Composites in Crash Recovery Operations

Controlled by: Department of the Air Force
Controlled by: AFLCMC/EZPT-ACO
CUI Categorie(s): N/A
Distribution/Dissemination Control: Distribution Statement A
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3/12/26

Overview

- **Composite Basics**
- **Composite Damage**
  - **Structural Damage**
  - **Fire Damage**
- **Mishap Scenario**
  - **Personal Protection Equipment (PPE)**
  - **Applying Fixant**
  - **Recovery**
- **Closing Comments**

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Composites Basics - Definitions

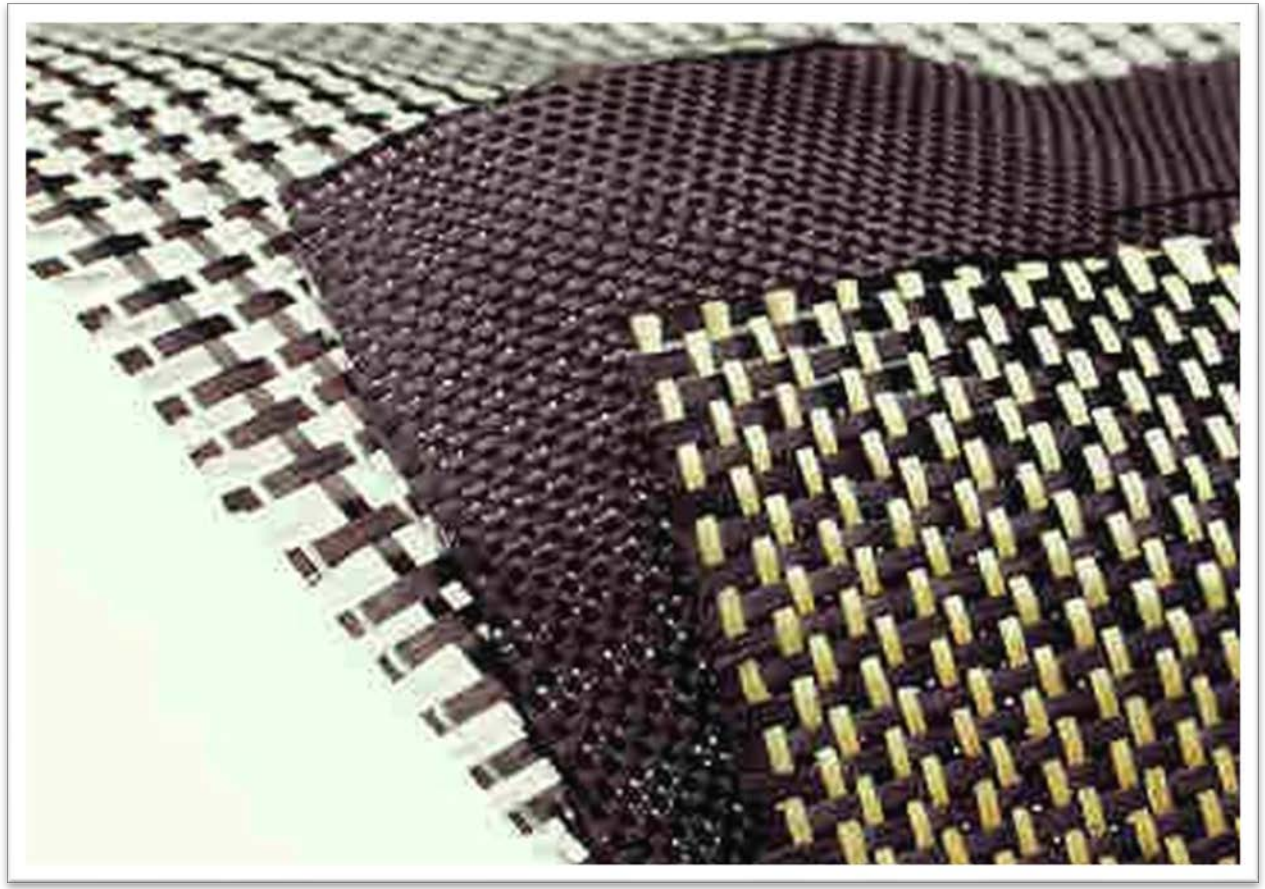
Composites are a system of materials:

- **REINFORCEMENT (the fiber)**
  - **Provides strength**
  - **Carries the load**

- **MATRIX (the resin)**
  - **acts to hold fibers together and protect them**
  - **transfers the load to the fibers in the finished composite part**

Composites Basics - Definitions

Fabric: material constructed of interlaced yarns, fibers, or filaments



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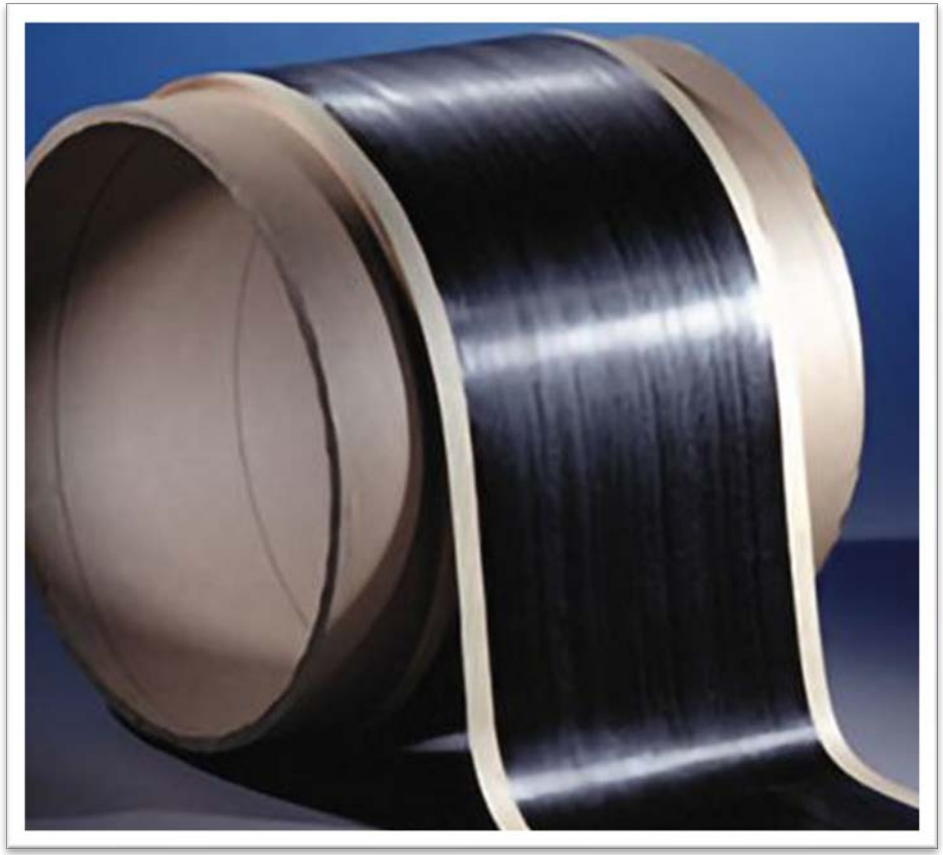
Composites Basics - Definitions

Tape: material in which the filaments are laid in a single direction within a resin matrix



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Composites Basics - Definitions

- **Advanced Composite: materials made by embedding high stiffness fibers (boron, aramid, graphite, glass) within a plastic like matrix (epoxy, Bismaleimides (BMI), thermoplastic)**

- **Ply: a single layer of tape or fabric**

- **Laminate: two or more layers (plies) bonded (glued) together**

Composite Damage - Overview

- **Composite fragments will be found along tumbling path**
- **A pool fire will spread composite strips and clusters around the site**
- **Composite parts with fire and/or structural damage can still be attached to aircraft**

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Composite Damage - Categories of Debris

- **What is the debris made of?**
  - **Metallic Only**
    - **(e.g. aluminum, titanium, etc)**
  - **Composite Only**
  - **Mixture of metallic and composite**
    - **(e.g. metallic structure bonded to composite skin, or metallic honeycomb with composite face sheet)**

- **How was the debris generated?**
  - **Physical damage only (e.g. broken by impact)**
  - **Fire damage only (e.g. engine fire, brake fire)**
  - **Both physical and fire damaged (e.g. crash and burn)**

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Composite Damage - Types of Debris

- **Fragments**
- **Strips**
- **Fiber Bundles**
- **Single Fibers**
- **Clusters**
- **Dust**

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Composite Damage - Fragments

- **Large piece of composite laminate debris**
- **Jagged edges that may cause cuts or puncture wounds**

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Composite Damage - Strips

- **Single layers that have been separated from the whole laminate**
- **Usually found near the fragment it was generated from**
- **Fire damaged strips may have some resin or char attached**

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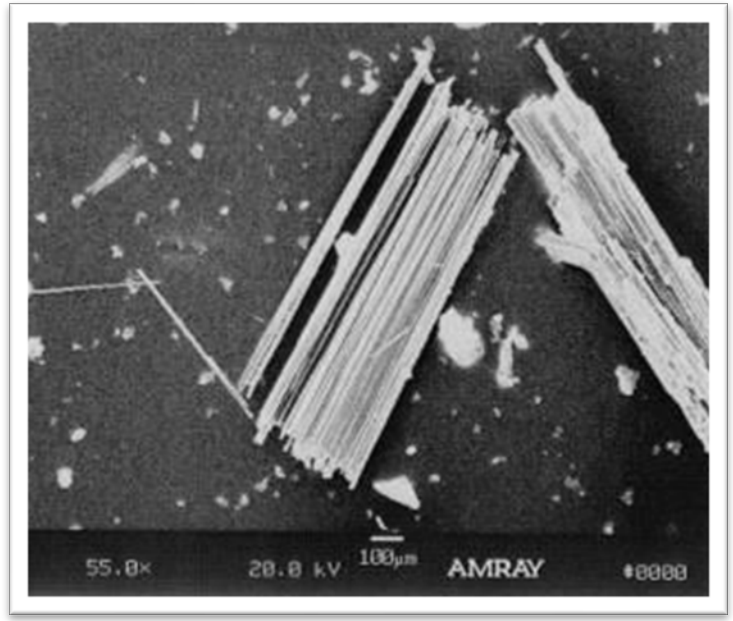
Composite Damage - Fiber Bundles

Broken sections of fibers, attached with resin

- **Large or small**
- **Resin coated fiber segments**
- **Can cause puncture wounds**



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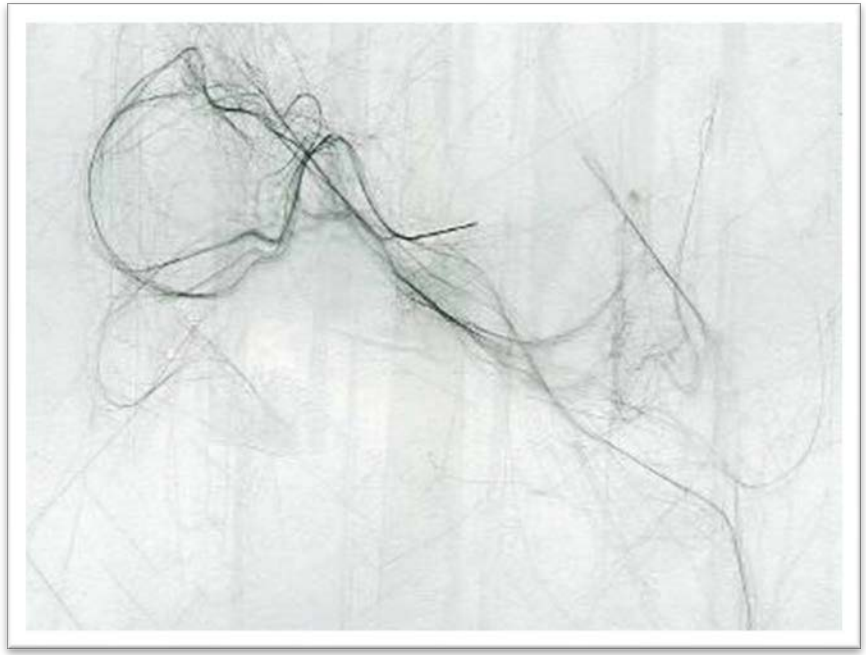
Composite Damage - Single Fibers

- **A fiber is small enough to become airborne**
- **Fire damage may contribute to free floating fibers**



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Composite Damage - Cluster

- Group of hundreds or thousands of unattached long fibers
- Have very little resin or char holding the fibers together
- May be dispersed around the mishap site
- Easily picked up by wind and blown around

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Composite Damage - Dust

- **Dust is generated from:**
  - **shattered or crushed resin fragments**
  - **crushed fiber fragments**
  - **resin char**
  - **fuel soot**

- **Dust is not fibrous**
  - **Found on or near damaged composites**
  - **Particulates may be a respiratory hazard**

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Composite Damage - Dust

- **Environmental conditions plays a role in dust concentrations**
  - **Crashes into swampland will present a lower composite dust risk than crashes into a hot, dry desert**
  - **High wind speed may carry dust and fibers away from the site and reduce the dust and fiber concentrations at the site**
  - **Precipitation will tend to mitigate exposure and associated risks**

- **Handling or cutting through burnt structure also generates dust**
  - **Fixant may be used to minimize this risk only after analysis of evidence is complete and approval has been given**

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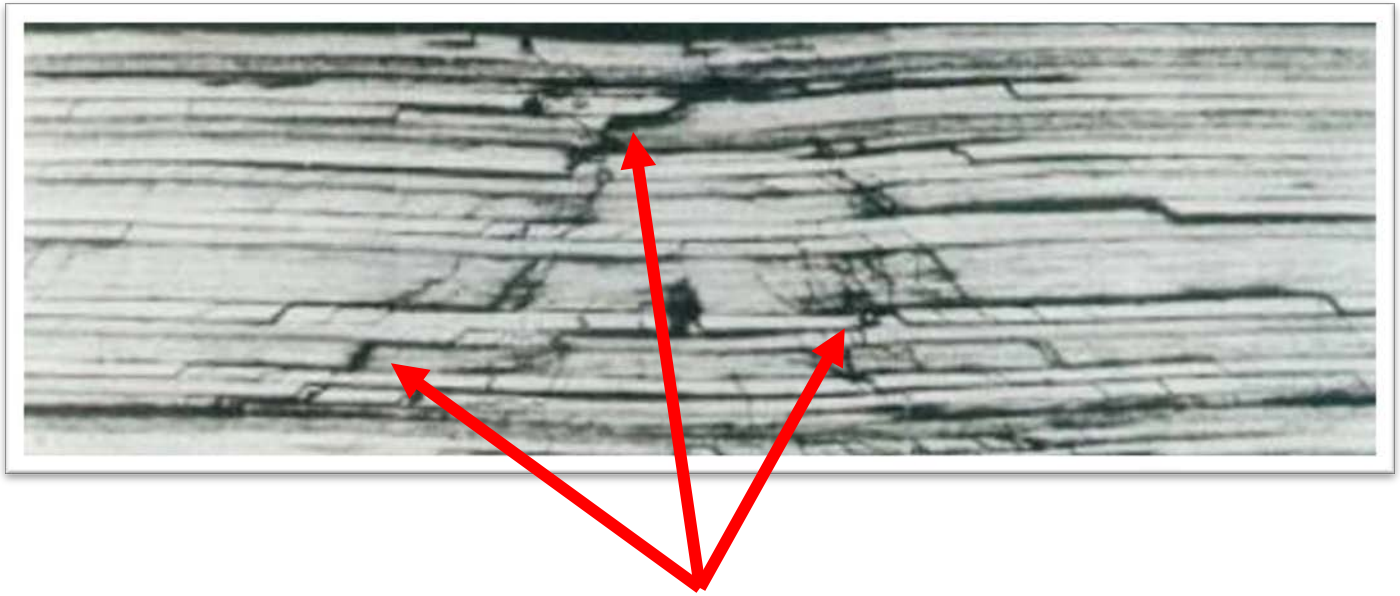
Structural Damage

Internal damage can be present without visible signs

- **Structure may appear to be intact until it is moved**
- **Severe structural damage can lead to collapse without visible warning**



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Physical Damage Summary

- Bulk fragments are inert to the touch
- Bulk fragments still behave like a homogenous solid piece
- Surface and internal layers contain dust
- Resin is still attached to the fiber
- Single fibers are not free to move around
- Particulate and dust size is similar to grinding seen in repair operations
- Puncture wounds from fiber bundles
- Composite dust is a sensitizing material
- Exposures occur right at the damage debris

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Composite Fire Damage - Overview

- Both materials (fiber and matrix) are damaged beyond design limits
- Matrix will combust and be a source of fuel
- Matrix may melt or char producing particulate (dust)
- Matrix volatize forming other chemical compounds
- Matrix smoldering is possible (burning without visible flame)
- Most resins will produce polynuclear aromatic hydocarbons (PNA) when burned (noxious fumes that smell bad)
- Some resins may produce an acidic plume
- Particulate is produced from fiber, fuel and resin

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Composite Fire Damage - Matrix

All resins are affected by fire (high temperatures)

- **Epoxies/BMIs are not very fire resistant**
- **The polymer chain starts to break down at about 450°F**
- **Degradation products are**
  - **Gases**
  - **Char material**
- **The gases produced are acutely toxic**
- **The gases produced at fire temperatures are different than the gases produced while grinding or sanding**
- **The char produced is only in small quantities compared to the amount of soot produced from JP8 fuel**

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Composite Fire Damage - Matrix

- **Burning plastics, resins, adhesives, coatings**
  - **Fuels the fire**
  - **Produces toxic smoke and soot**
  - **Produces heat and offensive odor**
  - **Produces char and smoldering debris**
- **Resin continues to combust after fire is out**

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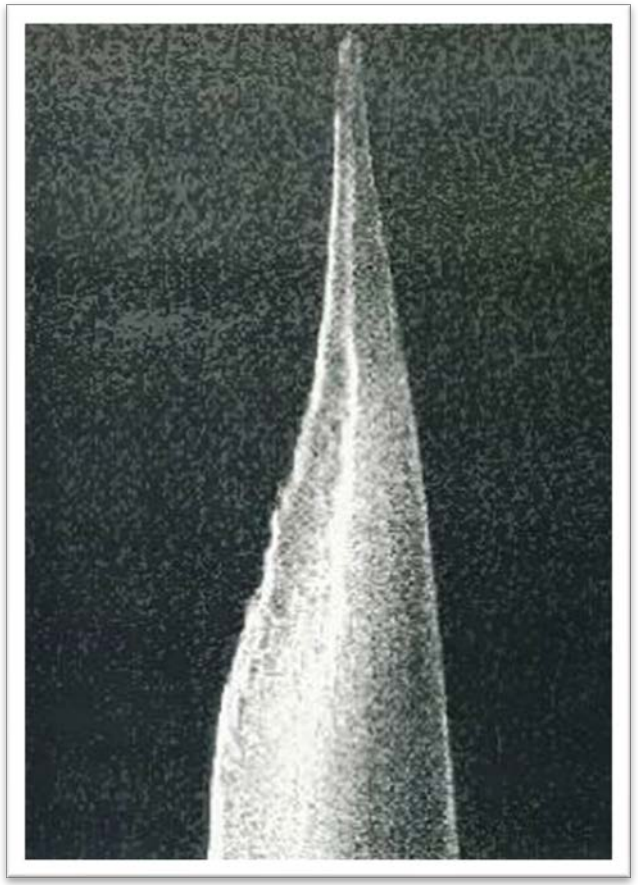
Composite Fire Damage - Fiber

- **All fiber types are affected by fire conditions (high temperatures, > 1000°F)**
  - **Some can melt**
  - **Some can be oxidized**
  - **Fiber dimensions change**
  - **Surface conditions change**
    - **Etched**
    - **Removed completely**



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Composite Fire Damage - Laminate

Heat penetrates composite thickness layer by layer

- **Varying degree of damage through the composite thickness**
- **Flame out on surface with internal layers still burning**
- **Can have loss of composite strength even if it didn't catch on fire**
- **Layers fall apart by slight hand movement and light pieces can be carried around the site by wind**

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Composite Fire Damage - Summary

- **Fire**
  - **Greatest quantity of soot is generated from the fuel**
  - **Burning resins create gases that are toxic**
  - **Burning/burned composites release fibers and dust**

- **Post Crash**
  - **Broken composites are usually a nuisance concern**
  - **Burnt composites are a significant health hazard, do not handle aggressively**

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Mishap Scenario - Overview

- **Initial Response**
- **Follow-on Response**
- **Interim Safety Board Response**
- **Secondary Response**

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Mishap Scenario - Initial Response

- **Firefighters**
  - **Full gear/SCBA**
- **Class B foam**
  - **Effective on burning composite material**
- **Flame suppression**
  - **Composite debris piles to be in a combustion state**
    - **The combustion state could be smoldering of the resin and core material or carbon fiber combustion**
- **Deep-seated smoldering of plastic/composite material**
  - **Post-fire does not begin until composite material is at ambient temperature**

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Mishap Scenario - Follow-on Response

- Cleared by incident commander
- Base bio-environmental engineering is safety authority
- All wreckage at ambient temperature
- Site specifics can affect procedure
- Cordon areas established
- Initial assessment of composite debris to determine PPE before work begins
- Avoid excessive disturbance of immediate fallout area around the composite debris

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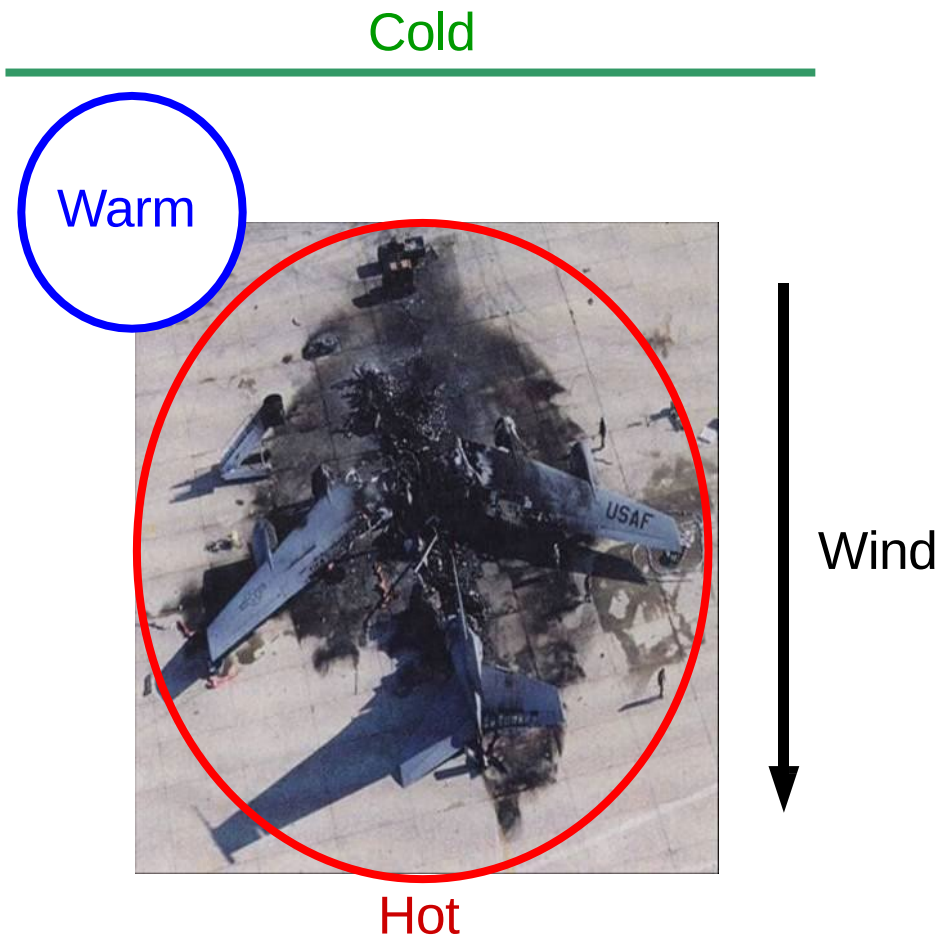
Mishap Scenario - Cordons

- **Three Cordons**
  - **<u>Hot</u> → composite debris area**
    - **Min 25 ft. distance**
  - **<u>Warm</u> → area upwind of wreckage for removing PPE and decon of equipment**
    - **Entry Control Point**
  - **<u>Cold</u> → clean area**
    - **Incident Command Post**



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Mishap Scenario - Interim Safety Board Response

- **Handling selected debris for investigative analysis**
  - **Do not spray investigative debris with fixant**
  - **Tag and label all debris at the crash site prior to transportation**
  - **Wrap in 0.006” thick plastic and tape**
  - **Cover plastic with canvas to pad sharp fibers when needed**
  - **Wreckage transported to a “safe-area”**
  - **Place in proper transport containers**
  - **Unwrap plastic at the “safe area” wearing gloves and a long sleeve garment**
    - **Burnt pieces will require protection from organic vapor**
    - **Beware: Plastic attracts loose carbon fibers**
  - **Beware: burnt debris will off-gas noxious odors**
    - **Consider if the “safe area” is a dual-purpose work environment for others**

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Mishap Scenario - Secondary Response

- **Determine PPE**
- **Fixant Spray Application**
- **Aircraft Recovery**
- **Cutting Mishap Composite Materials**
- **Mishap Debris Containment**
- **Site Cleanup**
- **Transporting Debris**

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PPE Guidelines

Mishap Condition	Protection
Physical damage	Minimum mishap response protection consisting of: nitrile gloves, hard sole boots, long pants and long sleeves, safety glasses. *plus* Leather gloves
Explosion or high energy impact	Minimum mishap response protection *plus* Leather gloves and Protective suit *plus* Respiratory protection against composite dust
Fire damage	Minimum mishap response protection *plus* Leather gloves and Protective suit *plus* Respiratory protection against nuisance vapor in close proximity to burnt debris, or in enclosed space
Structural and fire damage debris pile	Maximum mishap response protection includes Leather gloves and Protective suit Dual respiratory protection against nuisance vapor and particulate in close proximity to burnt debris, or in enclosed space

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PPE

Maximum Level

Minimum Level

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Donning PPE

- **Donning Overview**
  - **Insert foot through leg**
  - **Insert hand through arm hole**
  - **Put on protective rubber boots**
  - **Zip suit and duct tape zipper leaving a pull tab**
  - **Pull long-cuff plastic/nitrile glove over arm**
  - **Loosely tape top of glove to garment**
  - **Put on respirator**
  - **Pull hood over head and tighten (tape if needed)**
  - **Pull puncture resistant gloves over plastic/nitrile glove**

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Donning PPE

- **Insert legs into suit and put arms in sleeves**
- **Don’t zip up the suit yet (put on over-boots first)**

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Donning PPE

- **Pull on rubber over-boots and then zip up suit**

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Donning PPE

- **Put nitrile gloves on over sleeve cuffs then loosely tape to suit sleeves**

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Donning PPE

- **Donn approved respirator (full face respirator shown)**
  - **Ensure filter cartridge is good and installed correctly**
  - **Ensure tight fit and good seal**

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Donning PPE

- **Pull hood over head and align opening with face plate**
- **Secure hood to respirator with duct tape (top and bottom)**

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Donning PPE

- **Finally, pull on leather gloves over nitrile gloves**
  - **Leather gloves provide puncture protection**
  - **Nitrile gloves provide contamination protection**

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Alternate Respirator Type

- **PAPR System – Powered Air Purified Respirator**
  - **No annual respirator fit test required**
  - **Excellent for augmentees and specialists**
- **Battery powered air pack**
  - **Vest system**
  - **Belt system**
- **Hood**
  - **One size fits all**
  - **Workers must have eye protection underneath**

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Donning Alternate Respirator

- **PAPR in bag/vest and opened**

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Donning Alternate Respirator

- **Put on PAPR vest then connect hose to back of hood**

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Donning PPE

- **Final view of different PPE options**

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A few tips about Doffing PPE

- **Actual doffing/decon procedures may vary**
  - **BEE, Safety, or CCT may alter, augment, change, or direct different procedures based on site and/or mishap conditions**
- **Vaguely similar to MOPP decon line - but several notable differences**
  - **MOPP gear protects you from CBRN materials that are specifically designed to KILL YOU**
  - **Mishap debris can be toxic – It can injure you, but it is much less lethal**
- **Strongly recommend dedicated personnel assist in removing and cleaning PPE**
  - **Prevents self contamination**
  - **Gear is difficult to take off alone – you will be tired**

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Doffing PPE

- **Doffing – Roll back method**
  - **Pull leather gloves off**
  - **Remove protective boots**
  - **Remove tape securing hood to respirator**
  - **Roll hood back from face and turn inside out**
  - **Remove tape securing zipper and unzip suit**
  - **Lower suit by rolling back (inside out) past shoulders**
  - **Pull arm and plastic glove off turning inside out**
  - **Lower suit by rolling back**
  - **Raise a leg releasing rolled suit**
  - **Remove 2nd leg from suit**
  - **Remove respirator**

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Doffing PPE

- **Remove leather gloves**
  - **Depending on condition, may be done in hot zone and reused**
- **Remove over-boots**
  - **Likely to need help (and a place to sit) to do this**

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Doffing PPE

- **Pull off tape holding hood to respirator**
- **Then roll back hood**

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Doffing PPE

- **Unzip suit and roll back past shoulders**

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Doffing PPE

- **Remove suit from arms/hands (turn inside out)**
- **– May need to cut tape around wrist if it is on too tight**

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Doffing PPE

- **Remove suit from legs (roll back & turn inside out)**

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Doffing PPE

- **Final Step – Respirator Removal**
  - **Note individual wearing respirator does NOT handle respirator**
  - **Note that individual removing respirator is wearing gloves**
  - **There is no vapor threat in the warm zone; only surface dust and loose fiber contamination to control**

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Aircraft Recovery

- **Identify downwind direction especially when working around burnt carbon fiber composite debris**
- **Contain fire damaged composites with fixant and canvas/plastic before beginning aircraft recovery operations**
- **Aerial recovery of aircraft will disperse loose dust or debris.**

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Fixant Purpose

- **Stop composite surface dust and burnt fractured fiber**
- **ends from becoming airborne**
- **Surface application only**
- **Does not strengthen damaged composite**
- **Fixant is a temporary control measure**
  - **Weather, sunlight and other environmental elements will degrade fixant useful life (how long it holds stuff down)**
  - **Thicker applications (spraying debris multiple times) will last longer than thin applications**

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Temporary Fixant

- **Several commercial products available**
  - **18% solids minimum concentration acrylic wax recommended**
- **Dilute with water**
  - **2:1 water to fixant agent (i.e. acrylic floor wax) recommended**
    - **(e.g. 2 gal of water mixed with 1 gal wax product)**
  - **1:1 is the minimum water to fixant agent mixture**
    - **Use if the 2:1 mixture is too thin to adequately cover the debris**
    - **Higher concentration will be more difficult to spray (clogs easily)**

NOTE

The dilution level (mixture) may need to be changed due to weather or other site-specific conditions. If the sprayer is becoming clogged, add a little more water to make the fixant easier to spray. If spraying in extremely hot conditions and the fixant is evaporating in container, increase the amount of water slightly until problem is resolved. If spraying in extremely cold conditions and the fixant is freezing in container, decrease the amount of water slightly until the problem is resolved. Note that changing the amount of water in the fixant will alter the drying time; more water increases the drying time, less water shortens the drying time.

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Identification and Spray Teams

- **Two-man team (minimum)**
- **Use buddy system**
- **Multiple teams depending on conditions**
- **Use appropriate Personal Protective Equipment (PPE)**

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Fixant Spray Procedure

- **Completely wet fire damaged composites or debris containing lots of dust and loose fibers**
- **Avoid unnecessarily thick coatings (waste of fixant)**
- **Allow 30 minutes to dry (more time if needed)**
- **Additional coatings as necessary (e.g. before moving)**
- **For added protection, drape or wrap composite with plastic or canvas**
- **If spraying is not possible, cover debris with plastic or canvas**

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Fixant Spray Application

- **Spray all fire damaged composite debris unless specifically told not to do so; (e.g. investigative evidence)**
- **A slow sweeping action of the nozzle should be used.**
- **A continuous coating of fixant must be established over the entire surface and broken edges.**

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Follow Up Application

- **Additional spray applications may be necessary**
  - **Moving debris**
  - **Exposed honeycomb**
  - **Wicking areas**
  - **Weather conditions**
  - **After cutting debris**

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Cutting Mishap - Composite Materials

- **Do not bend or flex fibers over a small radius**
- **Do not run hands along the end of the laminate or fracture surfaces**
- **An abrasive cut-off wheel blade will work for most mishap-composites**
- **Dual-phase respiratory protection is required**
- **Cutting operations can create:**
  - **Resin dust and particulates**
  - **Single fibers and fiber bundles**
  - **Nuisance-level organic vapor**

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A Few Tips About Cutting

- **Only cut something if you have to**
  - **Cutting is a last resort for breaking down the wreckage**
  - **Could this component be repaired or reused?**
  - **Could we build a bigger container instead?**
  - **How will it be lifted and carried/transported afterwards?**

- **Plan out the cut before you start**
  - **Where will you cut? What's behind or underneath?**
  - **What am I cutting? Will the saw be able to cut it?**
  - **Is this going to damage critical investigative evidence?**
  - **Cut to the largest size practical (container size or weight limit)**

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Wrapping Procedures

- **Start by spraying part/debris with fresh layer of fixant**
- **Be sure to spray all sides**
  - **Especially areas not previous sprayed (e.g. stuck in ground, underside of debris on ground)**
- **Then lay plastic/canvas sheet over debris on ground**

OR

- **Pick up and place debris on top of sheet**
  - **Use two or more people to handle sheet and debris**

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Wrapping Procedures

- **Then carefully fold edges of sheet around all sides of debris**
  - **Want to contain entire debris element to prevent dust & loose fibers from escaping**
- **Use duct tape or similar to secure sheet around debris**
- **May use a marker to write identifying info on wrapped debris**
  - **ID damage type, where removed from site, what part or aircraft it came from, etc.**

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Mishap Debris Containment

- **All debris requires a sorting process and proper identification and containment**
  - **Large bulk pieces: wood box or crate with a cover**
  - **Small size pieces: five or ten- gallon plastic buckets with closeable lids**
  - **Plastic/canvas wrapping and sealed plastic pouches**
- **Must accurately identify and label debris in each container**
  - **HAZMAT, evidence, classified, aircraft component, etc.**

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Mishap Debris Containment

- **All composite debris shall be appropriately contained before transporting off site**
- **Physically damaged debris only (not burned), either composites or mixed composite/metallic debris:**
  - **Composite dust and fibers either removed (e.g. HEPA vacuumed) or contained (e.g. fixant applied, wrapped with plastic/canvas, sharp edges and points padded)**
- **Fire damaged or burned composites (in addition to above):**
  - **Small debris and medium/large components in sealed plastic pouches or bags**
  - **Buckets are sealed with lids**
  - **Large debris in a wood box/crate with a lid and caulk sealed seams**

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Transporting Debris

- **Factors to consider for transporting mishap debris**
  - **By truck/rail – Ensure all wreckage and containers are adequately secured to or within trailer or rail car**
  - **By ship – Sea-land containers are great for consolidating large quantities**
  - **By air – Consider pressure differences at ground and at altitude**
    - **Rule of thumb – Double size of sealed pouches to allow for expansion**

- **Customs and border inspections**
  - **Accurate labeling of containers is key**
  - **Ensure all needed documentation and permits are in order**
  - **Proper documentation prevents the need to open containers in order to verify contents**

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Transporting Debris

- **Considerations for burned composites debris**
  - **Considered HAZMAT or HAZ Waste**
  - **Ventilation impacts/requirements**
    - **Container must contain dust, fibers and noxious gases without leaking or cross contaminating other cargo or passengers**
    - **Especially challenging for air transport**
  - **Limit opening of containers**
    - **PPE is required when opened**
    - **Off gassing is the primary threat (noxious gases build up in containers)**
  - **Minimum of two barriers to contain dust/fibers and prevent escape**
    - **Example 1 - Debris in sealed pouch and placed in sealed box**
    - **Example 2 - Debris wrapped in plastic and then placed in sealed pouch**

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Closing Comments Disclaimer

- **<u>Recommended Guidelines</u>**
- **Site Specifics will affect response**
- **Base bio-environmental engineering is safety authority**
- **Incident commander is in charge of mishap site**

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Closing Comments - PPE Recommendation

- You can never have enough gloves
- Use powder-free gloves
- Wrong size garments and gloves will interfere
  - Tyvek Suits must fit over uniforms and/or cloth coveralls
  - Large enough to allow for stretching/reaching/squatting
- Leather gloves will only last a few days
- Heavier duty Tyvek suits last thru shift

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Sources of Information

- **Aerospace Emergency Rescue and Mishap Response Information:**
  - **TO 00-105E-9 Ch. 3**
- **USAF Advanced Composites Office**
  - **Training: CBT – Mishap Awareness**
  - **Safety, Health & Environment: Rapid Response Information & Briefings**
- **00-80C-1-WA-1 Crash Recovery Technical Order**

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Composites in Crash Recovery Operations

Questions?

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USAF
ADVANCED COMPOSITES
OFFICE

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AIR FORCE LIFE CYCLE MANAGEMENT CENTER