wiring is usually copper and sometimes silver. The insulations have different properties and the investigator should be familiar with all varieties. Some insulations flash over and burn. Such a flashover fire leaves a distinctive burn pattern along the wire strand or bundle.

Wire bundles: Wire bundles are fabricated in shops before aircraft installation. They are typically fabricated by soldering precut wire lengths to male female connectors. Often the multi wire bundles have individual wires spliced. These splices should be randomly spaced throughout the line. One major manufacturer was delivering bundles with all splices done in the same area. This looked like a snake that had eaten an Easter egg. When possible the investigator should trace wire bundles and look for cracked and broken wires, cut insulation, heat areas and shorted and burned situations. An investigator can audit the bundle and see what wires are adjacent each other as well as auditing the connectors.

Loose connectors cause intermittent electrical problems. Connectors should be looked at for clues as to overheat arcing.

Wire Chaffing: The insulation of wire is there for the purpose of preventing short circuits and to prevent the flow of electricity in one wire from interfering with the flow of electricity in an adjacent wire (sneak circuits).

Bundles must be protected from chaffing wear and cutting by use of appropriate guides, clamps, retainers, brackets and smooth edges. Sharp edges and screw ends must be covered so that the wires insulation will not be cut. An investigator should track all the bundles and see that there were no short circuits or pre existing wire bundle fires pre impact. This is an easy job if there is no aircraft fire and difficult to impossible if there has been a conflagration. Wire bundles should be audited to ascertain if redundant equipment wiring runs in the same bundle. (If it does it is defective as it is susceptible to common cause failure.)

Wire Insulation: Wire insulations are of several varieties with differing properties. Manufacturers' varieties include Kaptan, Raychem, Tefzel and others. There performance and capabilities vary. These properties that are tested include: insulation cut resistance, Crush resistance, impact resistance, notch propagation, bendability, current overload, flammability and hydrolytic stability. They are rated differently for heat. Probably the most important characteristic are current overload, flammability and hydrolytic stability in the aspect of accident investigation where a bad wire effects systems adjacent or causes fire.

Witness marks: Witness Marks are the investigators name for marks and indentations made by closely adjacent parts scoring or scrapping or bending each other at impact. From these marks the investigator may determine existing relative positions of components and adjacent parts at the time of impact. Often there are more than one set of such marks that has been made during the impact and destruction sequence.

The marks on metal often show not only the impact, but the direction of relative movement at the impact. It is important that the investigator analyze and determine which set of witness marks occurred first since that set will determine position at first impact.

Yaw dampers: Yaw Dampers are devices that operate through the rudder automatically to damp out unwanted yaw. The system senses yawed flight and inputs a small rudder application to oppose such aircraft movement. Typically yaw dampers are present to counteract a phenomenon known as Dutch Roll. Yaw dampers only input a small correction -typically restricted to no greater than five degrees. When an investigator finds a yaw damper input in the wreckage he must become curious as to what caused this to occur.