C-IAUE

Crash Cause Report

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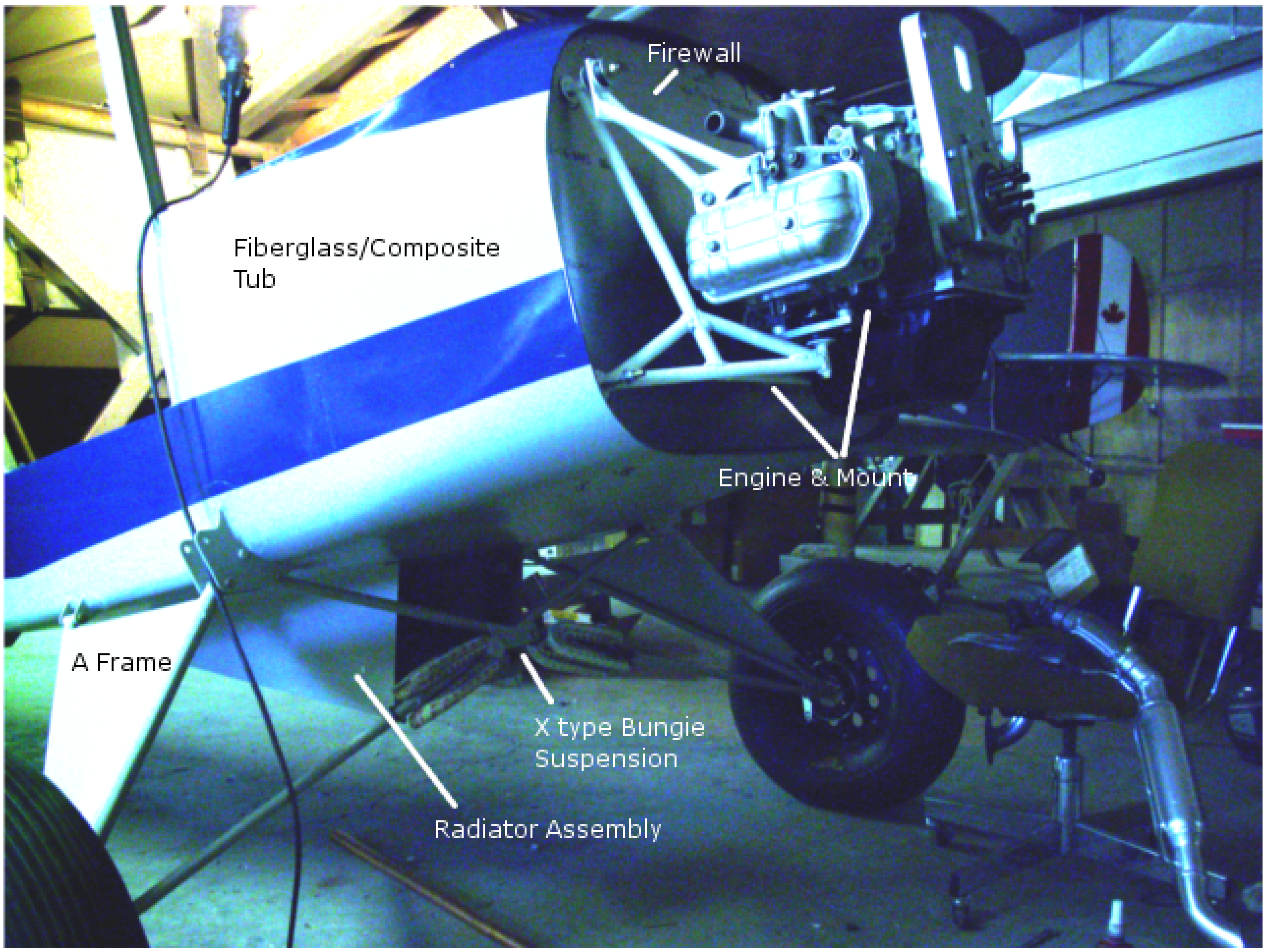
On August 17, 2009 just before 7 pm, a modified Sylvaire Bushmaster Canadian regestered ultraligt aircraft took off from Corman Air Park near Saskatoon, Saskatchewan, Canada.
On board were a highly experenced Instructor of several thousand hours and a first time student, outbound on a routine training flight.
The aircraft failed to return that evening and following an all night search by Canadian Search And Rescue and the Saskatoon Police Department, was found early the next morning from an aircraft search by a member of the Corman Aeroclub.
The aircraft had crashed in a field aproximately three miles southeast of the airpark.
Both occupants were faitily injured.
Transportation Safety Board investagated.
I attended the crash scene and due to circumstances I will not discuss here, I instituted my own investigation some time later.

C-IAUE Stock.bmp

Engine and Fuselage

Construction Overview

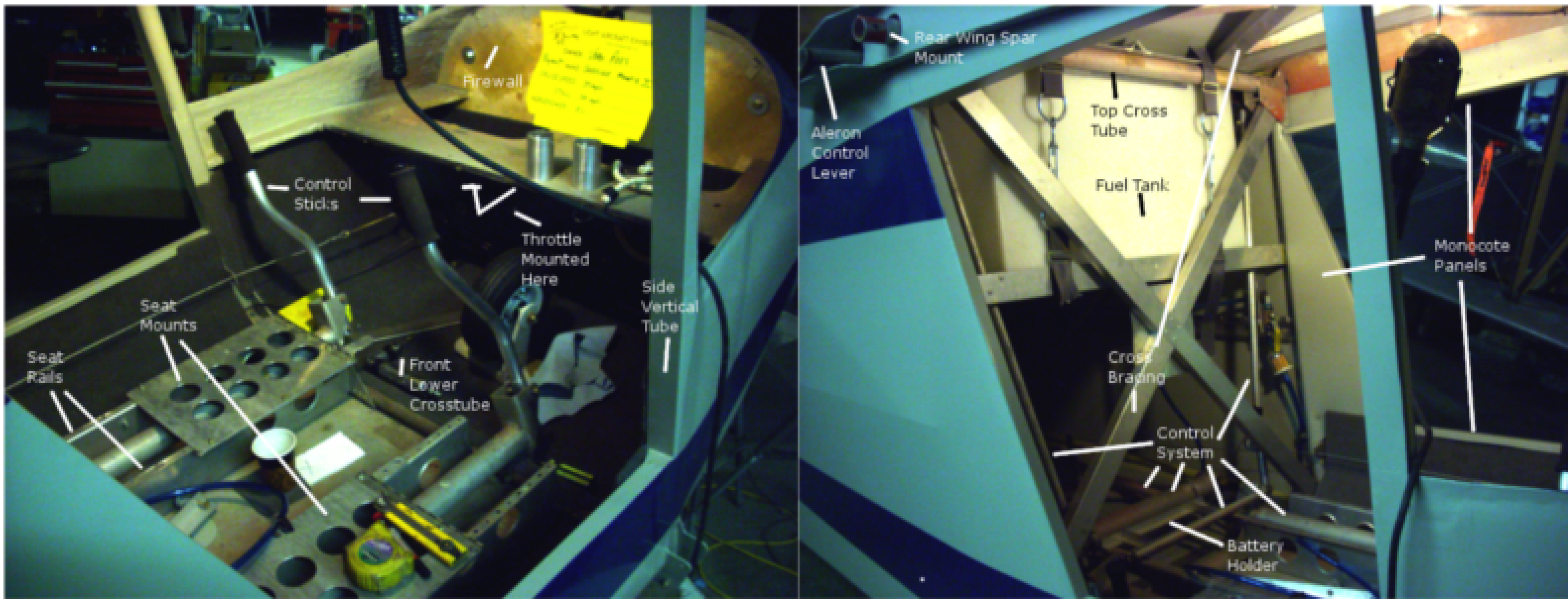
The fuselage of the original Sylvaire Bushmaster was constructed of aluminum, fiberglass/composite, foam, steel and fabric. The front section from the firewall back to the doors was a one piece fiberglass composite 'tub' with he lower front cross tube and the front vertical tubes molded into it. The original design incorporated a foam/fiberglass firewall with a steel frame mounted to the front to carry the engine. This aircraft had been modified in the firewall area. The original firewall and about two inches of the front of the tub were removed and a new plywood firewall was epoxy/fiberglass glued in place to carry a steel mount for a Subaru 4 stroke automotive engine. This was done to preserve the weight and ballance of the aircraft, as the new engine weight was almost twice that of the original 2 stroke engine. The new marine grade plywood firewall was also quite a bit stronger then the original foam/fiberglass one. The plywood firewall was covered on the front with a thin sheet of aluminum to act as a heat reflector. The engine had a synchronous belt speed reduction system to match the speed of the engine to the required speed of the propeller. The propeller was a three blade, ground adjustable carbon fiber composite design by Warp Drive Corp. The entire engine, drive assembly was enclosed in a cowl constructed of a fiberglass/composite nose bowl, with an aluminum top, bottom and sides.



Front End.bmp

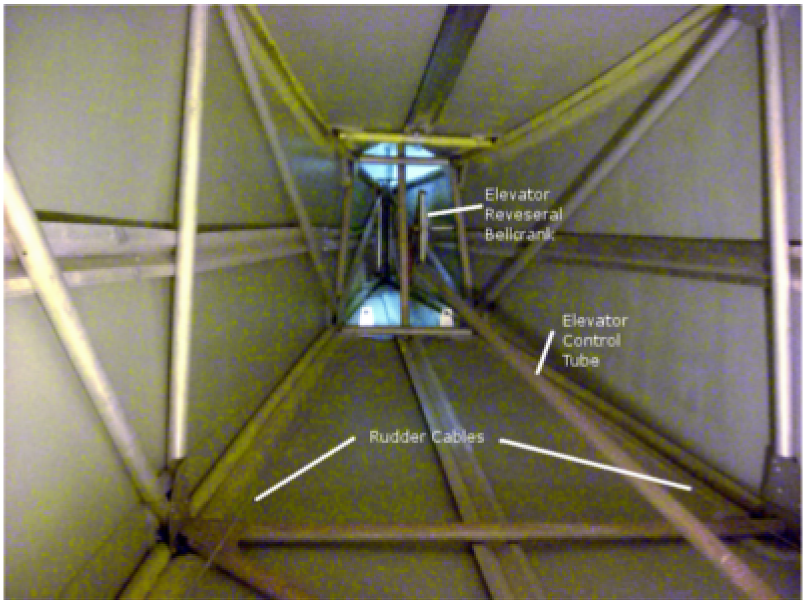
The cabin area consisted of the three front aluminum tubes with a cross tube on the top to which the main wing spars attached. The main wing struts attached to the bottom cross tube. All of the tubes were aluminum gusseted and bolted together. A similar frame was at the rear, connected to the front frame by 'Monocote' side panels top, bottom and rear and four large aluminum 'Seat Rails' at the bottom. The bottom was aluminum sheeted and a radiator assembly for engine cooling was mounted below this. The rear wing spars were connected to the rear top aluminum cross tube. Light weight aluminum 'U' channel gussets were cross braced across the top front and rear cross tubes and the rear top and bottom cross tubes. A 15 imperial gallon polyethylene fuel

tank was mounted directly behind the rear cross bracing near the top of the fuselage. The doors were aluminum tube sheeted with Lexan and hinged at the front. The windscreen was also Lexan.
The seat belt system was attached to the seat rails on the bottom and the rear upper cross tube ont the top. They consisted of a lap belt and a single sholder belt, both manualy adjustable. The seats were fiberglass/composite with foam padding and vinyl covering.
The controls were a standard three axis, dual control, stick and pedal system all of which were attached to the primary structure.
The throttle was a lever type, mounted in the center just below the instrument panel and could be operated from either seat.
The electrical storrage battery was mounted between the seat rails at the rear center of the cabin and was externally vented.
The main undercarrige was constructed of steel tubing, consisting of 'A' frames to carry the wheels and a 'X' type of bungy suspension system with oversize pneumatic tires on aluminum rims with hydraulic disk brakes.



Labeled Intrerior.bmp (Note: Wheel assembly in the left center is not part of the interior.)

The section from the rear cabin structure to the tail was constructed of aluminum tubing gusseted and rivited. The tail assembly was construct in the same fashion, with cable braced vertical and horizontal stablizers and hinged rudder and elevator assemblys mechanicaly coupled to the cabin controls.
The tail wheel was a pneumatic tire on a steel rim mounted on a leaf spring extending backward from the bottom of the rear fuselage assembly. It was spring coupled to the rudder for ground steering.



Rear Section.bmp

Crash Overview

The entire fuselage was very badly damaged during impact with the exception of the tail assembly. The forward fuselage was also very badly distrubed by rescue.

The first people on the crash scene have stated that the aircraft as seen in the T.S.B photos, looked nothing like it did before rescue was done with it. I did not get to see the aircraft until T.S.B was finished with it and most of my studies have were done after it was loaded on a trailer and removed from the crash site.

Aircraft As I First Saw It.bmp

No attempt has been made at this time to reconstruct the fuselage assembly as it does not appear to relate in any way to the cause of the crash. No reconstruction will be done unless this becomes warrented by some future event.
I will, however, describe observations that I have made.

The aircraft impacted the ground at an angle of about 30 to 40 degrees above the horzontal and at high speed (see air speed indicator in starboard wing section). The aproximate impact angle was determined by the final attitude at which the engine came to rest.
The Engine was mostly buried in the ground by the impact force, with one blade of the three blade propeller protruding. The other two blades were broken cleanly off, which would indicate the the engine was producing significant power at impact. All of the instruments except the airspeed indicator and the hour meter were broken free of the instrument panel and some ended up several feet out in front of the aircraft.
The fuel tank and electrical storage battery were both ruptured, but there was no fire.
The entire fuselage assembly from engine to tail ended up curved port-wise around the port wing and port undercarrige.
The main landing gear was folded inward on the port side and both sides were folded back about 90 degrees from their normal positions. The aluminum wheel rims of both sides were flattened, although the tires remained on the rims, inflated.
It was originaly thought that the aircraft must have impacted the ground with the wings almost horizontally level, because both wheels appeared to show aproximately the same amout of flattening. This, however has been shown by other evidence not to be the case. The probable explanation for the condition of the wheels is that the wheels and tires weighed several times that of their

support structure and that support structure was spring loaded on a bungy suspension system. The rims and tires collapsed mainly under their own inertia mostly uninhibited or aided by their support structure.

Both wheels and tires can be seen below

Left-Right Wheels.bmp

The entire fuselage ended up being compressed to less then two thirds of it's original length.
All of the damage on the fuselage assembly was consistant with being impact created. This included broken parts of the control system. Nothing could be found that would indicate any significant anomalies or malfunctions that could have initated the crash sequence.
The only possible exception to this would be the fully extended, flaps down position of the electric flaperon servos. At this time, however, all evidance points to this being post impact, because of the apparent neutral position of the flaperions on both wings as evidanced by their impact damage.

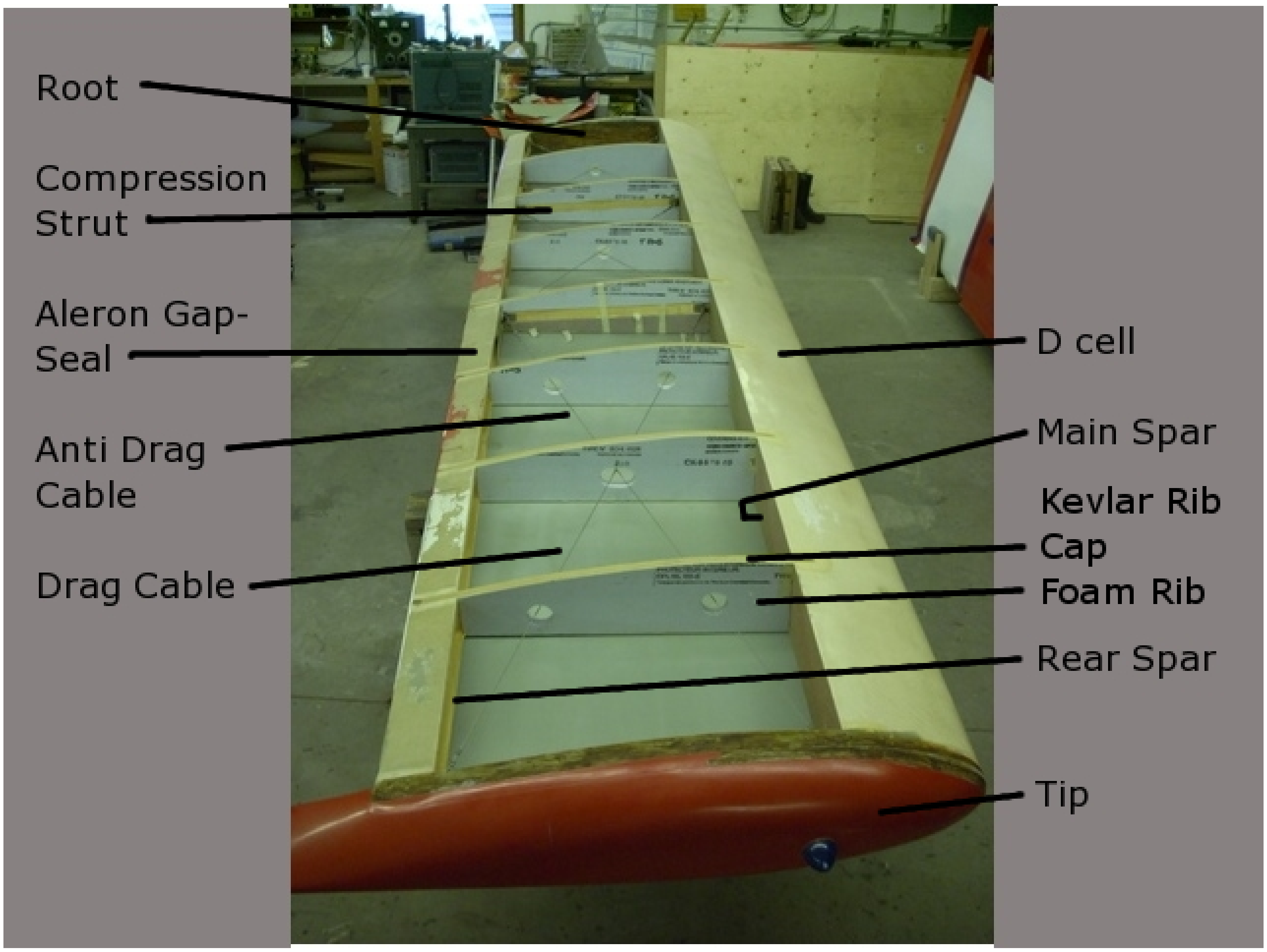
Wings General Overview

The structure of both port and starboard wings respectively was composed of three boxes, each with it's own drag and antidrag cables. The boxes shared the front main spar/D cell, the rear spar/gap seals and four compression struts between the front and rear spars. The ends of each set of drag/antidrag cables attached at the end of a compression strut to the front and rear spars via aluminum brackets and brass/steel aircraft turnbuckles for setting cable tension.
The main spar consisted of upper and lower wooden caps connected by a composite shear-web and this assembly was attached to a composite D cell structure that contained polystyrene foam ribs as stiffeners. The upper spar cap was larger then the bottom as it was designed to handle compression loads. There were wooden hard points running verticaly on the front of the shear webbs for attachment of cables and struts, and an extra layer of composite on the oppisite side of the shear-web as reinforcment at the

main strut attach points.

The rear spar was much the same as the main spar except that it was about one half of the vertical height of the main spar and instead of a D cell there were upper and lower composite flanges that provide lateral strength and closed the gap between the alerons and the rear of the wing (aleron gap seals).
Both spars had plywood load spreaders at the root end and these were bolted to aluminum brackets and piviot tubes that attached to the top of the fusalage.
The main front and rear struts were formed of partially flatened aluninum tubing (for streamlining), piviot bolted through aluminum flanges that spaned the thickness of the spars and were piviot bolted at the oppisite ends of the struts through flanges at the bottom of the fuselage.
Attach bolts were aircraft grade and in shear.
The wing ribs were constructed from polystyrene foam and capped with kevlar-composite strips that attached to the D cell material at the front and the gap seals at the rear.
The composite materal forming the D cell, shear-webbs and gap seals was formed from pieces of cotton 'tiger cloth' sandwiched between layers of light, woven strand glass cloth, all impregnated with polyester resin.
All non metal parts (except for fabric covering) were glued with two part structural epoxy. The exception to this were the aleron gap seals which were glued with two part epoxy mixed with 'microballons' as filler. Metal parts were bolted with aircraft grade bolts.
The wing tips were molded fiberglass composite and all wing open assemblys were covered with polyester heat-shrinkable cloth that was primed and painted.
The alerons were constructed as a frame assembled and rivited from preformed sheet aluminum components and covered in the same fashion as the wings. They were full span alerons built in two pieces per wing and hinged on pins at each end and one in the aproximate center of the wing to preveint binding when the wing flexed. The inboard aleron was somewhat longer then the outboard one. They were moved via the control sticks by pins offset from the piviot pin by a complex lever assembly inside the fusalage.

The wings were assembled from a kit built by Sylvaire Bushmaster in Sylvan Lake, Alberta, Canada.
As supplied by the manufacture the main spar/D cell assembly and rear spar except for gap seals were factory compleated.
The kit builder assembled the wing by mounting all the hardare and glueing the gap seals, ribs, rib caps and tip in place and then covering and finishing. The alerons were also assembled by the kit builder from preformed aluminum components, covered and finished.



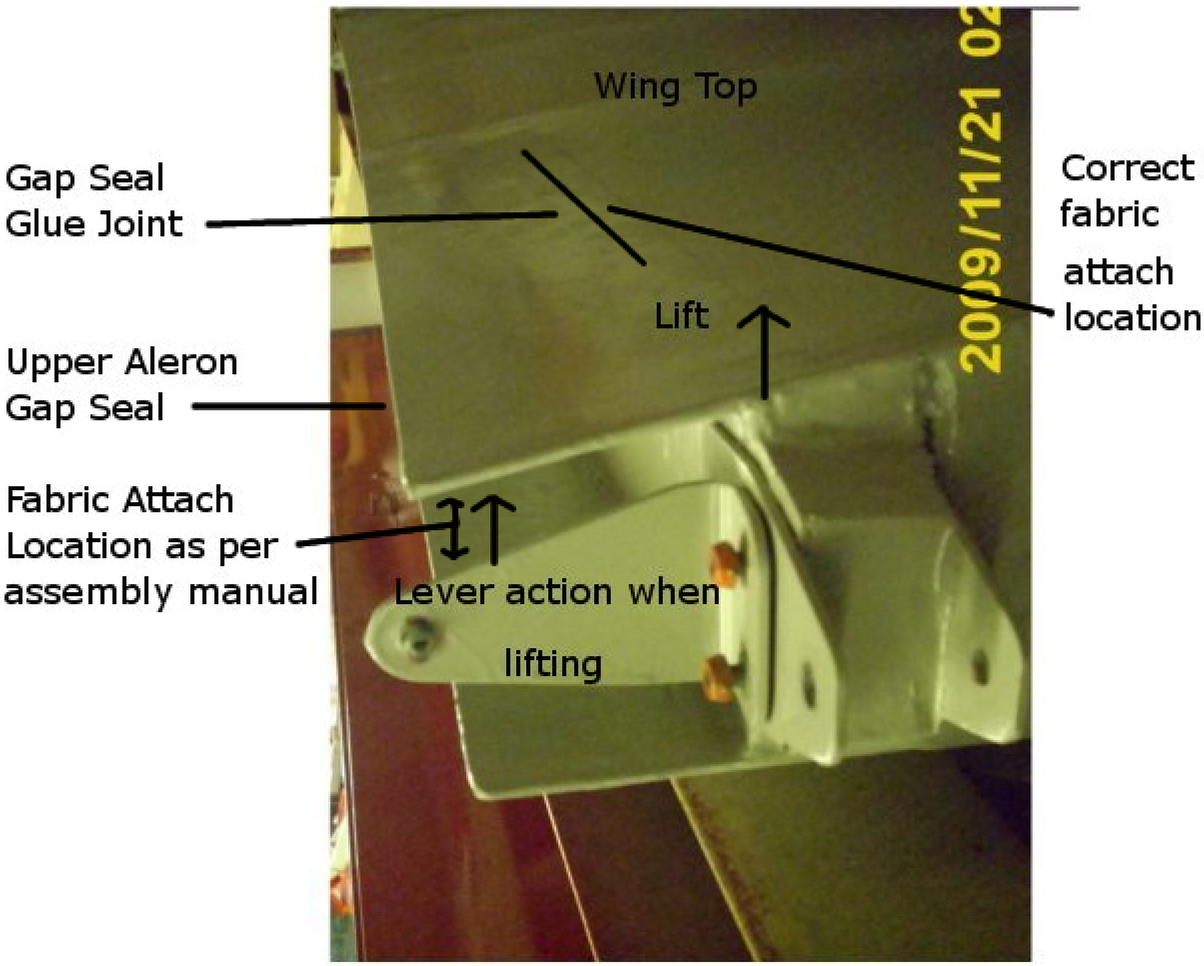
Wing Intact.bmp

This particular aircraft was modified to have the alerons double as flaps 'flaperons' and they were actuated by electric servo motors. There are only three known aircraft of this type that were built this way. The flaperons could also be set negitively, or up, to trim the wings for beter performance at higher speed.
The actuation time for full travel limit to limit was alarmingly short, being just over one second under no load.
Both servos were found in the fully etended or flaps down position.

Study of the Bushmaster assembly manual shows that there is minimal instruction for surface preperations of materals for glueing, or propper descriptions of conditions and enviroment for the mixing and applacation of epoxy glues and microballoons.
There is also no mention at all of the safety critical nature of the aleron gap seal glue joint.
The gap seals were the only attach points for the upper and lower wing fabric and the rear ends of the rib caps.

The manual does state that if the approved ENDURA (brand name) type of two part fabric primer is not used, the wing ribs must be rib-stiched. Rib stiching is a process of tieing the upper and lower wing fabric around the wing ribs together with strong thread. The type of primer mentioned also acts as a high pull away strength fabric glue and on certain types of wing structures can remove the need for rib-stiching.
Neither the recomended primer nor rib-stiching was present on this aircraft and the fabric was not attached to the rib caps at all.
The recomended method of attaching the fabric to the gap seals has also caused problems with gap seal warpage and partial seperations in the past. The fabric on these wings was attached as per the manual, wrapped around the rear edge of the gap seals

and glued underneath. This creates tremendous leverage forces on the gap seal glue joint when the top wing fabric lifts the aircraft. If the fabric is glued to the gap seal just above the glue joint these leverage forces are removed. An important point of note here, if the approved type of primer had been used, the fabric would have effectively been glued to the gap seal in this fashion. This was not covered in the manual.

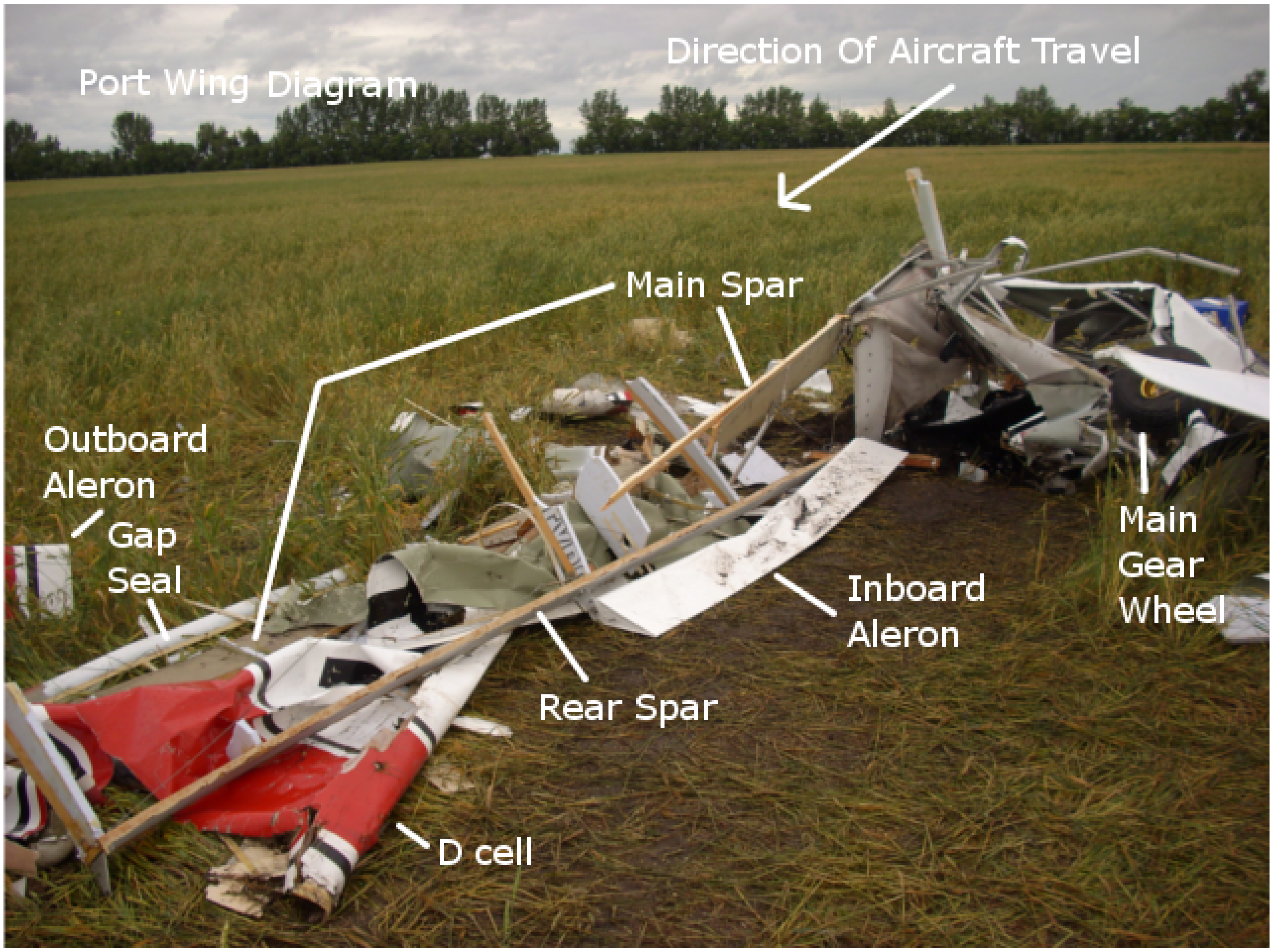


Gap Seal Labeled.bmp

Port Wing

The port wing rear spar and a portion of the front one remained attached to the aircraft after impact, although by the time I was allowed to see it, the rear spar had been cut away by rescue workers and flipped over the front one.
The inboard aleron remained attached to the rear spar and the outer one had broken free.
The wing tip fractured and seperated at impact and all of the fiberglass D cell broke free of the front main spar.
All four of the aleron gap seals broke free of the rear spar, some with the rib caps still attached to them.
The bottom wing fabric was pulled away from the wing by the D cell with some of the bottom aleron gap seal still attached to it.
Only one rib cap remained attached to the D cell near the root end.

The inboard upper aleron gap seal was found in the field aproxamately 150 yards due west of the impact site, and pieces of fabric were found between 150 yards west and southwest of the impact site and up to it.
The main spar was broken off about four feet from the wing root at the location of the first shear-web splice block.
The rear spar was broken but remained in one piece except for the gap seals.
The wing strut were moved by rescue workers so their post impact position could not be determined.

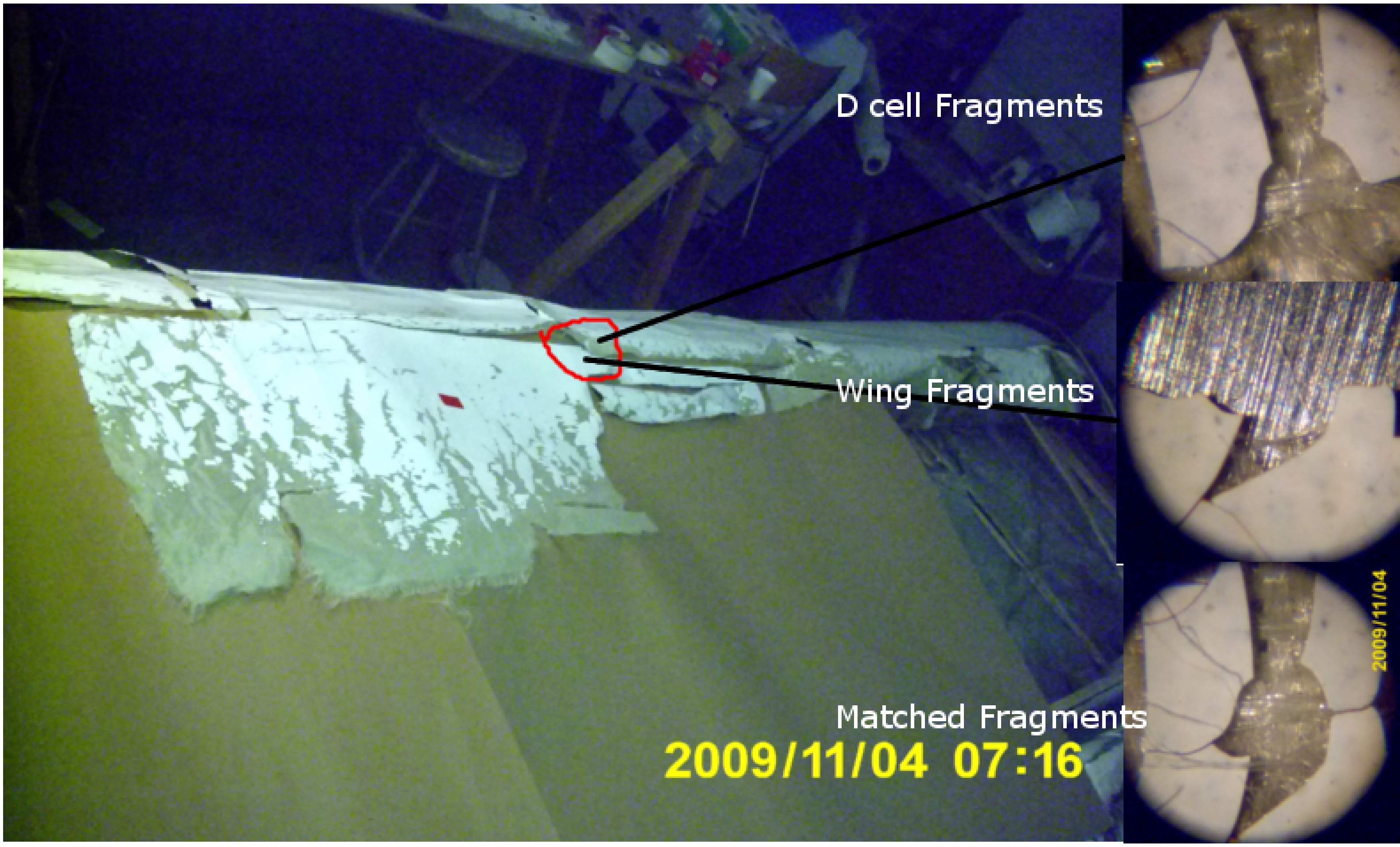


Crash Site Port Wing.bmp

The port wing was reassembeled at our shop.
All of the fabric covering the D cell was still in place and all of the lower fabric was accounted for, much of it still attached to the D cell.
All of the lower fabric seperated from the wing at the impact site.

Port Reconstruct Frame.bmp

Placement of the upper fabric was initally dificult to establish, because of dammage to the fabric edeges, but a paint chip match was established using a microscope.



Microscope Match.bmp

After the inital match several more matches were possible and are shown below.
As can be seen in the following photo, except for a section near the wing tip that can not at this time be accounted for (T.S.B. may have some of these pieces) almost all of the upper wing fabric shows significant flaging which would indicate that the upper wing fabric was torn during flight. This would mean that all of the upper port wing lift would have been lost.

Root Fabric.bmp

The pieces of fabric with red tape patches were found out in the field. The rest were found at the impact site.
Except for a very small piece of fabric at the tip no matches were made for pieces attaching to the top rear aleron gap seal.

Tip Fabric.bmp

We still have quite a bit of fabric that cannot be placed at this time. The large pieces shown below, can be verified to be from a wing by the indentations left by the wing ribs. Again the pieces marked with red patches were found out in the field. The very small unmarked pieces on the left were also found in the field. The rest was found at the impact site.

Unplaced Fabric.bmp

A lot of the fabric on this wing top shows serious 'flagging'. This occurs when the edge of a piece of woven fabric is exposed to violent turbulent airflow. It shreads like the end of a flag exposed to very strong winds.
It should be noted that all of the pieces of fabric that we found in the field showed flaging. This may or may not be true of those found by T.S.B., however, I saw only a very few pieces that showed this phenomena when I was there, as far as I know the location of those pieces has never been determined and there is a very high probability that they are from the left wing.

Flaging.bmp

Tests were run to try and determine the time frame required to cause flaging to a piece of fabric removed from the top of the aircraft fuselage. These tests involved attaching a piece of fabric to a test jig equiped with a airspeed indicator and camera and pushing the fabric into the airflow outside of a vehicle opperating at a closed track (local dragstrip).

Fabric Test.bmp

Unfortunatly, the track proved to be too short to acheive siginificant exposure times at high speeds and the test results were inconclusive. They show only that significant flaging would appear to take more then just a few seconds, higher speeds, greater turbulance, or a combination of all of these.

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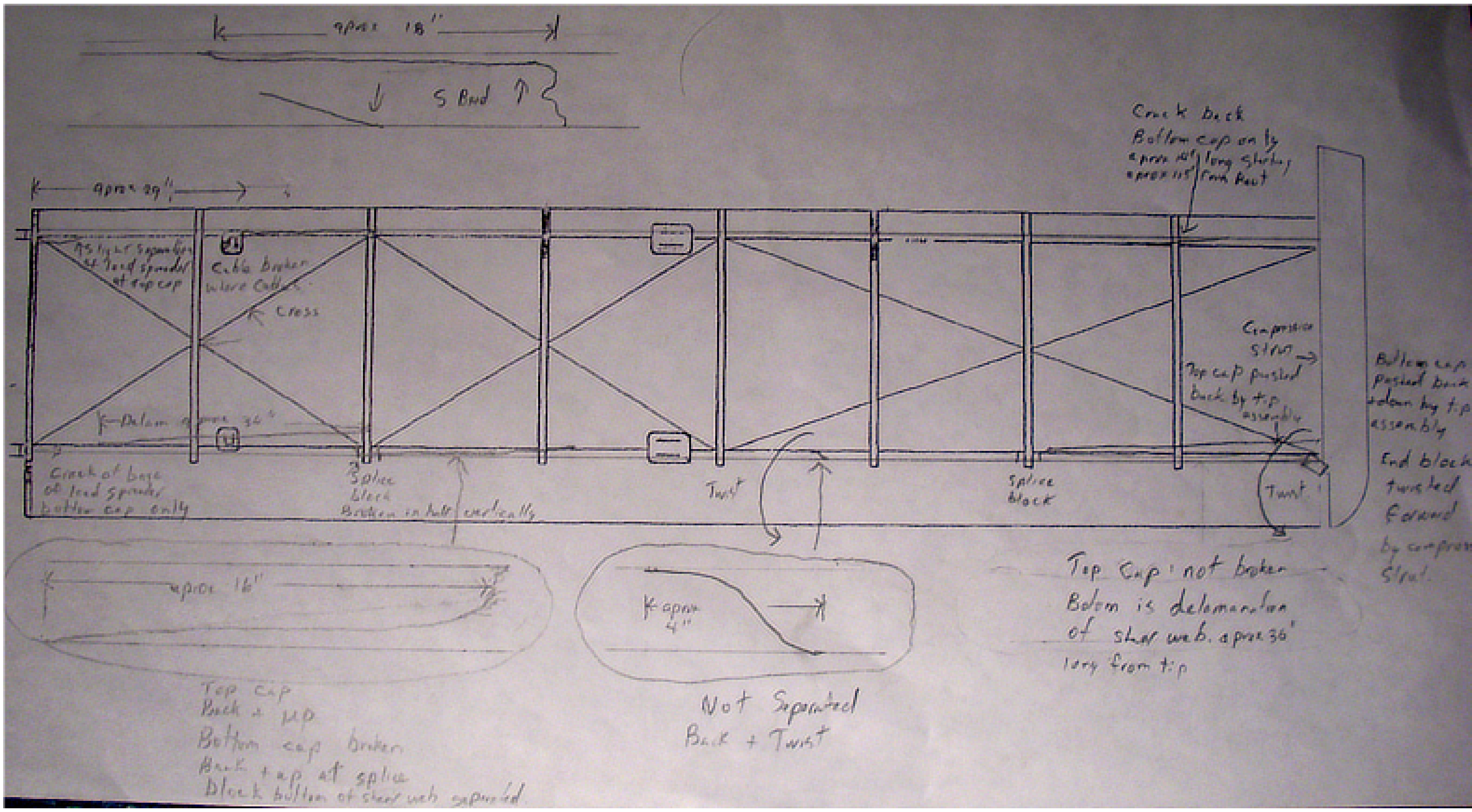
The following photo shows a test sample that reached a peak speed of 90 mph starting at aproximately 70 mph over a time span of about 20 seconds. The edges started as free hand tears.

Fabric Test Sample.bmp

Exanination of the structural damage to the port wing frame showed the following:

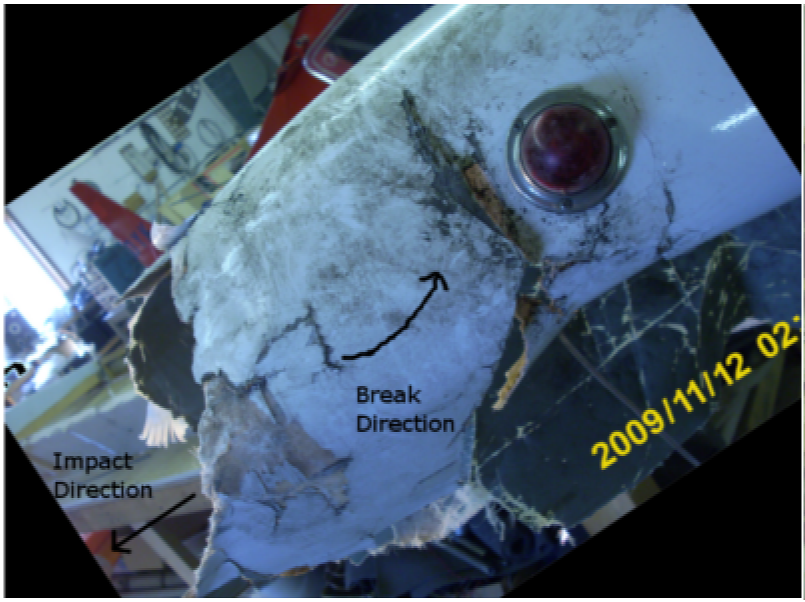
The four compression struts seperated at their front bolt attach points when the main spar rotated, counter clockwise (viewed from port wing tip) at the tip and clockwise on the inboard ones.
The root compression strut also seperated from it's rear bolt attach points, but it is not known if this was an impact break or caused by rescue workers.
The tip compression strut also broke aproximatrly ten inches back from the front attach bolts.

The following sketch was done during the reconstruction and shows the aproximate location of the spar breaks. It was drawn in pencil, so it is a bit hard to read.



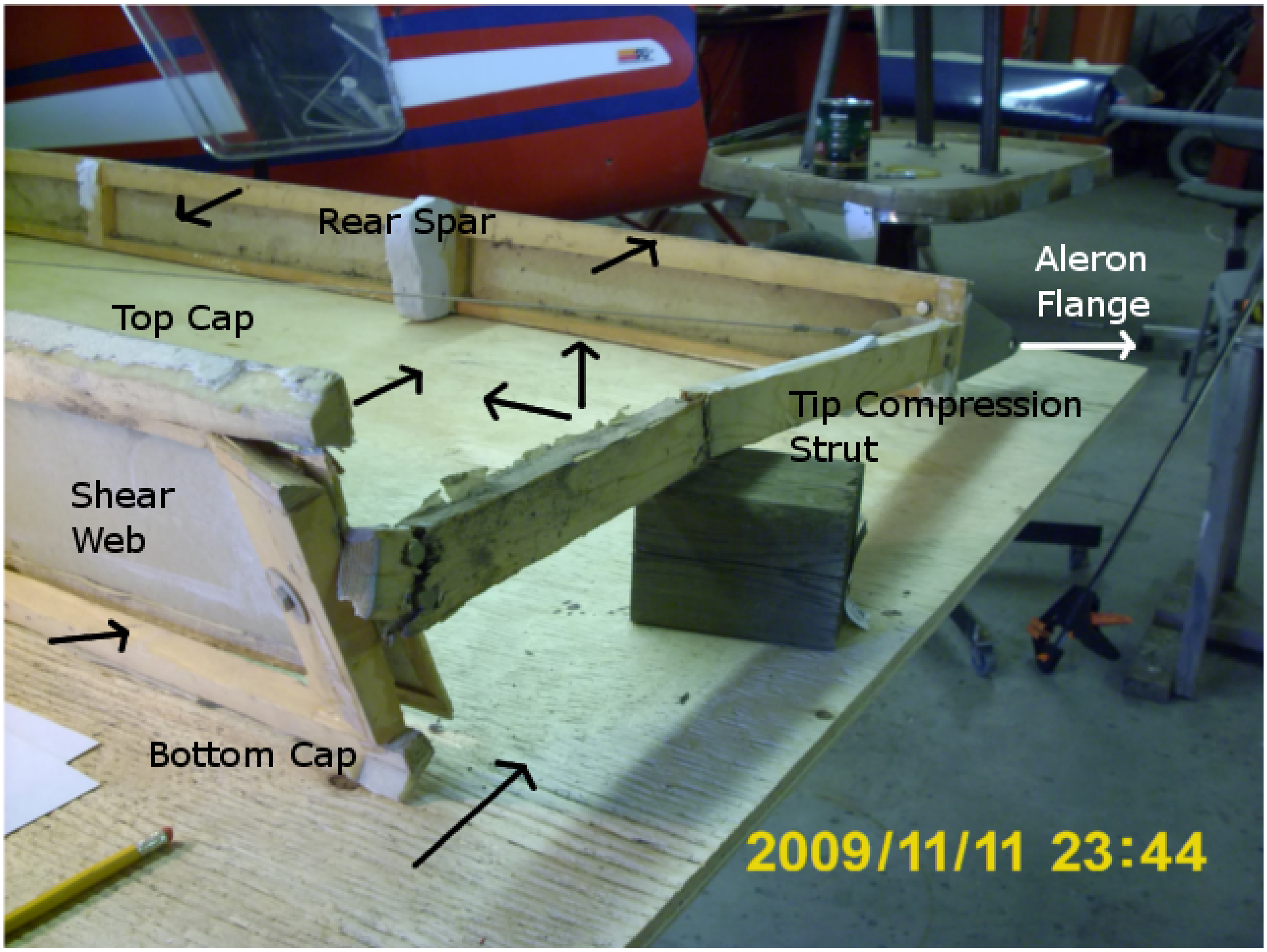
Break Drawing.bmp

The fiberglass composite wing tip had a large piece broken from the tip front top.
Examination of the fractures show that it broke up and back.
The front section of the tip structure was glued to the main spar caps at the top and bottom and the inboard section where it was attched to the wing was filled with a foam rib split down the middle and attached to the top and bottom of the tip compression strut.
The following tip photos show the breaks and the aproximate angle the tip would have impacted the ground to have caused them.



Tip Composite.bmp

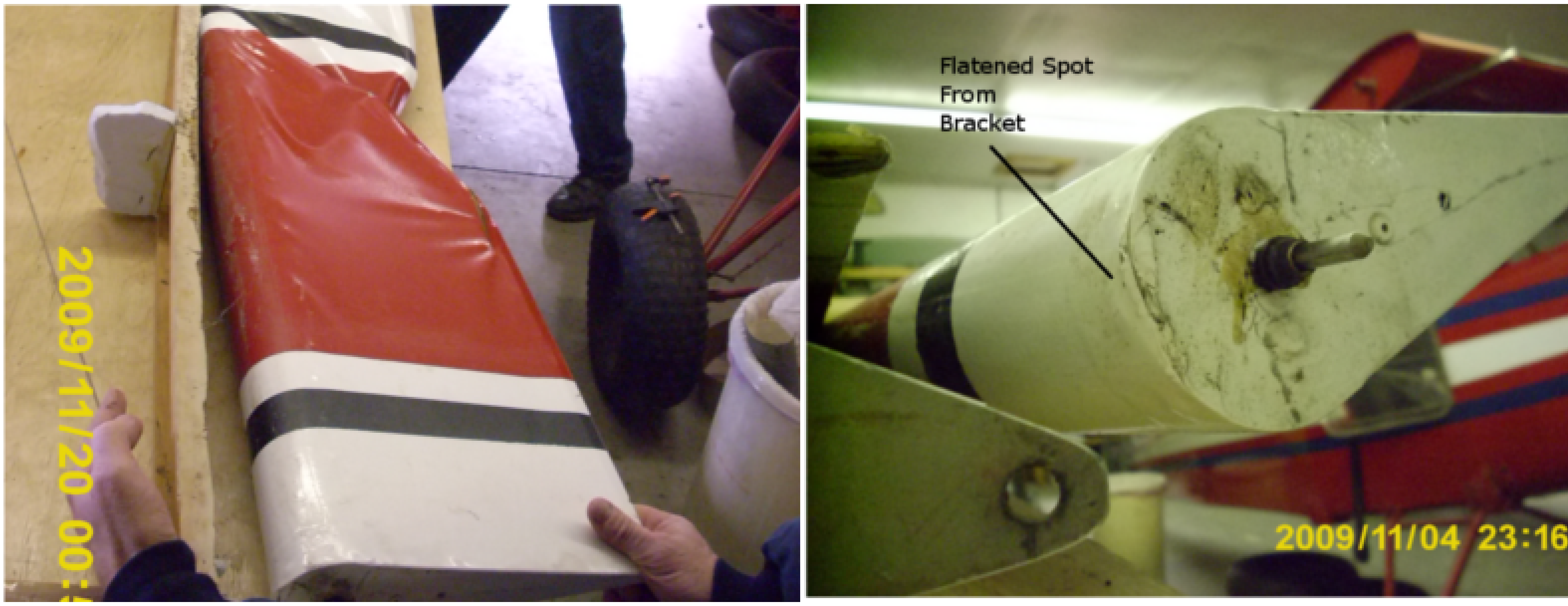
Force from the impact of the tip structure with the ground caused the lower main spar cap to push back and shear from the spar shear web. The top cap also pushed back, but several inches less then the bottom cap. This had the effect of causing the main spar to twist in a counter clockise direction as viewed from the tip.
The tip compression strut was broken in compression at the front attach bolts and also aproxamately 10 inches back from these bolts. It was broken upward and inward toward the root. The rear spar tip end was pushed back and against it's drag cable causing the section inboard of the tip to bend back. This is most likely when the tip upper and lower aleron gap seals seperated at their respective glue joints. The composite tip assembly completely seperated from the wing taking a small section of upper fabric with it. The direction of these fractures are shown in the following photo.



Tip Frame.bmp

The twist of the main spar would have been greater then is shown in the photo. It would be closer to the angle of the short piece of the compression strut still attached to the main spar.

The bend in the rear spar caused the outbard aleron to kink at the bend in the spar and also pressed the rounded end of the aleron against the aleron bracket, as shown in the following photos.

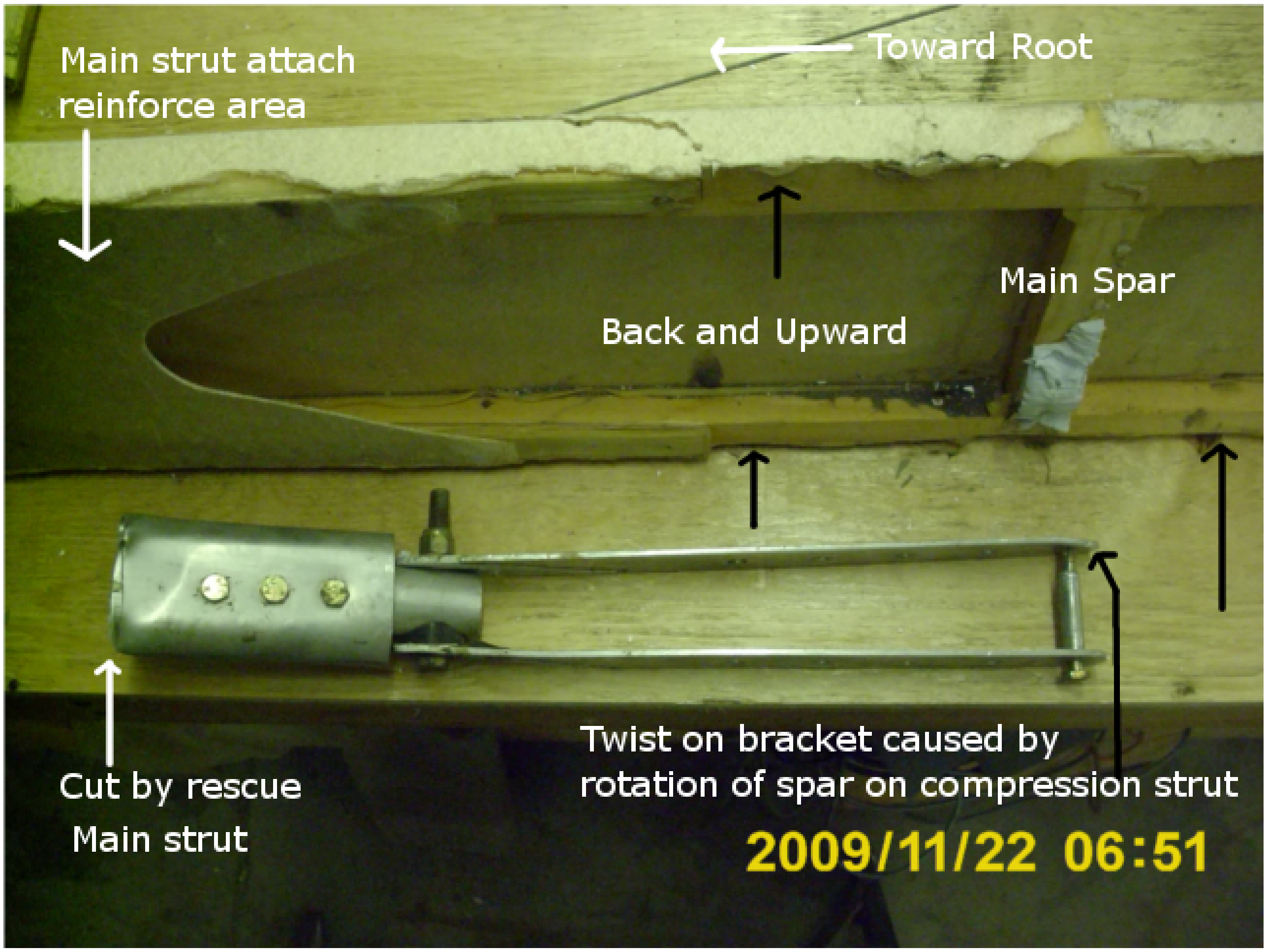


Aleron Composite.bmp

There was a splinter crack in the bottom rear spar cap that is aproxamately 14 inches long at about the center of the aleron red section. The crack coresponds with the rear spar being twisted in a clockwise direction (as viewed from tip) as the rear spar was being bent back against it's drag cable. This twisting motion coresponds to the tip compression strut being pushed upward at it's center compression break.

The main spar was also broken just outboard of the main front strut attach point reinforcing area. There is a splinter break in the bottom cap and a compression break in the top cap although the breaks did not seperate.

This would indicate that the spar broke here while being pushed back and upward as it was being twisted CLOCKWISE from the bottom as viewed from the tip. The bend jn the end attach bolt and bracket that was attached to the compression strut bracket between the front and rear spar at this point would also indicate the clockwise twisting motion of the main spar.

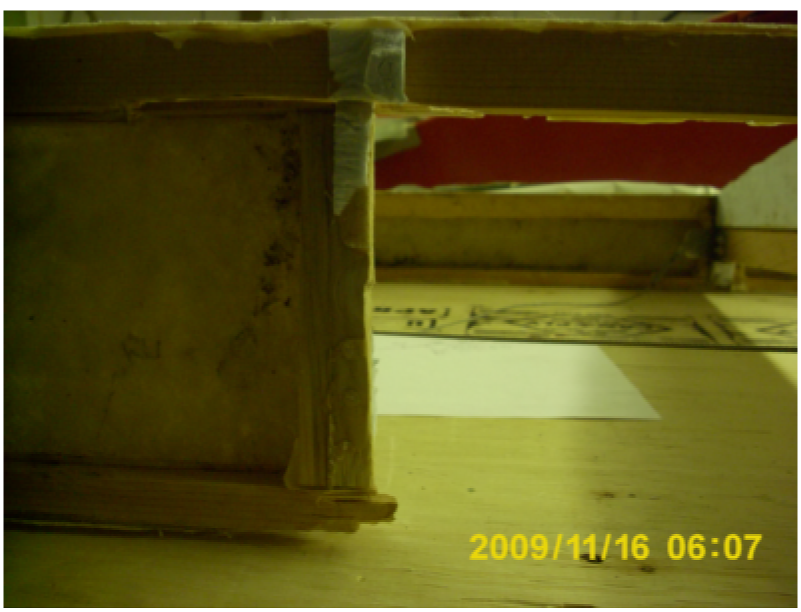


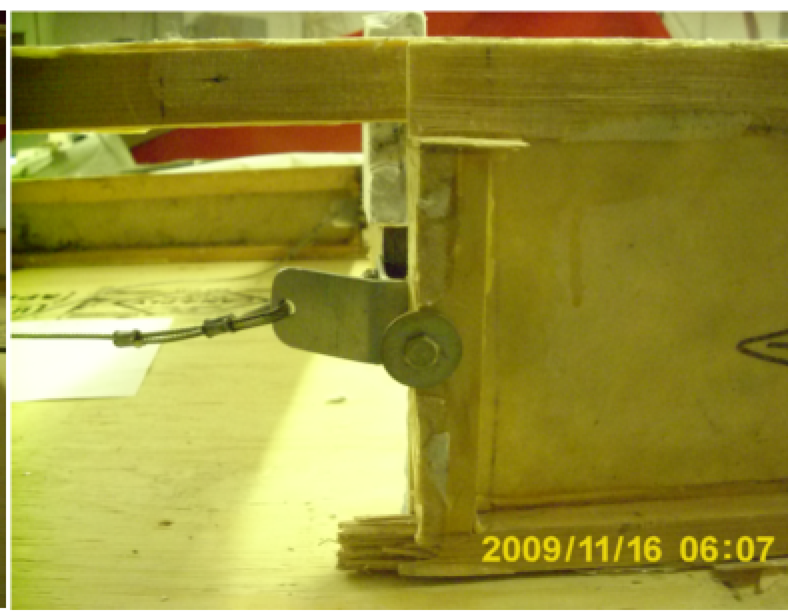
Center Main Spar Break.bmp

The main spar seperation break shown in the following photos occured aproximately 4 feet out from the root and consisted of a very long splinter break in the top cap about two and one half feet in length streatching from the shear web splice block to the main strut attach point. There is a break in the bottom cap that can be seen to have been broken back and upward around the bottom of the shear web splice block as referenced from the tip end of the spar to the root end. The shear web splice block was also split in half vertically 90 degrees to the spar.

Main Break.bmp

Above is a partial view of the long splinter break. Below is shown the broken splice block and the lower break.





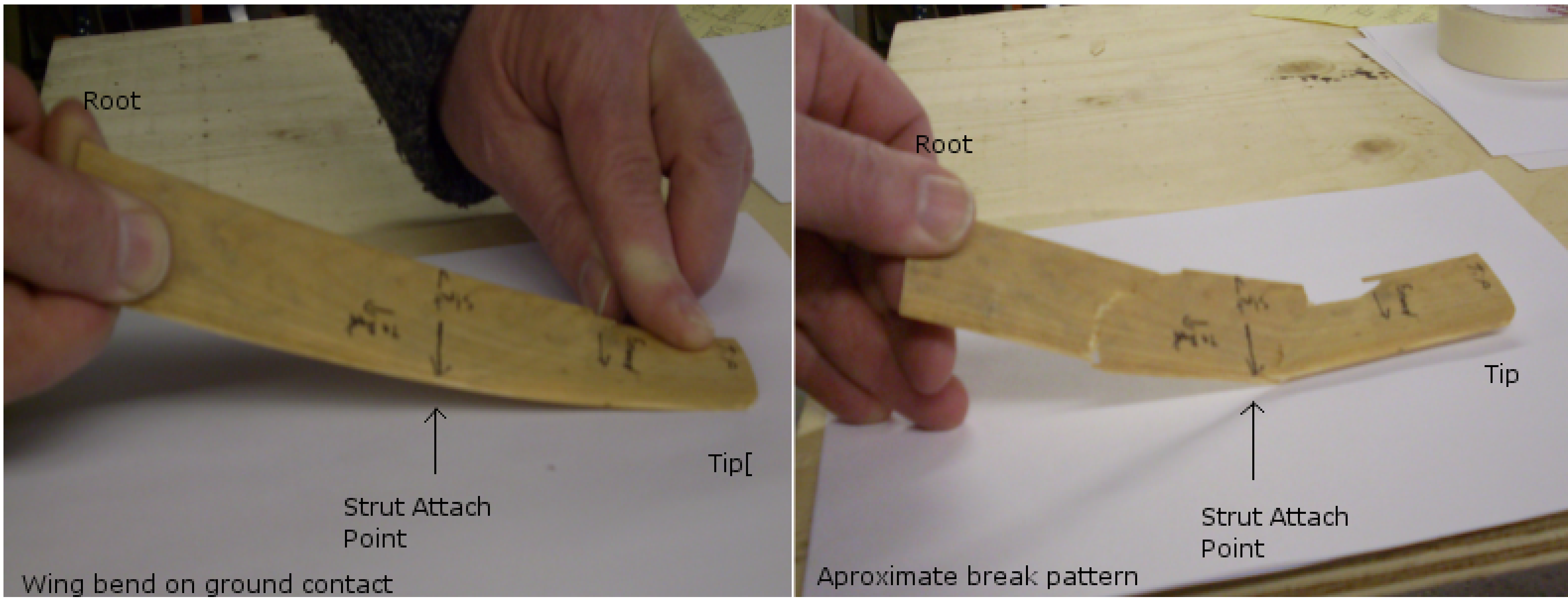
Main Spar Seperation Break L-R.bmp

These breaks also show twisting in a CLOCKWISE direction as viewed from the tip
The break directions and twisting directions are all related from the tip side of a break as compared to the adjacent piece of the spar on the root side of the break.
The counter clockwise twisting of the tip section of the main spar and the clockwise twisting in near the front main strut can be understood from the following pictures.

Pre Impact.bmp

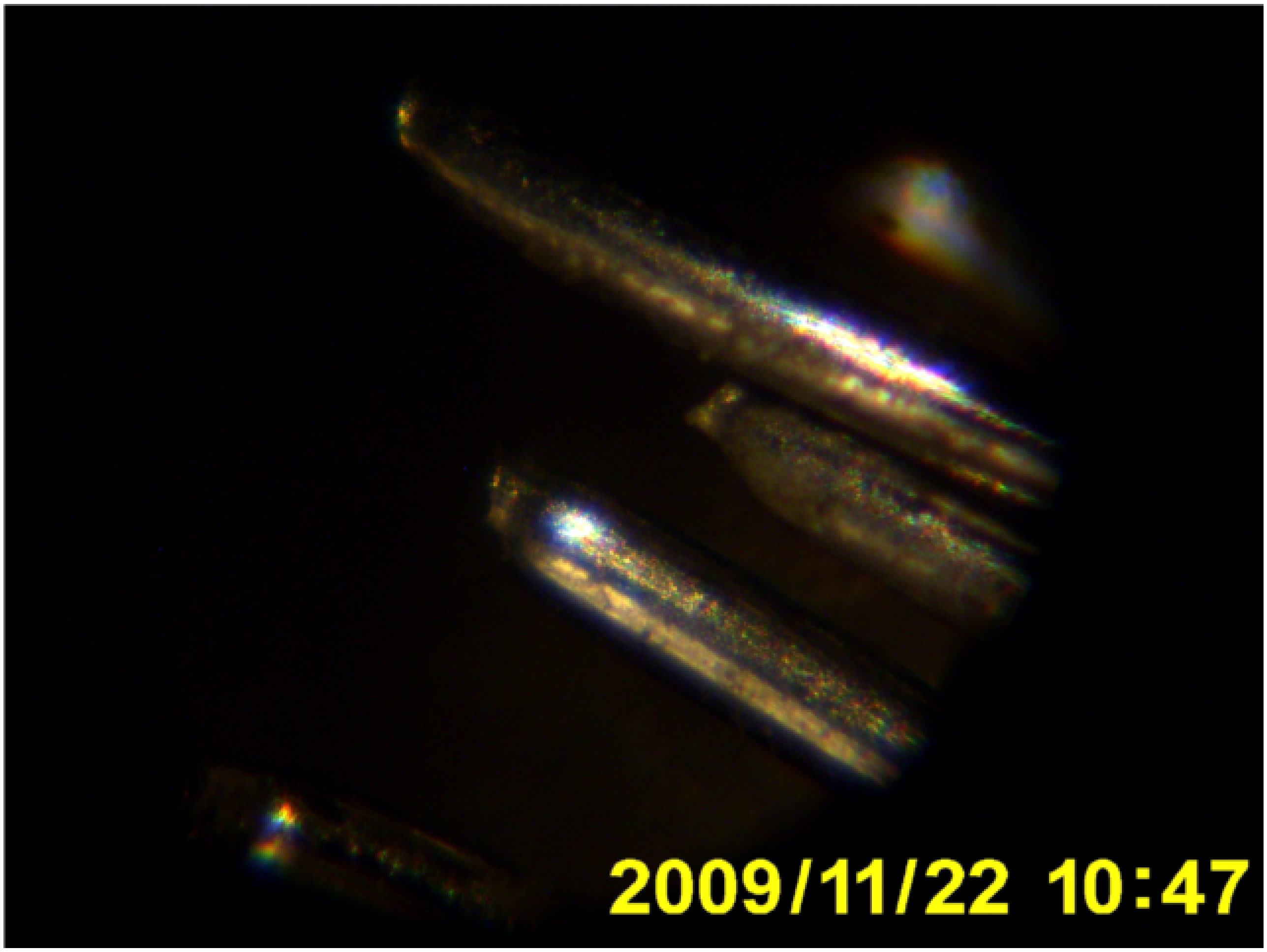
The above composite photo aproximates the most likely attitude of the aircraft just as it struck the ground as supported by the evidence of the wreckage.
The port wing struck the ground just before the front of the main part of the aircraft.
On contact with the ground, the wing tip broke and started to roll the end of the main spar under as shown earlier.
The outboard section of the wing would then have started to flatten against the ground as shown below left. This would cause a clockwise twist of the outboard wing section (as viewed from the tip) as related to the inboard section.
The support of the main strut would tend to cause the fracture outboard of the main spar reinforcement area and due to leverage would cause a much greater force to be transfered in to the inboard side of the reinforcement area where the spar failed and seperated.

The tip compression strut forced the outboard end of the rear spar against that sections' anti-drag cable causing the rear spar to bend inwards tward the front spar kinking the outboard aleron (see 'photo Aleron Composite.bmp').
The following photos show how the wing would break and bend as it impacted the ground.



Wing Bend_Break.bmp

Because there was little or no upper lifting surface on the port wing, this wing could not be flying in the normal sense of an airfoil and could only produce lift by the angle of attack of the intact fabric on the bottom of this wing. So at 0 degrees angle of attack it would produce zero lift.
The wings of this aircraft were analyzed using NASA's Foilsim program and it shows that at 0 degrees angle of attack either port or starboard wing would normaly produce about 850 lbs of lift at 94 mph (final reading of airspeed indicator).
Of course as noted the port wing would produce 0 lbs. of lift. This would cause a violent roll to port. The parasitic drag of the port wing may have been higher then the starboard wing because of flapping fabric, but the induced drag of the starboard wing would be much higher then the port one because the starboard wing was producing so much more lift. The large drag difference would have tended to cause the port wing tip to lead the starboard one in the roll.
The port wing cut a swath in the barley crop just a few feet wide in the direction of its forward travel at the tip end. This can be seen in the overhead photos (these are not available to me and I am working from the memory, only having seen them once).
The wing flattening to the ground and sliding absorbed much of the impact force from this wing, but the tip ground impact coupled with the upper fusealage colapsing forward as the engine impacted transfered large rearward forces down the wing, breaking compression struts and the inboard drag cable. The rear spar developed an S bend fracture near the root as a result of the rearward force of the wing tip being transfered down the spar trying to compress it. The S bend is clearly visible in the photo 'Port Reconstruct Frame.bmp' shown earlier.
The S bend is about the center left in the photo just this side of the blue partialy intact foam rib.
The broken drag cable can be seen in the lower center of the photo. It seperated in its center where it crossed the anti-drag cable. It is not known if the drag cable crossed over or under the anti-drag cable but there was not a lot of vertical travel on it as the plastic cable ties that kept the two cables from chafing were not broken. The drag cable broke and pulled through it's cable tie.
The drag cable ends were examined under the microscope to ensure that the cable was tension broken and not cut as seen in the next photo.



Cable Break.bmp

The S bending of the rear spar also kinked and flattened the leading edge of the inboard aleron.
The flat spot in this aleron, the kink in the outboard aleron and the slight flattening of the tip against the support bracket of the outboard aleron, indicates that the port aleron/flaperon was almost exactly at its netural position at impact.

No hard structure components were found out in the field, with the exception of the inboard upper aleron gap seal and a few very small pieces of foam rib. The exposed foam ribs would have been very vunerable to the violent, turbulant air flow especially after the rear seperation of the inboard rib caps.
This coupled with the direction of the breaks and the placement of wreckage debree, would indicate that the port wing was in place and except for the noted gap seal, fabric and seperated ribcaps, was intact at impact.

Starboard Wing

The starboard wing had already been removed by T.S.B. before I was allowed on the crash site, so all of my descreptions of the impact scene as related to this wing can only be based on relatively low resolution photos supplied to me by them.
I Traveled to Winnipeg to look at their reconstruction but I only spent a couple of hours there and it should be noted that at that time I had no intention of persuing my own investigation.
That came much later.

If the wing is ever returned here I will do a reconstruction to verify and probably update this report. I expect some details will change, however unless there is detail information that is not in the pictures, I do not expect my final conclusions to change significantly, although some of the specific details may change.

Because of the condition of the starboard wing and the way the main spar was imbedded into the soft ground, it was initally thought that the starboard wing failed in flight.
Examination of the wing structure photos by myself however, show that none of the fractures are consistant with that theory. They are all consistent with impact and deceleration forces, not flying load forces.
Impact breakup is also consistant with the almost complete lack of wing hard structure found in the field either by T.S.B. or us. The only hard structure found in the field at all was the port wing upper outboard aleron gap seal and a few small pieces of foam rib.
T.S.B did not collect all of the starboard wing pieces and they released the remaining on-site wreckage to us (Registered owner).
Pieces of this wing were subsequently found and identified by myself and forwarded to them.
These included the outer upper aleron gap seal from starboard wing, (they had the one from the port wing) and most of the pieces missing from the main spar break.These are shown below. The gap seal is on the left, it is sitting on top of a finished wing.
The Main spar break pieces are shown on the right.
I also have a piece of strarboard wing D cell that was not identified as such at the time of shiping. T.S.B. has not requested it and it is still in my possession.

Starboard Wing US Located.bmp

There were several other pieces of wood that were picked up by us that could not be found to match any locations on the port wing.
Since on this aircraft the wings and firewall are the only places that contain wood and the pieces were not plywood (Firewall), it was

deduced that these pieces must be fom the starboard wing. They wee forwarded to T.S.B. and are shown in the photo below.

Non Port Wing Parts.bmp

The inner portion of the starboard wing remained attached to the airframe after impact and I believe that all of the wing hard structure can be accounted for
at the impact site. We picked up two medeium size trash bags of small debree there and left nothing we found behind except for small paint chips.

Starboard Wing & Fuselage.bmp

In the above photo, the main spar embeded in the ground can be seen (center). Ground penetration was somewhere between 11 and 16 inches.
The spar appears to be vertical in this shot but that is not really the case it leans quite a bit in towards the aircraft tail section as can be seen in the following photo.

Site Starboard Rear.bmp

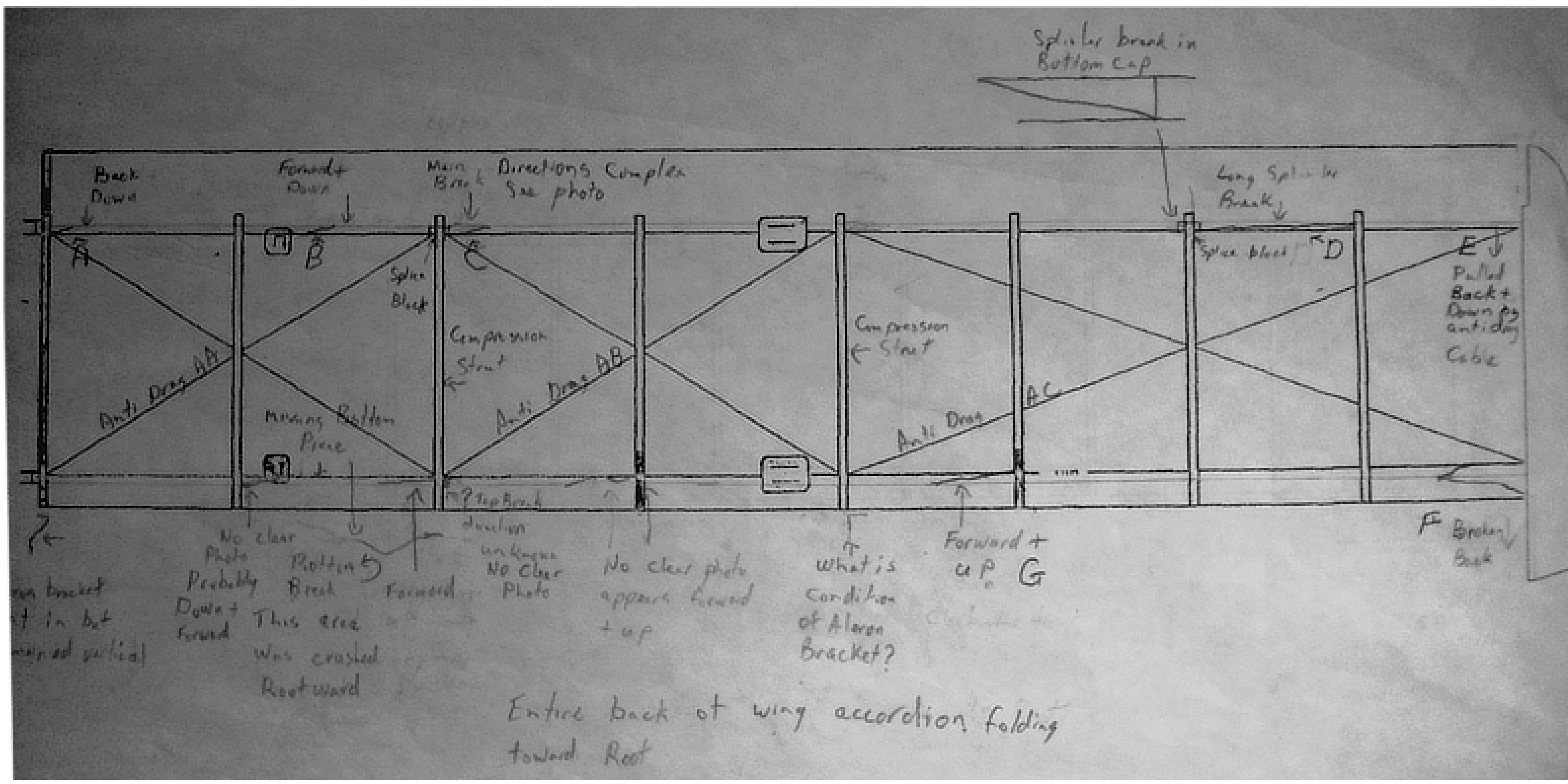
This location and position of this spar section has led T.S.B. to the assumption that the wing failed in flight.
I have been studying the wreckage left behind by them and the photos of the sections that they removed for the past two+ months and I dissagee.
Here is my explanation:

It should first be noted that at the speeds and distances involved, all of the events starting at first impact of the port wing tip, likely took place in a time frame of less then 200 milliseconds.
Because of the loss of lift on the port wing due to fabric sepperation and loss, the aircraft would be in a tight spiral dive to port. This would be a corkscrewing motion with the port wing tip leading the starboard one. This would be the case because when a airfoil (wing) produces lift by moving forward through the air a large portion of the forward energy is converted into vertical motion (lift). This is termed induced drag.
Because of the loss of fabric on the port wing, this wing was no longer an airfoil. The starboard wing would have a much higher induced drag coefficient then the port one. There is no reason to expect that the parasitic drag on the port wing (drag created not producing lift) would be that much greater then when the wing had all of its fabric. This is because the still intact leading edge would still present the same area to the the air flow as it ever did. A little less in fact, as part of the upper buldge presented by the fabic would be missing. It is even possible that the parasitic drag on the port wing in some attitudes would be less then the starboard one.
The tail of the aircraft would tend to push it's self in the oppisite direction of the wing lift (normaly down). This is because this

aircraft, as most are, was designed to be slightly nose heavy for stability reasons. The horizontal stabilizer and elevator were designed to counter this in normal flight.
Their angle of attack (negitive to the wings) was ballanced against the lift of the wings, but half of that lift had been lost. This would tend to cause some tumbling motion combined with the corkscrew roll.

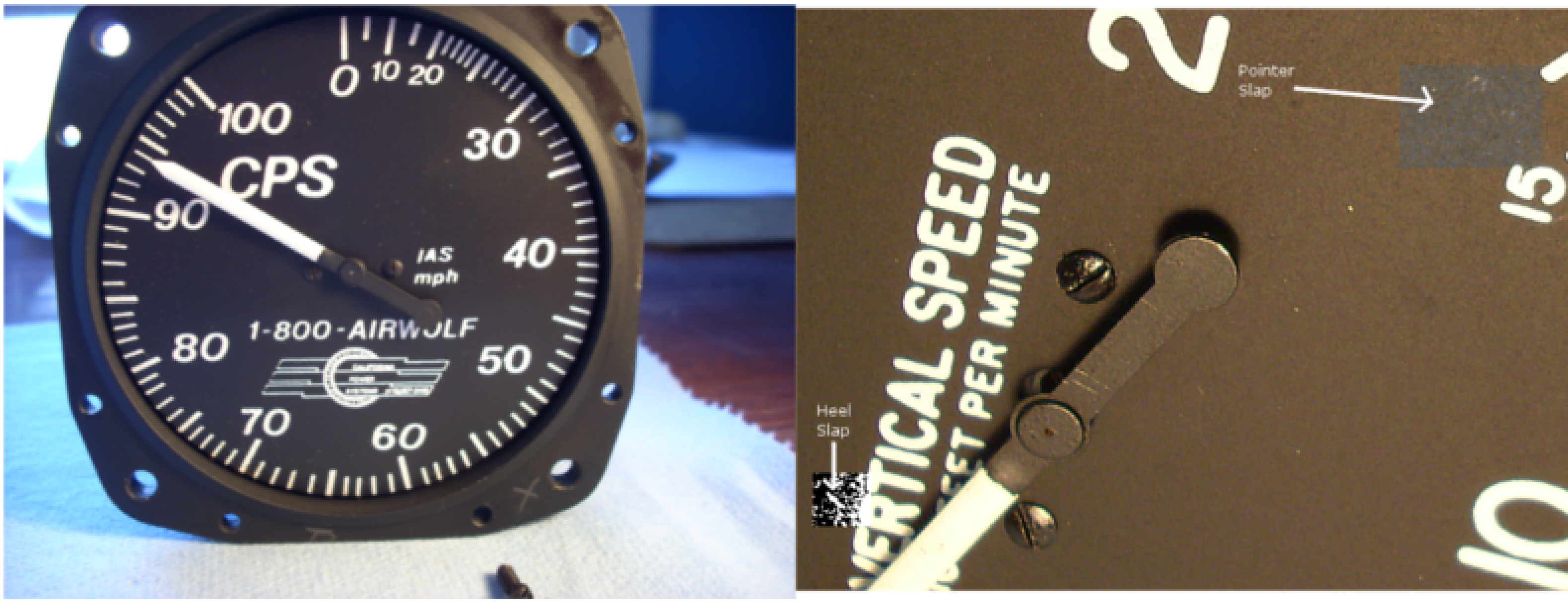
At impact deceleration forces greatly exceed the wing lift forces. This is obvious from the condition of the aircraft in the photos. The port wing tip had already impacted the ground and was decelerating but the engine/fuselage was still traveling forward. This combined with the drag that was still happening on the starboard wing, because it was still flying (induced and parasitic drag), would create forces trying to push both port and starboard rear wing spars toward each other. This energy woild be transfered through rear fusalage wing support cross tube.

As the main impact started, the port wheel impacted the ground followed by the starboard wheel and then the engine. The impact angle of the port wheel would tansfer a large amount of energy up the undercarrige and through the fuselage structure to the starboard wing. This force would be additive to that already being generated by the port wing impact, as noted earlier.



Starboard Wing Diagram.bmp

As the starboard inner rear spar was compressed by the port wing impact, the drag cable running from A to the rear spar would take the load (see schematic above). This would transfer energy forward into the compression strut at C driving it forward. The cable and rear spar were already under load from the drag of the starboard wing. This load was quit considerable due to the speed that the aircraft was traveling (Airspeed indicator was impact stuck at 94 mph.). The aicraft was decending (VSI impact marked at -1600 ft/min) and in normal flight at these speeds, the angle of attack on the wings would have been quite negitive, more then -2 degrees.

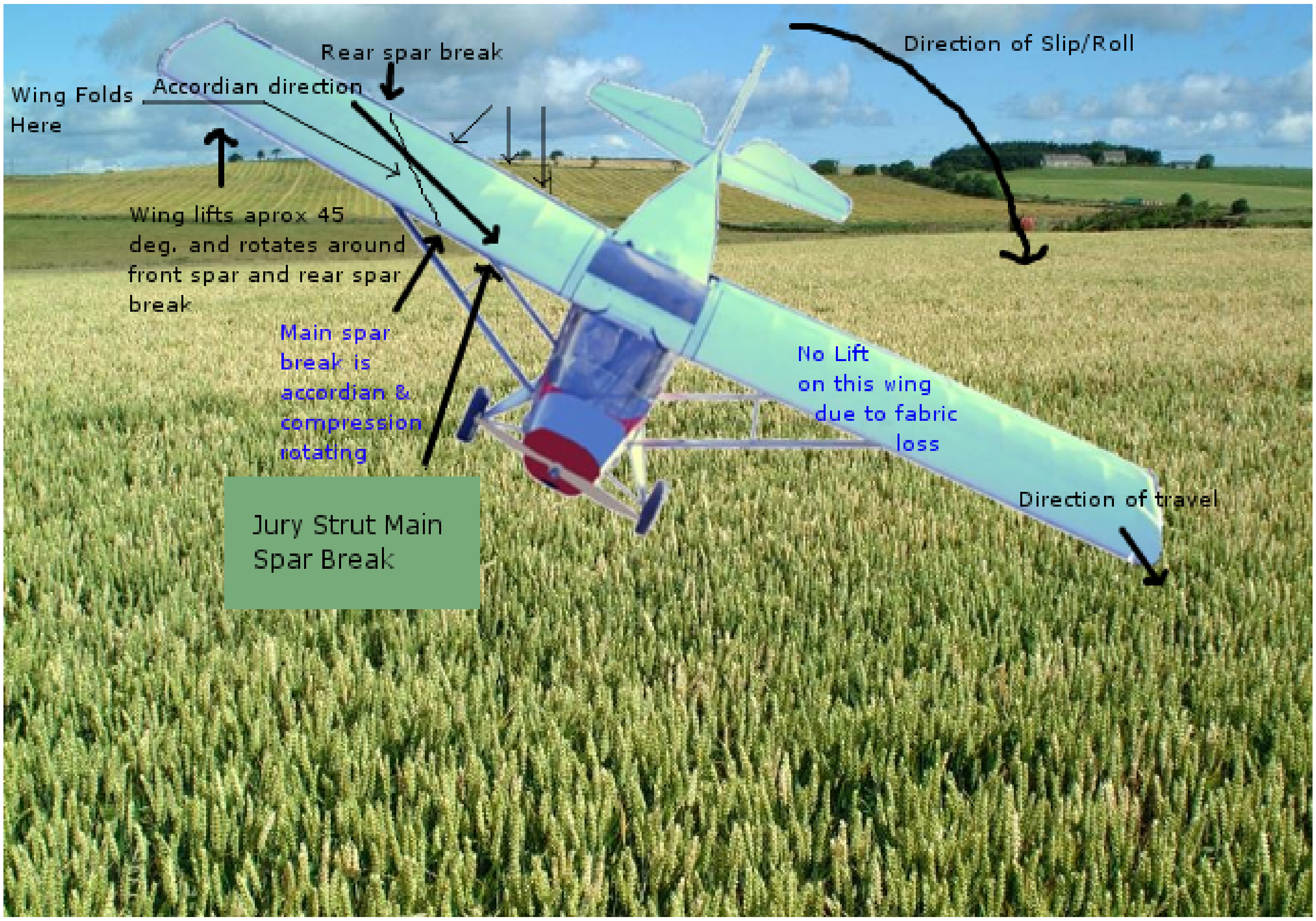


Gauges.bmp (enhanced)

The Rear spar collasped under the combined loads between the root and the compression strut at C. The antidrag cable AA would normaly divide this load back into the rear spar attach point, but the rear spar was now broken. Because of this the, compression strut at C drove through the front spar shear web breaking the splice block. This put load on the drag cable running from C to the rear spar past the rear strut attach point which tried to compress this section of rear spar. Combined with the port wing impact compression force running up the rear spar from the root the rear spar broke here also. The same likely happened to start the break at G.
It should be noted that all of the rear spar fractues would have likely occured pretty much together.

As the engine impacted, fuselage motion would start to come to a halt along with the root end of the wing. The tip would still be trying to continue flying and antidrag cable AC would take the load. This force would transfer forward through the compression strut at the main strut attach points and be transfered down the drag cable connecting the rear end of cable AC to C. This would also cause the cable pull break at E.
The front end of the compression strut at C was no longer rigidly attached to the main front spar, so the spar would move forward and the compression strut back, tearing it's self out of the shear web and broken splice block. The cables AA and from A to the rear end of AA would still take load but the compression strut at C would now be just floating and it would collapse as soon as it became skewed enough.
It is also possible that the compression strut at C was boken on the initial impact, in which case the sequence described above would be different. The end result, however would be the same. The main spar would have been verry badly comprimised at C.

The instantaneous deceleration forces on the starboard wing would greatly exceed it's lifting forces at this point (lift was pobably less then 600 lbs.) and the wing levered down on the front main strut. At the same it time started to swing forward and force it's self rootward at the leading edge because of the direction of the aircraft roll/slip and the enegy transfered from the port undercarriage and the starboard wing forward/slip inertia (kenetic energy).



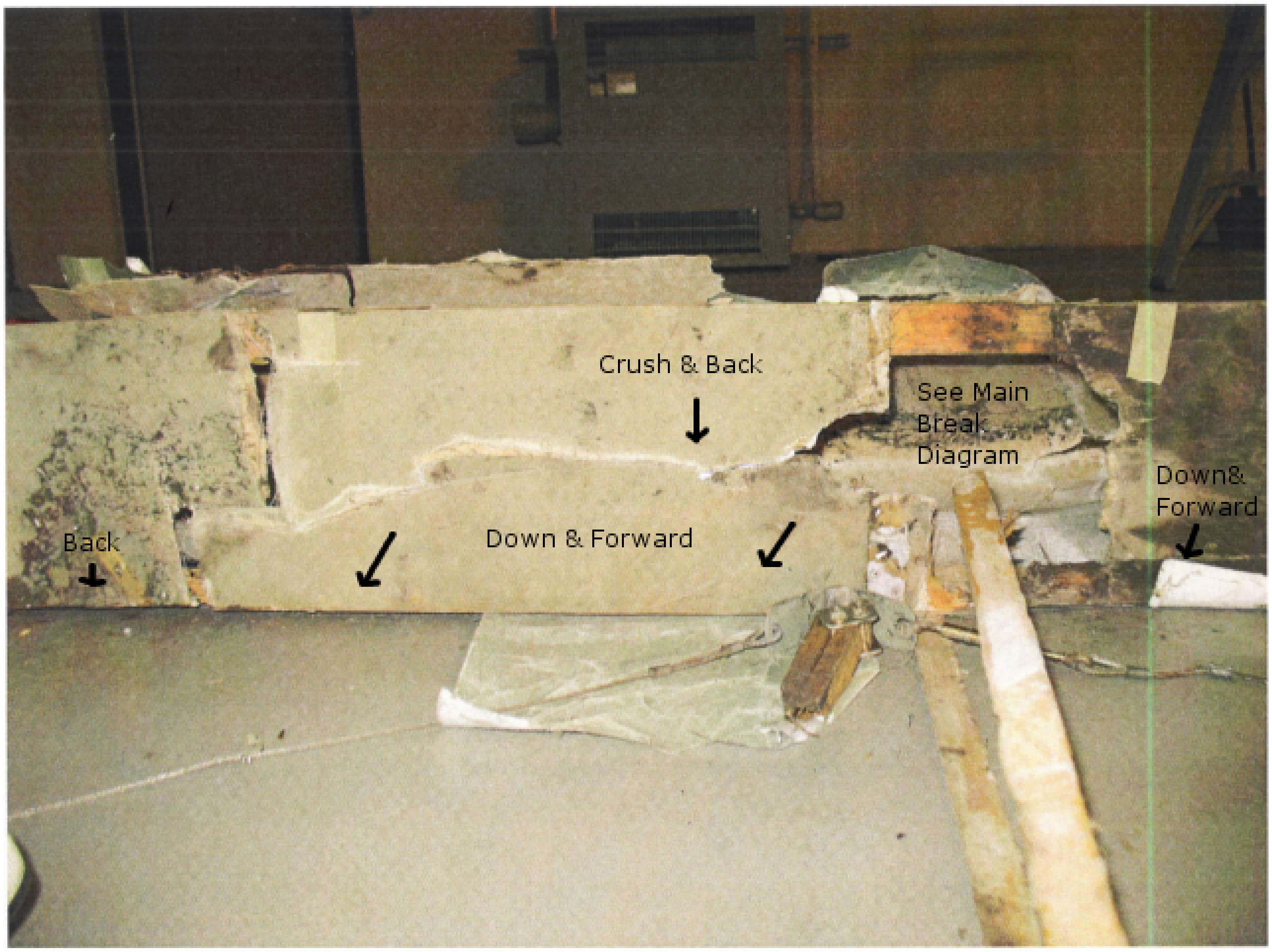
Pre ImpactRW.bmp

As the impact progressed, the lower main spar cap was put in compression and the top cap was put in tenision. This is the reverse of what the caps were designed to carry. The lower cap could not carry a lot of compression energy without fracturing. (The wings were only rated at -3 g's. when completely intact).
The main strut was in compression with it's center supported by it's jury strut. A jury strut is a small sub strut connected from about the center of the main strut back up to the wing. It's purpose is to help the main strut carry compression loads caused by negitive wing lift or negitive g's from landings. The jury strut tends to keep the inner section of the wing from main spar section A - B in line, 90 deg to the wing chord.
Position C is the point of maximum stress on main spar because all forces on the wing must be transfered down the spars to the aircraft and the main spar is levered between the main strut, the jury strut and the fuselage. The shear web and splice block had also previously broken as noted above.
The section of the main spar at C collapsed forward and down under deceleration forces and as the shear web collapsed, it caused the break at B as the spar tryed to rotate around the jury strut and it's support block.

The main spar break is shown below left and a photo composite of the main break parts below right. The dark area on the spar on the far left is where it was embeded in the ground.

Main Comp.bmp

Below is a view looking toward the font of the starboard wing from the rear, of the breaks at B, ont the left, and C on the right.



Both Main Breaks Back.bmp

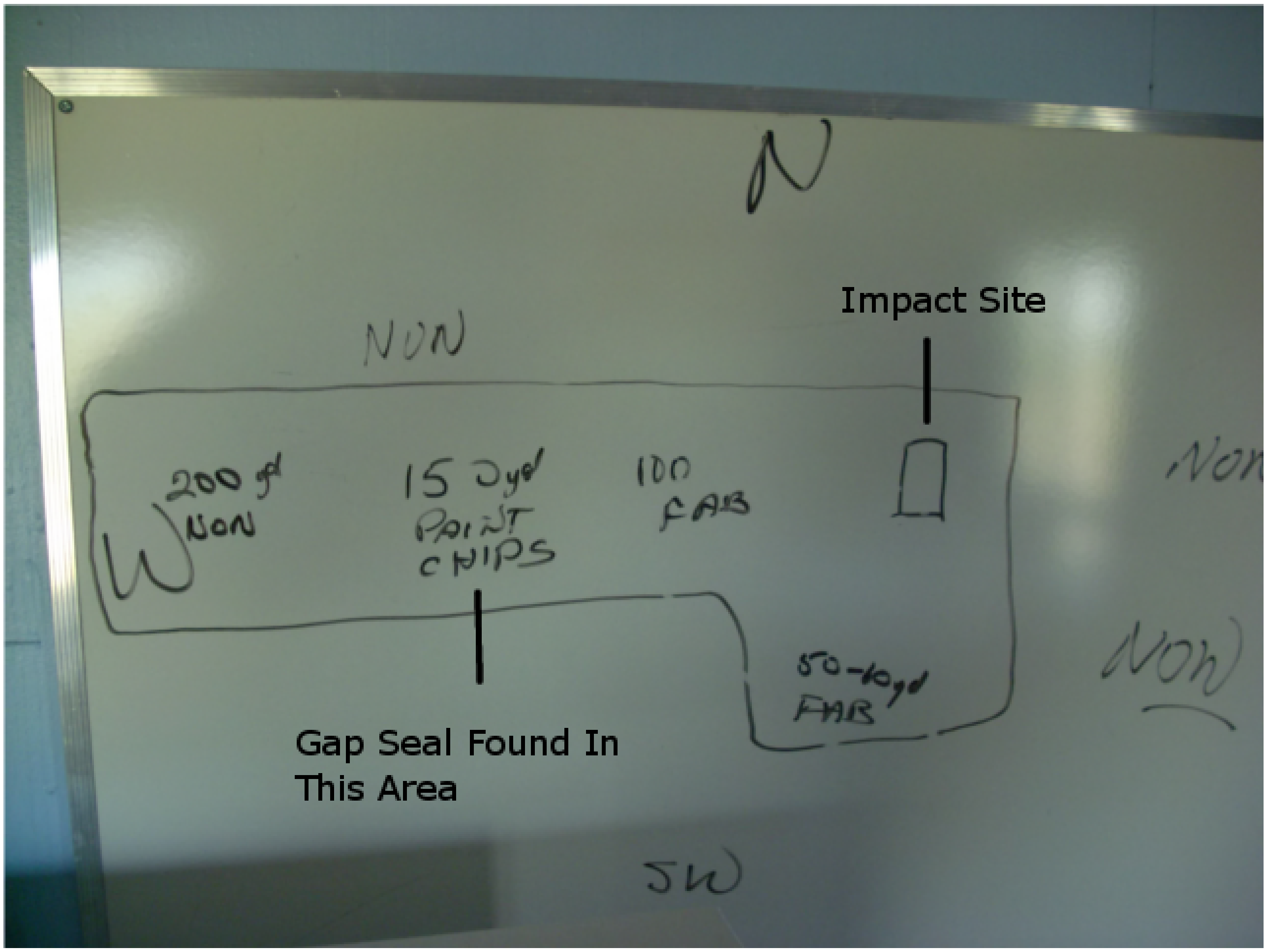
After the fracture at C the deceleration forces were no longer transfered past this point out to the wing tip and there was nothing to stop the wing section from the main strut to the tip from lifting. The wing here was still intact and was generating very large lifting forces. Now that this section was no longer carrying the weight of the rest of the aircraft, it rose very quickly.
The outer wing hinged (rotated) on the main front strut.
The end of break C which was connected to the outer wing section rotated toward the ground.
Because of the spar rotation around the main front strut and the folding angle created by the line of breaks C and G, the angle of attack at the tip was positive and additive from the main front strut outward and negitive and additive from the main front strut inward.
The main strut was not very strong under this compression load, but once the rotation was started, the opposing + and - lift force on oppisite sides of it would tend to stabilize it. The compression load would become a tension and inward load. The force on the inboard side would become more and more negitive and the opposite would be true on the much larger outboard section. This is because of the changing angles of attack caused by the angle that the wing had folded at. These opposing forces would increase the allready very rapid rate at which the outer section was rising.
This rotation would also cause the rotating break at G because the rear main strut is still in place, attached to it's associated compession stut and the front main spar was rotating upward at the tip around the front main strut. This rotation tried to stop as the broken end of the main spar embeded itself in the ground and caused the break at D. The wing tip assembly broke away at E and F and then the outboard aleron was no longer captive between it's brackets. It was flung forward and came to rest aproxamately fifty feet ahead of the impact site.

Damage to the aleron is visable in the photos and would indicate that the aleron was at or near the neutral position at impact. This coupled with the same position on the port wing would indicate that the flap position must have been netural at the time of impact.

Starboard Wing From Root.bmp

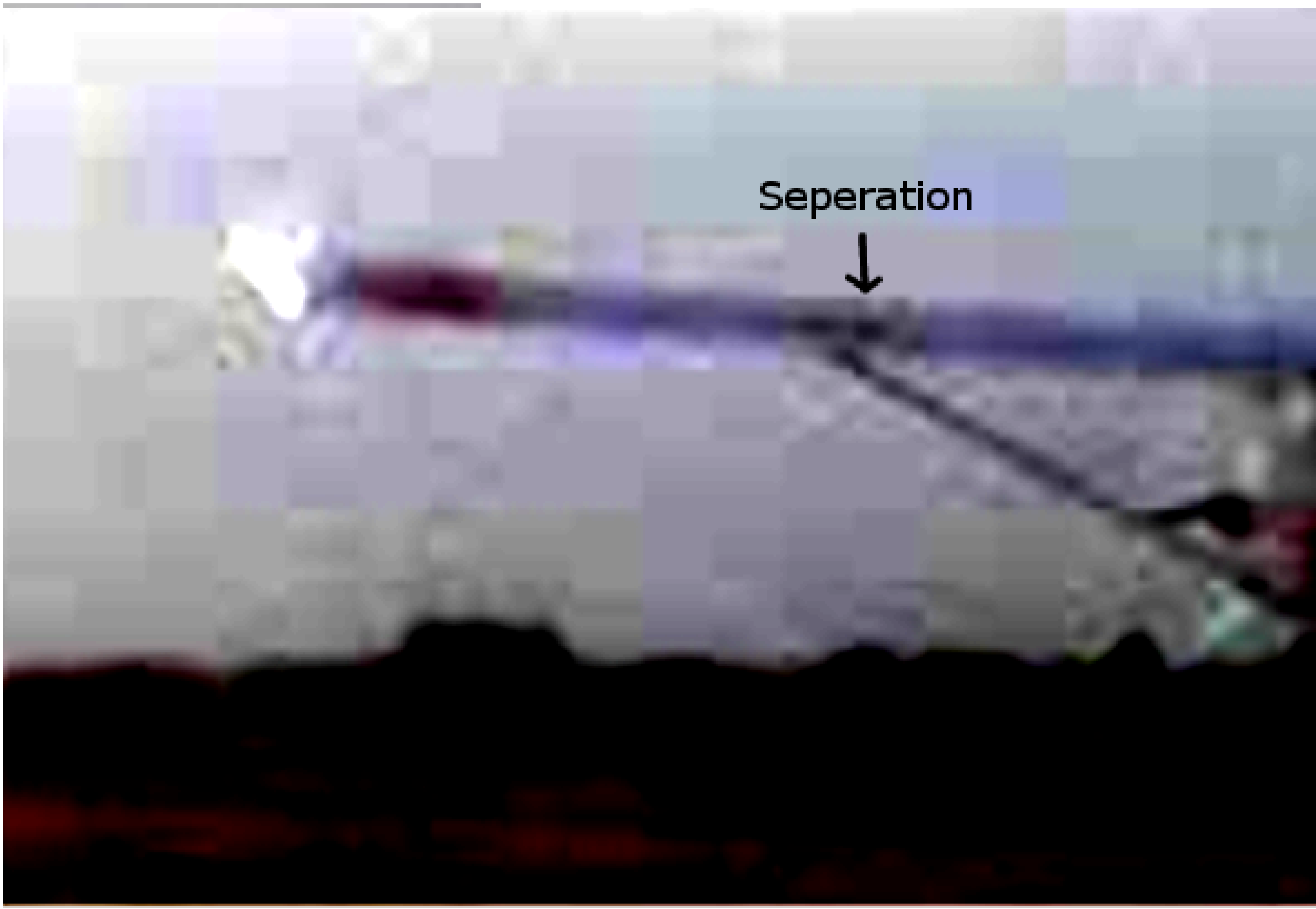
Conclusions and Recomendations

The only airframe anomalies relevant to the crash were with the port wing.
The deployed position of the flaps ia a control configuration anomaly, but this cannot be absolutely verifyed as pre or post impact at this time.
All of the hard structure of the airframe except for the port wing upper inner aleron gap seal was intact and in place at the time of impact.
The piece of gap seal described was found aproxamately 150 yds. west of the impact site followed by paint chips and then fabric.
The following photo is of a sketch done by a person helping T.S.B with the field search.



Site Diagram.bmp

The order and locations of the gap seal and fabric indicate that the seperation of the gap seal caused the loss of fabric.
Lack of hard structure parts along the flight path makes an in-flight breakup of the aircraft a very low probabilty.
The gap seal seperated due to glueing problems and incorrect fabruc attachment originating from the time of assembly of the aircraft kit by the original builder.
The start of seperation of the gap seal can be seen below in the enlarged and enhanced photo taken by the runway camera at Corman Airpark during the final takeoff of this aircraft.



6:51 pm Aug 17, 2009
C-IAUE Final Takeoff
Runway Camera 27 Corman Airpark

Takeoff1.bmp

Because one half of the port wing upper fabric is attached to this piece of gap seal, it's loss immediately resulted in loss of one half of the wing's lift.
Most of the rest of the upper fabric on the port wing departed soon after the gap seal loss as a result the fabric not being attached to the rib caps.
Control of the aircraft was lost and it crashed shortly thereafter.

The crash was a result of a failure of a glue joint on the aleron gap seal of the port wing. This caused the gap seal to seperate from the aircraft and thereby resulted in a loss of the fabric covering on the upper side of the port wing. This resulted in an uncontrolable flying condition of the aircraft.

The glue joint seperation was a result of poor and/or inexperienced workmanship on the part of the original kit builder and of the badly written assembly manual by the manufacturer. This was compounded by an inappropriate choice of recomended glue by the manufacture and a fabric attach procedure that did not take into account what could be considered reasonable in field construction modifications. Detection of the problem during a standard pre-flight inspection without prior knowledge of the problem would have been difficult to impossible.

Inspection of five aircraft has revealed that three of these have similar problems with the gap seal glue joint and of the two that do not. One of the unaffected aircraft has had a complete wing disassembly and rebuild within the last six years and the other is a very low time aircraft. It used a different type of structural glue on the gap seals. Of the three with a problem, one of these has been taken out of service for a complete rebuild, another MUST be and the third, although only showing the first signs of a problem will be in the very near future.

Based on these very preliminary results and the large number of these aircraft still flying, I believe that the proability of this same type of failure and crash happening again is extreamly high.
I am doing my best to make other owners and operators of these aircraft aware of the potential hazard and procedures to try and detect and prevent these occurances.