ENGINES

Aircraft Engines come in many variations. The most important single thing to be said of all of them is that when they are running they have many moving parts. If engines crash while they are running, the investigator is left many clues. The most important is whether or not the engine was producing power. The next important aspect is to determine how much power, if any, was being produced.

Before continuing, I will attempt to discuss the typical aviation engines in use today. They are:

1. PROPELLER

a. Inline -radiator cooled-combustion.
b. Radial -air-cooled- combustion.
c. Inline opposed -air-cooled – combustion.

2.TURBINE-PROPELLER

a. Thrust driven propeller.
b. Direct driven propeller.

3. PURE JET

a. Turbo jet
b. Turbo - Fan Jet
c. After burned -Reheated - Jet

Each of the above engines must have three things and one condition to run. They are fuel, air, ignition source, and the condition is working mechanical condition.

Engines may fail because of:

1. Mechanical failures
    a. Innumerable possibilities.
2. Fuel starvation
    a. Ran out of fuel.
    b. Fuel line integrity.
    c. Fuel ice.
    d. Fuel contamination, water, algae, f.o.m., and sabotage.
    e. Wrong type fuel.
    f. Fuel pump failures.
    g. Carb or fuel injector failures.
    h. Jet fuel control failures.
    i. Throttle, mixture, fuel shutoff, tank selector valve.
    j. FADEC failures.

3. Lubrication failures
    a. Loss of lubricant.
    b. Loss of pressure to lubricant.

4. AIR.
a. Carb.
b. Fuel injector.
c. Icing.
d. Fuel control- inlet condition jets.
e. Ice, snow, rain, hail.
f. Ducts.

5. HEAT SOURCE
1. Ignition-igniters.
2. Magnetos.
3. Spark plugs.
4. Electric line integrity.
5. Switch position.

Thus the investigator must first determine if the engine was running at impact, and then determine why it wasn't if that is the case. In propeller aircraft the propeller condition and its gearing provide evidence of the production of power at impact. In fact PROPELLERS are so important that a separate section is devoted to propeller condition and evidence.

An investigator, to be at all efficient should have an aircraft flight manual, a systems schematic and an illustrated parts breakdown for the aircraft to aid him in identifying parts and their operation. The first step is to photograph everything thoroughly before touching it. This photo audit should be complete enough that all components are identified and all movable parts are recorded in the as found condition. A trained investigator will not succumb to the urge to move handles and switches in order to determine if they are free. This comes later. Notes should be made as to the as found condition and the parts tagged or otherwise identified. A good investigator may also take a Polaroid along and take duplicate photos since these are instant records. During the IRAQ WAR I lost some film in luggage since they had the XRAY machines turned up! Luckily they were fishing pictures not evidence.

The first type of engine system described is an inline engine with a radiator for coolant. This is very rare and universally an old design. It is very similar to the operation of an inline straight block car engine. In all probability the average investigator will never see one in a lifetime of investigating.

The second variety of engine is the air cooled - opposed cylinder variety. This is the engine favored in general Aviation circles. They may be 4, 6 or 8 cylinders and each cylinder is mounted 180 degrees opposite the other, thus the name opposed. All pistons are connected to a single crank shaft. I estimate 95 percent of all general Aviation airplanes produced in America use this engine type. The two major builders were AVCO- Lycoming and Teledyne Continental. Each individual cylinder is exposed and covered with heat transfer fins for air cooling.

The third variety is a radial engine, always of an odd number of cylinders equally spaced and emanating from a central crankshaft. In bigger engines there may be second or third banks of cylinders behind the first set and still connected to the

Same crank shaft. The designations of the common engines of this design are Radial 900 series, radial 1800, or radial 2700. This is not a horsepower rating but rather denotes number of cylinders.

You will find this variety of engine in Antique Bi Planes, War birds, D-18, DC-3, DC-6, DC-7, Lockheed Constellation, CONVAIR AIRLINERS, Lockheed lodestar and some crop dusters.

An Investigator can derive information as to whether an engine was running from examination and tear down of the engine itself, from review and teardown of the propeller system itself(covered in another section)and from review and teardown of the accessory section components that are driven by the engine. For the purpose of this chapter, Information about engine condition and power will be called **primary information.** This information includes information derived from the engine itself. It includes the drive shaft emanating from the engine to the propeller and drive shafts emanating from an engine to accessory drives. The gear boxes, accessory drives and the propeller system will be defined as providing **secondary information** as to engine power and condition at impact. This choice of nomenclature is not to be construed as a prioritizing of the credible and substantive evidence gleaned from either. Rather it is a nomenclature commonly used in the field to delineate the source of the information not its value.

Within each of these varieties of reciprocating engines there are parts of similar design and use. They all have a central crankshaft/camshaft. This shaft rotates at high speed and is balanced .It usually is connected to one or more balance weights called fly wheels. The crankshaft is resting on at least two sets of bearings so that it can rotate easily.

The shaft protrudes from one end of the engine and acts as the drive shaft for the propeller gear box. The shaft also has machined cams that are designed to operate lifters that open and close fuel input and exhaust valves. Here designs may vary greatly.

Each engine has connecting rods that attach to the crankshaft and the individual piston. Each piston is equipped with a series of seal rings that fit closely against cylinder walls insuring compression to each cylinder. At the top of each cylinder is the cylinder head and gasket. In reciprocating engines with individual cylinders there is a gasket at the bottom as well.

Valves allow fuel in and exhaust out. These valves are usually spring loaded closed, cam lifted open devices. The lifters are linear devices. (up- down) whose authority is derived from cam position.

PRIMARY CLUES THE INVESTIGATOR HAS THAT THE ENGINE WAS PRODUCING POWER AT IMPACT

Since an Engine parts at high power are rotating extremely fast while others are moving linearly certain failures are expected if the engine is suddenly stopped at ground impact. During engine teardown the investigator is looking for overload failures and deformations throughout the engine consistent with sudden stoppage.

a. A very good indication of engine power at impact is torque failure or rotational deformation of the crank shaft as it leaves the engine to connect to the propeller.
b. A torque failure or deformation along that shaft or where it attaches to the fly wheel weight. Remember that a body in motion wants to continue in motion.

c. Torque failures or rotational damage of accessory drive shafts emanating from the engine.

d. Clean spark plug gaps.

e. If the engine case is broken or deformed or cylinders sheared numerous indications of movement, scoring and overload failures.

f. Scoring distributed throughout the engine showing relative motion of parts.

g. No fatigue failures

h. absence of metallurgical evidence usually associated with pre existing engine failure.

i, secondary evidence consistent with primary evidence.

Engines that have failed pre impact will continue to rotate due to the wind milling effect of the propeller unless the propeller is feathered. Thus even a dead engine will be rotating somewhat at impact. The engine is being driven rather than driving and rotational damages can be expected to be significantly less or non existent when compared to a high power engine.

PRIMARY CLUES an investigator may have that the engine had failed pre-impact

a. Radio from pilot. “I’ve lost an Engine"

b. Absence of evidence of rotational overload or torque.

c. Absence of overload failures of internal moving parts from sudden stoppage.

d. Dirty -oily spark plug gaps.

e. singular internal pre-existing failures such as: fatigue, rod bolt failures, bearing failures, piston detonation damage, cylinder blow out, gasket blow out, burned and ruined valves, singular rod failures , bearing overheat.

f. Some uniform internal damage, but subjectively much less than expected on an engine stopped under power.

SECONDARY INDICATIONS THAT THE ENGINE WAS POWERED

a. Torque shaft failure to the generator

b. Severe rotational damage to generator

c. Fan blades to generator all bent or broken opposite rotation.

d. Torque shaft failure to engine driven systems such as hydraulic pumps, fuel pumps, oil pumps, air conditioning systems etc.

e. Torque overloads failures of shafts within gearboxes, transmissions and accessory drive trains.

f. Gear chatter and gear overload failures opposite rotation in accessory gear boxes, and transmissions.

g. internal overload destruction of gearboxes and transmissions.

h. Shearing of gear teeth

i Absence of indications of pre existing failures.

j. Evidence consistent with **PRIMARY** indications.

THE PROPELLER IS DISCUSSED SEPARATELY

If it is determined from consistent evidence(primary ,secondary and propeller that the engine was producing power at impact it probably had little or nothing to do with the cause of the accident.

If it is determined that the engine was not running at impact and the investigator finds no internal reason why he must look elsewhere. Actually as a practical matter an engine teardown comes late in the investigation, so the investigator is already documenting other possible factors as to why an engine was not producing power at impact. Let it be said that even a sophomoric investigator can derive an on scene feel for engine power after examining the prop which was easy to inspect while in the field.

FUEL CONSIDERATIONS

To determine if there was fuel available to the airplane the investigator will note some or all of the following evidence.

a. The investigator will determine if it was fuel starvation.

He will do this by determining fuel load at takeoff. From this he will determine worst case fuel burn to exhaustion scenarios.

b. He will examine the tanks for fuel (if available)

c. He will note if there was a large fuel fire.

d. He will note that there is a large grass kill.

To determine that fuel was potentially available to the engine he will.

a. Check the integrity and condition of all fuel lines from tank to engine.

b. When possible the investigator will sever these lines or other wise disconnect them to see if there was fuel available within the segment of fuel line. I prefer a horse syringe since I disdain cutting up evidence.

To determine if the fuel was contaminated the investigator will:

a. Attempt to obtain a fuel sample and it will be analyzed at a laboratory for contaminants, algae paraffin's, water and whether it was the appropriate fuel for the airplanes engine. I have on three occasions investigated accidents where jet fuel was wrongfully placed in a prop airplane. On other occasions I have seen wrong octane fuel used. On several occasions there was too much water and in one there was an abundance of sugar.

The investigator may suspect icing. This icing failure may manifest itself as ice within the fuel that blocks fuel filters, or fuel icing within a carburetor that changes the fuel air ratio.

To make determinations concerning icing the investigator will:

a. Check to see if flight and temperature conditions were appropriate for formation of ice.

b. Check fuel to see if it had an abundance of water.

c. Check fuel load to see if anti ice additives such as Prist were utilized.

d. Check to see if the aircraft systems are susceptible historically to ice failures.

e. Check to see that whether the switch positions in the cockpit and at the heat devices were on or off and that the associated devices agreed with the switch positions.

f. Check the radio tapes to see if there were any radio calls about ice.

Most airplanes have two fuel pumps associated with each engine. One is an electric boost pump and the second is the main engine driven fuel pump. An investigator will:

a. Bench check both types for operational flow rating and pressure.

b. With respect to the boost pump check switch position for on or off.

c. Most General Aviation aircraft can operate and are designed to operate on engine driven pumps only. Jets are different.

The investigator will check out the carburetor, fuel injector and fuel control units. He will:

a. Ascertain that the linkages to the cockpit were intact pre impact, and where possible, determine that cockpit placement was the same as found at the device. (The fuel unit was being asked to deliver the same as the condition in the cockpit handle dictated.)

b. If a fuel injector the investigator will determine that there was fuel downstream of the injector in the lines. This includes the lines, fuel flow divider and at the lines to the individual nozzles.

c. Determine that there were no mechanical failures to the unit.

d. In the case of a carburetor ascertain that the heater was not inadvertently on.

e. He can have the units' bench checked for operation.

f. As last resort he can conduct a unit tear down inspection for condition of internal parts as well as for witness marks to determine condition at impact.

g. An investigator should obtain the failure history of such devices. For instance one type fuel injector was notorious for fuel leakage between the fuel air seals.

The investigator will have determined at the crash sight the conditions of the throttle, mixture, switch positions and fuel tank selector valve positions .He will have done this since on many occasions a pilot may miss-position switches and levers.

I overheard a Naval Commander in the training command say about a dead student who had turned off the fuel rather than retard the prop.

"If the son of a bitch did something that stupid he deserved to die"

It is not to unusual to investigate accidents where a pilot has run out of fuel in one tank, the engine has failed ,the airplane crashed, and the investigator found a full tank of gas that the pilot had not switched tanks. So these accidents do happen. For the attorney I suggest reading “DESIGN INDUCED PILOT ERROR" reference supra.

LUBRICATION CONSIDERATION

When a loss of lubrication occurs the investigator will see many indications. If the loss of lubrication goes unnoticed or disregarded by the pilot you can count on some bearings overheating and seizing. Almost always there is metal bluing due to overheat when an engine is run out of oil. The investigator will.

a. Search for overheat signs
b. Search for seizure signs
c. Try to ascertain oil line integrity
d. Search for oil leakage residue external to the engine
e. Check oil pump for operational capability.

AIR CONSIDERATION

An investigator must realize that all engines require a proper fuel air mixture to occur. This is true for props, or jet engines. This is true for carburetors, fuel injectors, fuel control units or afterburners. For prop airplanes the amount of air allowed to be mixed with fuel is determined either by the carburetor or fuel injector system. In some airplanes the air is ducted to the carburetor or fuel injector inlet through ducts.

An investigator will attempt to determine that the ducts were intact and unobstructed pre engine failure. I have investigated one accident where a maintenance oil wipe rag was sucked into such a duct.

The carburetor senses pilot throttle position and opens or closes fuel metering valves. Air is sucked into the carburetor by the operating engine. The proper fuel air mixture is controlled by a flutter valve and a venturi system within the carburetor. Fuel is directly sprayed into the carburetor and mixed with air. This fuel air mixture is then delivered through the manifold to the individual cylinders.

Carburetor icing is a major potential problem just below the venturi near the fuel nozzles. The spraying and evaporation of fuel in this area reduces temperatures in this part of the carburetor such that icing can occur when outside air temperatures are above freezing. Icing should be suspect in carburetors with high humidity, rain or freezing conditions and temperatures as high as sixty degrees ambient. The investigator must realize that the internal temperature of parts of the carburetor will be much colder than ambient air.

In some situations the aircraft may have entered such severe conditions of torrential rain, freezing rain, icing, snow or hail that the ducting system simply delivers too much of the inclement situation into the engine and it simply can't compensate and it fails. The investigator must be familiar with each systems protective capabilities for inclement operation to understand and evaluate the probabilities correctly.

Heat source

For there to be a running engine there must be an ignition source. **In propeller engines this is accomplished through dual magnetos and double spark plugs for each cylinder**. The engine is supposed to be designed so that the loss of one system will not result in engine failure.

The investigator will:

A. Attempt to dismantle and bench test the magnetos for proper operation
B. Check the wire leads for insulation and integrity
C. Check the spark plugs for prober operation, and gap spacing
d. Check cockpit condition of switches

In the jet engine there is a set of igniters. These are only used for start. The jet simply keeps the fir going with continual fuel input. Supplemental ignition is available for optional use airborne in "**TILTER**" conditions.

a. **T**AKEOFF
b. **I**cing
C. **L**anding
d. **T**urbulence
e. **E**mergency Descent
f. **R**ain

The investigator will determine what flight conditions existed and he will:

a. Check out the system if it should have been in usage.
b. Check covered cockpit switch position to verify usage /non usage.

The Turbine -Prop Engines

These aircraft power plants are a hybrid of the older reciprocating /propeller set ups. The difference is that these power plants utilize a jet engine to drive a propeller.
There are two distinctly different ways for a jet engine to power a propeller. Almost every lay person knows that a jet engine parts rotate very rapidly. Everyone also knows that jet engines produce lots of thrust force in the form of jet exhaust. One method of rotating the propeller of this power plant is to simply attach a gear box to the rotating drive shaft of the jet turbine section directly. (This is the Garret solution/RR)The other method is to funnel the hot thrust jet exhaust from a jet engine through and over an entirely separate turbine that is geared to the propeller. (This is the Pratt and Whitney solution).

For the investigator there are some interesting differences. If you impact stop a prop in a system attached directly to the jet you obviously stop the entire system including the jet engine. If you impact stop a prop in the segmented, unattached engine you only stop the prop and gearbox. The engine is freewheeling.

Since all jet engines are basically variants of the same theme we will discuss how those jet engines work before we discuss how they fail and what an investigator is looking for.

JET ENGINES

All varieties of Jet engines have at least four component sections that are identical in function if not construction. These sections are a compressor section, fuel control, a combustion burner section (sometimes referred to as the hot section) and a turbine recovery section.

The compressor section is a series of rotating blades, that suck air into the engine and compresses the air as it passes that air over alternate rotating compressor blades and stationery stator blades. After a number of such compressor blades the volume of air sucked in is now in a very hot and compressed form.

This hot, compressed air is now channeled into burner cans where fuel is sprayed and atomized. In these burner cans an igniter starts a controlled and continuous fuel air fire. This fire creates extreme heat and gaseous expansion in the form of jet exhaust.
The expanding exhaust gas is directed through another set of recovery turbine blades that rotate a shaft through the core of the engine and this shaft powers the compressor blades that suck in outside air. Once the engine is started, the application of more fuel creates more exhaust gasses and thrust. This in turn spins the recovery turbine faster and this in turn sucks in more air. The converse is also true. Thus more fuel equals more power, less fuel equals less power and engine core speed.

The trick of keeping a jet engine running is to always keep a proper fuel air mixture available in order to keep the fire lit in the burner section. It is a complex Fuel control unit that is designed to handle this chore. It must adjust for engine speeds(R P M), power requirements, acceleration, deceleration, altitude and more. These units adjust devices known as inlet guide vane positions at the front of the engine, and the fuel control meters appropriate amounts of fuel to the individual burner cans.

Jet engine rotational speeds are very high, and core temperatures at the turbine section are recorded in the area of 575 C degrees at full power. These numbers vary by engine type, but they are universally fast and hot when running.

Tolerances in a jet engine between moving parts are measured in hundredths and thousandths of inches. These close tolerances are needed in order to get the high compression without leakage. Thus the rotating pieces are moving at thousands of r.p.m. very close to stationery parts, and there is a vacuum cleaner effect sucking air and debris through the machine. Any machine rotating that fast has to be perfectly balanced or else vibration occurs and with vibration comes fatigue.

The compressor, combustion area, and turbine area are fit into a hard long case with the air inlet at one end and exhaust at the opposite. The tolerance between rotating compressor blades and the case is also very tight. These rotating parts are freewheeling on extremely high quality lubricated bearings.

A TURBOFAN JET ENGINE

The only significant difference between the engine described above and a turbofan engine is that a shaft from the turbine section is used to run back to the front of the engine and rotate a very large compressor like disk that sucks air over and around the core engine in a separate outer duct. This ducted fan acts like a propeller and provides thrust like a prop would. The air so routed around the core engine also is cool and it acts to cool the case of the inner engine thereby allowing the inner engine to operate at high power without overheating.

A turbofan is simply a newer variant of the basic jet engine. It gets better gas mileage, and is considered an improvement except for the increased engine diameter due to the size of large fan.

AN AFTERBURNER

Part jet- Part rocket describes an after burned jet engine. Modern military aircraft have varying geometry tailpipes to control exhaust pressures and therefore thrust. Some of these can act as a rocket nozzle when used as an afterburner. An after burner is simply a design that allows the pilot to squirt raw fuel into the exhaust gases to obtain extra combat thrust. Some afterburners have six stages of burner and each is different as to the amount of fuel, thrust and burner configuration. Each burner design then has specific geometry associated with each individual stage of burner application. Burner application is restricted to an engine already operating at full power. Full burner doubles full power, but burns about 5 times full power fuel. Afterburner is fuel in efficient. So is getting shot down from behind!

Before leaving the design of jet engines, one point should be made about the turbine section (hot section) blades. New jet engines run so hot that turbine blades are typically sophisticated metallurgy. At room temperature these metal blades are almost ceramic like (brittle) and when struck with a sledge will shatter like ceramic. With the extreme heat that they operate at they are more malleable and ductile. They do not shatter in the same fashion as when cold.

PRIMARY CLUES A JET ENGINE WAS OPERATING AT IMPACT

Let us assume a crash with sufficient impact forces to only distort the case of the engine.

If this was to occur then the rotating blades would impact the stator blades and rub against the case as well. All blades would core out and the engines center rotating parts would look like an eaten ear of corn .The blades of the turbine would have also cored and broken but from a metallurgy standpoint they wouldn't have shattered. A metallurgist would be required to determine the heat range they were operating in at impact

The engine would leave rotational scoring and bluing where the blade tips rubbed the case. Blade tips of the compressor ant turbine would be broken .deformed and bent opposite the normal direction of rotation. The stator blades would be broken bent and deformed in the expected direction of engine rotation.

In such an accident the case has remained intact, and the core continued to rotate, as a result secondary the secondary information gained from accessory sections might be unhurt and therefore non existent.

Next let's assume a crash where the impact forces scatter and break the entire engine into sections

In this case the damage seen and described above will be the same except worse. Rotational overload failures will be found throughout. Moreover since there is sudden stoppage of the rotational forces torque damages will be discovered in multiple places through out the engine. The hot section will be deformed and again the metal blades will have exhibited some plastic deformation because of the high heat. Had they been cool they would have shattered. Shafts to accessory sections may show torque overload failures. Gear trains will show overload failures or teeth breakage in overload.

FOREIGN OBJECT DAMAGE TO A JET ENGINE

Often Foreign objects are sucked through Jet Engines. When this occurs a distinctive pattern is left behind as a fingerprint for the investigator. At the front of the engine there is little damage. As the object progresses through the engine more and more blades are broken free and sucked deeper into the engine. Each sequential break creates more foreign objects and by the time the shrapnel has reached the turbine it is coring itself apart.

A TOTAL COMPRESSOR OR TUBINE wheel FAILURE

Inside a jet engine each compressor and turbine is a rotating circular wheel to which thirty or so blades are attached. When a turbine wheel or compressor wheel lets go or fails all the parts and blades are released but trapped inside the shrapnel proof case. From the point of wheel failure and aft the engine blades will be cored. Forward there will be no or less damage.

SECONDARY JET ENGINE POWER CLUES

Because jet engines rotate so fast, their speed is rated in percent.100% is takeoff (about max) 92% is climb (about) 82% is about cruise, and they idle at about 42%. These numbers vary with make and model. The speeds translate to thousands of R.P.M.

As discussed earlier, in all jet engines the air intake section is dedicated to ingesting and compressing air. This section of the engine is called the compressor section. It consists of several discs of rotating compressor blades, alternated with discs of stator (stationary) vanes or blades. From front to back these are called stages and are numbered. Thus every time a molecule of air has past a set of blades it is said to have past a numerical stage of compression.

Pass six sets and you have achieved sixth stage compression. Pass thirteen sets and you have achieved 13th stage compression. The deeper you go into the compression stage cycles the greater the heat and pressure of the air.

Pure high temperature, high pressure air is valuable to run other aircraft systems and so small portions of air are allowed to be ported or bled off for these functions. The name bleed air is used to describe air that is removed directly from the jet engines compressor. It will be further described by where it is removed from. (6th stage bleed air, 8th stage bleed air, 13th stage bleed air etc.) Remember the bigger the number the higher the temperature and higher the pressure.

Bleed air is used to provide:

1. Anti compressor stall relief
2. Engine anti ice heating air
3. Wing anti ice heating air
4. Aircraft pressurization
5. Aircraft temperature control
6. Air for cross bleed engine starting
7. Some windshield hot air

Each engine make will differ as to what the bleed air is used for and from which stage it is ported. Every time bleed air source is used the engine performance (power available for thrust is minutely diminished) the manufacturer will vary the placement of these bleed air valves based on design decisions. Since bleed air is used for breathing and pressurization it must be clean and pure. An investigator should know each engine system, the location and method of operation of these bleed air valves. Often they are electrically initiated, air regulated and spring loaded closed. They do differ,

The investigator should try to determine the position of all such bleeds during his investigation and the following teardown.

These may help tell the condition of the engine prior to and at impact. Some valves modulate dependent on requirements and power settings. Some valves are relatively delicate. If these are deformed and stuck full open, this may be as a result of a pre - existing engine problem where a compressor stall explosion has occurred pre impact. (Jet engine equivalent of a severe backfire)

When running a jet engine it acts as a huge vacuum cleaner. It sucks everything in. When it is running at high power and crashes through trees and underbrush it ingests wood pieces. Like a wood chip maker it pulverizes the wood and forces it through the engine. By the time it gets through the engine it is fine sawdust. If the engine had failed pre impact it is still rotating and will make some sawdust, but the engine is cool thus the sawdust will be recognizable. If the engine were running and was hot the sawdust will coke and appear as powdery charcoal. The same holds true of grass, wheat, bushes, undergrowth etc.

If the aircraft impacts earth that was wet or soggy and the engine failed and cold the dirt scooped in is recognizable. If it (the engine) is hot the dirt will dry out and become sandy, while the organic matter will coke.

Since all the bleed air valves exist on the case (outside of the rotating compressor section), and since all rotating blades create a centrifugal force ingested matter will be forced outward toward the valves. In the case of wood chips, sawdust and other foreign material that has been ingested these will be thrown outward as they are ingested. Such material found in a duct tube and its condition(coked or pristine) will help determine whether the bleed air valve was open at the time of impact and whether or not the engine was hot and running.

Sometimes a phenomenon of spattering occurs in the hot section, usually just aft of the combustion cans in the first stage of the power turbine section.

AN EXAMPLE

THIS SCENARIO SPECIFIES THAT THE JET ENGINE WAS NOT INVOLVED IN A SUBSEQUENT CONFLAGRATION AD GROUND FIRE.

In this case some metal with a low melting point has somehow been involved in the combustion section while these temperatures were very hot and has gone to a molten state and been sucked into the turbine section leaving a molten spattering effect. (This spattering is usually seen on the turbine blades where they are attached, and not usually at the tip). Another explanation is that some lower melting point metal is ingested and thrown into the hot section where it is melted and deposited on and around the hot turbine blades. A third explanation is that a compressor stall has effected the engine because of overpressures and the combustion section is overheated and metals with a low melting point are molten and thrown toward the turbine section.

In an engine that is operating normally pre impact the flow of air is always from front to rear. To find the spattering phenomena on compressor blades is unusual since this would mean that the airflow in the engine had reversed. This only occurs during an internal explosion or compressor stall. For spattering to occur there must be high heat. For spattering to occur forward of the hot section the metal deposited would have to be molten as it is deposited since the compressor temperature although hot is not sufficient to melt metals other than lead solder.

The investigator must employ a metallurgist to determine the source of the spatter, it's metallic make up and from where it came, in order to determine how it was deposited, and more important precisely when.

TEAR DOWN REPORTS (THE EXAMPLE)

As an example an attorneys investigator may receive a teardown report with several hundred photographs. The investigator should thoroughly understand the report before his own wreckage analysis. If the teardown report is indeed factual then the attorney's have good information from which to speed their own review. Remember it is often a potential defendant that has done the teardown in front of a non expert government official witness.

A. FAN ROTOR, Portions of the rotor blades were bent opposite rotation. Small portions of these blades were nicked .Small portions of these blades were missing.
WHAT IT MEANS: Fan rotating at impact-could be wind milling.

B.There was dirt in the fan housing area.
WHAT IT MEANS: Aircraft engine hit ground at inlet.

C. Portions of all compressor stator vanes were nicked.
WHAT IT MEANS: Probably ingested F.O.D.

D. The fan was missing blades through 270 degrees, the others were damaged.
WHAT IT MEANS: Probably rotation and deformation.

E. All fan vanes were nicked.
WHAT IT MEANS: Probably rotation and F.O.D.

COMPRESSOR

A. There was blade tip rub on all first stage blades. Blades were nicked due to FOM.
WHAT IT MEANS: Probably rotation, deformation and ingestion of F.O.D.

B. There was tip rub on second stage compressor blades. The blade shroud was rubbed.
WHAT IT MEANS: Probably deformation and rotation.

C. There was blade tip rub on third stage compressor blades.
WHAT IT MEANS: Probably rotation and deformation.

D. There was blade tip rub on third stage blades. The shroud was rubbed.
WHAT IT MEANS: Rotation and Deformation.

E. There was dirt at the first stage stator vanes.
WHAT IT MEANS: Ingestion of foreign object material (ground)

F. All second stage vanes were nicked.
WHAT IT MEANS: F.O.D.

G. All third stage vanes were nicked.
WHAT IT MEANS: F.O.D.

H. There were contact marks on the blade tip shroud near the fourth stage blades.
WHAT IT MEANS: Rotation and Deformation.

HIGH PRESSURE COMPRESSOR.

A. There was heavy blade rub on impeller blades. There was compressor shroud spray metal on platforms between blades.
WHAT IT MEANS: Deformation, Rotation, Rub, and high heat. If shroud is aluminum at least 110 degrees.

B. The impeller shroud was heavily rubbed. So heavy as to rub down to base metal.
WHAT IT MEANS: Deformation and rotation, significant rotation.

COMBUSTION SECTION (hot section)

A. There was compressor section shroud metal spray on liner and dished area.
WHAT IT MEANS: High Heat.

B. There was compressor shroud spray metal on the inside of the plenum case.
WHAT IT MEANS: High heat

C. There was compressor shroud spray metal on all diffuser vanes.
WHAT IT MEANS: High Heat.

D. There was compressor shroud material on the de-swirl vanes
WHAT IT MEANS: High Heat.

TURBINE SECTION

A. There was heavy tip rub on all turbine tips. There was metal spray on the suction side of all blades.
WHAT IT MEANS: High Heat, rotation.

B. There was compressor shroud spray material on the leading edge of all turbine stator vanes. **WHAT IT MEANS:** High heat

C. The turbine shrouds were rubbed. **WHAT IT MEANS:** Rotation.

D. The first stage turbine rotor had heavy metal spray on all rotor blades. The blades had hit the adjacent stator slightly.
WHAT IT MEANS: Rotation, deformation and high heat.

E. The second stage turbine rotor had spray metal deposits.
WHAT IT MEANS: High heat

F. The third stage turbine rotor was distorted and trapped against the third stage stator. **WHAT IT MEANS:** An anomaly that needs to be studied. This seems incorrect for all other descriptions.

G. The first stage turbine stator had contact rub.
WHAT IT MEANS: Rotation.

H. The second stage turbine rotor had several stators nicked.
WHAT IT MEANS: F.O.D.

I. The third stage stator was deformed and blades missing.
WHAT IT MEANS: Anomaly

J. The temperature harness was undamaged.
WHAT IT MEANS: That the temp gauge could still receive data.

The N one tachometer showed 77 percent. The N two tachometer showed 88 percent, Tail pipe temperature was at 750 degrees, all instruments had off flags showing.
WHAT IT MEANS: If the off flags were crash damage, and the instruments were captured then these readings were valid at impact.

CONCLUSION: (preliminary) The engine was producing significant power at time of impact.

WORK TO BE DONE.

1. I would order my investigator to get a metals man to see that the spray was in fact shroud material metal.
2. I would ask how the third stage turbine rotor could be trapped in the stator without total rotational destruction if the engine was really at high power at impact.
3) I would get a system analysis of what the off flags meant on the instruments. (Would they freeze at last reading when flagged?)