Description of document:	National Transportation Safety Board (NTSB) Aviation Investigation Manual Regional Investigations, 2008
Requested date:	2017
Release date:	06-August-2020
Posted date:	19-July-2021
Source of document:	National Transportation Safety Board Attention: FOIA Requester Service Center, CIO-40 490 L'Enfant Plaza, SW Washington, DC 20594-2000 Fax: (240) 752-6257 Freedom of Information Act (FOIA) Public Access Link Email: foia@ntsb.gov

National Transportation Safety Board
Washington, D.C. 20594

August 6, 2020

Re: National Transportation Safety Board (NTSB)
Freedom of Information Act (FOIA) No. FOIA-2017-00143

This letter responds to your FOIA request seeking a digital/electronic copy of the NTSB Regional Investigator's Manual, which may be alternatively called the NTSB Regional Investigation Manual.

The Safety Board located 143 pages of responsive documents. The 143 pages are released in full and enclosed.

The NTSB has concluded processing your FOIA. You may contact Ms. Joy Gordon, the analyst who processed your request, or our FOIA Public Liaison at 202-314-6540, for any further assistance and to discuss any aspect of your request. Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration (NARA) to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows: OGIS, NARA, 8601 Adelphi Road-OGIS, College Park, Maryland 20740-6001, e-mail at ogis@nara.gov; telephone at 202-741-5770; toll free at 1-877-684-6448; or facsimile at 202-741-5769.

If you are not satisfied with the response to this request, you may administratively appeal by writing to the NTSB, Attn: Ms. Sharon Bryson, Managing Director, 490 L'Enfant Plaza, SW, Washington, D.C. 20594. Your appeal must be postmarked or electronically transmitted within 90 days of the date of the response to your request.

Sincerely,

Melba D. Moye

Melba D. Moye
FOIA Officer

Enclosure

NATIONAL TRANSPORTATION SAFETY BOARD

AVIATION INVESTIGATION MANUAL

REGIONAL INVESTIGATIONS

RECORD OF REVISIONS

This manual and its appendixes have been revised significantly, and any previous versions of these documents should be replaced in their entirety. Future revisions will be logged using the table below.

REVISION NUMBER	DATE OF REVISION	AFFECTED PAGES	REMARKS/PURPOSE

FOREWORD

The *Regional Investigations Manual* is an NTSB staff product and is intended to provide information and guidance to NTSB employees who are involved in organizing and conducting regional investigations. The manual provides general information to assist regional air safety investigators/investigators-in-charge, and others who may participate in a regional aviation accident investigation. It is intended to provide guidance on the process of conducting regional investigations, but does not replace or supersede the most current internal NTSB policies and directives.

The Deputy Director for Regional Operations (AS-2R) will be responsible for keeping this volume updated. Use the "Record of Revisions" on the preceding page to acknowledge receipt of revisions to this document. The effective date of any page change will be indicated by the entry on the revision sheet. Recipients of this manual are encouraged to submit proposed amendments to AS-2R.

This manual has not been adopted by the Board Members, is not regulatory, is not a binding statement of policy, and is not all-inclusive. Recommended procedures in this manual are not intended to become obligations of the NTSB or to create any rights of any parties to an NTSB investigation. Deviation from the guidance offered in this manual will, at times, be necessary to meet the specific needs of an investigation. However, such deviations from the guidance offered in this manual will be at the sole discretion of the appropriate NTSB employees and will not be the prerogative of parties to the investigation or other individuals not employed by the NTSB.

CONTENTS

Abbreviations

AD	airworthiness directive
ADMS (eADMS)	(electronic) accident data management system
AFSS	automated flight service stations
ARTS	automated radar tracking system
AS	Office of Aviation Safety
ASI	air safety investigator
ATC	air traffic control
CDR	continuous data recording
CFIT	controlled-flight-into-terrain
CFR	*Code of Federal Regulations*
CVR	cockpit voice recorder
DoD	Department of Defense
EPR	engine-pressure-ratio indicator
FAA	Federal Aviation Administration
FAR	federal aviation regulation
FBI	Federal Bureau of Investigation
FBO	fixed-base operator
FDR	flight data recorder
FSDO	flight standards district office
GPS	global positioning system
ICAO	International Civil Aviation Organization
IIC	investigator-in-charge
NAVAID	navigational aid
NTAP	national track analysis program
NTSB	National Transportation Safety Board
OpSpec	operations specification
PAI	principal avionics inspector
PMI	principal maintenance inspector
POC	point of contact
POI	principal operations inspector
RC	regional office chief
RE	Office of Research and Engineering
SAR	System Analysis Recording
SB	service bulletin
SDR/MDR	service difficulty report/malfunction defect report
SL	service letter
SOP	standard operating procedure
TRACON	Terminal Radar Approach Control
TSO	technical standard order
ULB	underwater locator beacon

1 Pre-Investigation Preparation

1.1 Overview

The procedures in this manual apply to the investigations performed by the Office of Aviation Safety's (AS) regional investigators. Unlike the air safety investigators (ASIs) who are assigned as investigators-in-charge (IICs) for major investigation teams from headquarters, the ASI/IIC for regional investigations may be responsible for all aspects of the investigation without being able to divide the work among a number of different groups. The regional IIC is also responsible for all administrative details associated with investigations.

1.2 Pre-Investigation Preparedness

Each region[1] will maintain a communications capability that ensures timely notifications of all aviation accidents and significant aviation incidents within the region's geographic area of responsibility. Regional chiefs (RCs) will ensure that efficient "on-call" systems are in place for regional investigators to assess and/or respond to accident/incident notifications in a timely manner. On-call systems may vary as deemed appropriate for the different geographic areas of responsibility. Whatever system is implemented, consistent with operational requirements, the minimum number of primary and backup investigators to handle the anticipated notifications should be on an immediate on-call status. The on-call investigators are required to be available by telephone or other electronic means during non-duty hours. It is highly desirable that on-call investigators be capable of responding back to a notification contact within 15 minutes.

All on-call investigators will maintain a readily available "go-bag" that has the proper tools and clothing in the event that the investigator must travel to the scene of an accident. The go-bag should include sufficient equipment to document the scene of a general aviation accident.[2] The diversity of aircraft accidents makes it difficult to have all the necessary equipment available beforehand. Items commonly used in every investigation should be readily available. Accidents in remote areas require special consideration for shelter, food, and water. Remember, the investigator's go-bag may have to be hand carried to a remote site of an accident. Do not overload it with unnecessary or duplicate items.

Investigators will have available the most current list[3] of the telephone numbers and contact details of key NTSB management personnel. Investigators will also maintain current contact information for industry flight safety departments and personnel that may be invited as parties to assist in an investigation.

[1] The NTSB has 4 "regions" that are organized and staffed to investigate accidents and incidents throughout the United States: Western Pacific Region; Central Region; Eastern Region; Alaska Region.
[2] See Appendix 1 for a detailed listing of the tools and equipment that should be available as part of a "go-bag."
[3] The NTSB Communications Center in Washington, DC, publishes a weekly HQ go-team roster that has contact details for NTSB management, on-call Board Members, and on-call investigative staff.

2 Notification, Classification, and Initial Response

Headquarters AS management and the public affairs officer must be notified of any nationally significant accident, an accident of special interest to a Board Member, an event likely to garner high or intense media interest, or any event involving issues that have been deemed of high priority by AS management.

Notifications to the Chairman and/or the on-call Board Member regarding an accident of significance is the responsibility of AS headquarters management. In these circumstances, it is essential that RCs contact headquarters management through the NTSB communications center in the following order: AS-2R (or Assistant AS-2R), AS-2, AS-1.

Early notification is essential to initiate and organize the investigation. Initial information concerning the facts and circumstances of the occurrence will often be incomplete and erroneous. Therefore, early factual information transmitted for alerting purposes must be handled with considerable caution and discretion. Parties notified are to be cautioned about the preliminary nature of the data.

The response to any accident will depend on a variety of factors, including the type of aircraft, damage to the aircraft and other property, injuries, type of operation, FAA involvement, oversight responsibilities, visibility, safety issues, public interest, location of occurrence, and the background of the pilot. Based on review of these and any other factors, the RC, deputy RC, or supervisor (in consultation with the regional IIC) will decide to how to ***classify*** the investigation. Occurrences meeting the NTSB's public confidence/oversight and special emphasis areas will be given priority as full field investigations.

Regional investigations can be ***classified*** in the following general categories:

a. **Major (Regional):** Accidents that may involve new or sophisticated aircraft, multiple fatalities, high public visibility, accidents involving extensive air traffic control (ATC) issues, or significant safety issues. Typically a major regional investigation will involve the launch of a senior ASI as the IIC and at least one other NTSB employee.

b. **Field:** Accidents where an on-scene investigation is initiated and controlled by an NTSB ASI. Normally, the wreckage is secured until the NTSB investigator arrives at the accident site. Typically, a field investigation involves a fatality or a significant amount of follow-up investigation and non-on-scene travel. The aircraft is usually certified in the normal category.

c. **Limited:** Accidents involving no on-scene ASI presence. A Federal Aviation Administration (FAA) inspector typically conducts the on-scene fact gathering. If these investigations involve extensive work, they may be upgraded to field status to account for the additional workload.

d. **Incident:** Occurrences that do not meet the definition of an accident but can be investigated as an incident. This category may include an occurrence that did not cause substantial damage or have serious injuries but involved a potential safety issue. All investigations of incidents will have a probable cause.

e. **C-Form Accidents**: Accidents that meet the following criteria:

- No or minor injuries, or "non-critical" serious injuries involving simple fractures, that do not involve long-term hospitalization or permanent disability.
- Known circumstances.
- No obvious safety issues.
- No significant public visibility.
- Information can be obtained from the pilot that explains what happened and does not contradict an evaluation of the circumstances.

Do not use C-Forms for accidents that involve any of the following:

- Part 121 operations, except those involving a simple injury (fracture) resulting from turbulence encounters, ground collisions with vehicles and objects, and other accidents deemed to have no safety issues or industry visibility.
- Fatalities or "critical" serious injuries (i.e., long-term hospitalization or permanent disability).
- More than one aircraft is involved.
- High public visibility.

f. **Public Use Aircraft:** Public aircraft, as defined in the Federal Aviation Act of 1958, "means an aircraft used exclusively in the service of any government or of any political subdivision thereof including the government of any State, Territory or possession of the United States, or the District of Columbia, but not including any government-owned aircraft engaged in carrying persons or property for commercial purposes." When a public aircraft accident occurs, the NTSB's normal investigation and report procedures will be utilized, which includes making everything in the public side of the docket available to the general public and the determination of probable cause.[4] Additional information on Public Use Aircraft accidents can be found in Section 6.2.

All high-visibility accidents should have an NTSB investigator on scene in a timely manner. This does not normally allow the IIC to delay traveling or "launch" to the scene of the accident.

Although injuries are an important factor in deciding to launch on an accident, they are not the sole criteria. Depending on resources available, it may be advisable to launch on a non-

[4] When an agency has specific needs to withhold information from public disclosure (such as classified equipment or operations) and the release of this information could have a detrimental impact on that agency's mission, alternate reporting procedures may be acceptable, subject to the approval of the RC in consultation with headquarters staff.

fatal accident involving a safety issue while allowing the FAA to conduct the field portion of a straightforward fatal accident that has no safety issues. Likewise, it may be reasonable to launch on serious injury accidents involving critical injuries as fields while doing some straightforward serious injury accidents (involving a broken foot, for example) as a limited investigation. The objective is to provide the largest safety improvements possible within current staffing and funding limitations.

Regional management should assess all accident notifications in a timely manner so that a decision can be made about the appropriate response. Once the decision is made, the IIC will inform the FAA and local authorities about planned NTSB actions. Even on limited investigations, it is important to let all interested parties know that the NTSB will not be coming on scene or taking custody of the wreckage The operator should understand that the wreckage is released, and must remain in whatever conditions the NTSB investigator attaches to that release. For example, the wreckage can be released under the condition that the engine not be disturbed until an NTSB investigator or FAA representative has examined it.

On high-visibility accidents that require status reports, the IIC will send an initial notification memorandum to AS management as soon as possible following notification of the accident. If warranted, the IIC will send additional status report memorandums to AS management when new information becomes available.

Regional management will ensure that the FAA is informed of all aviation accident notifications that do not come through FAA sources. By statutory authority, the NTSB will always provide the FAA the opportunity to participate in the investigation. The investigation will not be delayed unnecessarily while waiting for the designation of an FAA coordinator (FAA IIC) or the coordinator's arrival at the scene. If necessary, inform the FAA of your plans and proceed with the investigation. Even when the FAA does not participate in the on-scene investigation, send a copy of the preliminary and final reports to the FAA flight standards district office (FSDO) with geographic jurisdiction.

2.1 Regional Responsibilities and Procedures

2.1.1 Notification to Headquarters of Accidents/Incidents

During duty or non-duty hours, regional offices will notify headquarters (AS-2R, AS-2, or AS-1) via the communications center whenever an accident (or incident with serious implications) occurs that involves the following:

- Air carrier, commuter, or air taxi operations.
- Public figures or officials with widespread recognition or prominence.
- Fatal midair collisions or collisions involving ATC.
- Matters of potentially high public interest.

A page should be sent through the NTSB communications center for any of the following events:

- Any aviation event that involves two or more fatalities.
- Any accident (fatal or non-fatal) that involves a Part 121 or scheduled Part 135 air carrier.
- Any accident, incident, or aviation event that would involve national media attention (in the judgment of the regional chief).
- Any accident or incident that involves a celebrity or renowned person on board.
- Any accident that results in serious injury involving air tour, air ambulance, or firefighting aircraft.
- Any aviation event in which an NTSB investigator is dispatched.

For those fatal accidents or significant serious injury accidents or incidents that do not meet the six criteria listed above, investigators are encouraged to contact the Communications Center with the accident/incident information for an entry in the daily shift log.

2.1.2 Regional Responsibilities for a Headquarters Go-Team Launch

When a decision is made to investigate an accident as a headquarters-led major investigation[5], the RC with geographic jurisdiction for the accident will typically designate at least one regional investigator to travel immediately to the site and perform initial coordination, ***stake-down*** duties, and brief the incoming IIC from Washington DC. The regional investigator may be assigned to provide additional support as necessary, or be released from the investigation. All NTSB regional personnel who travel to a major investigation site will be considered part of the investigation team until the IIC releases them from their duties.

Regional personnel assigned to ***stake-down*** a major accident have important duties that contribute to the overall success of the investigation. Those personnel include investigators dispatched to the scene as well as those handling administrative duties. Personnel assigned to respond to the accident scene are obligated to reach the scene as quickly and as safely as possible and to remain at the scene until properly relieved. NTSB representation, at this time, is essential to convey to the news media, local authorities, and the public that the investigation is under NTSB jurisdiction. However, the only information that should be released to the media is that the go-team is en route; names of the responding Board Member, the headquarters IIC, the media contact; and when the team is expected to arrive. Initial activities should be aimed at gathering as much pertinent information as possible to brief the headquarters IIC, and go-team upon their arrival.

Remoteness of the accident site or difficult accessibility does not diminish the need to establish NTSB jurisdiction. Every reasonable and ***safe*** effort should be made to get to the site,[6] even if environmental conditions preclude remaining at the site for any appreciable length of time.

On occasion, regional investigators may provide initial liaison with local media in accordance with NTSB policy and good judgment.

---

[5] The NTSB Major Investigations Manual contains detailed information on the conduct of major investigations.

[6] In most cases, the most effective and safest area for the investigator charged with ***stake-down*** responsibilities may be the command post that is established by local disaster response authorities.

Example: *"NTSB investigators from the regional office have arrived on the scene and have assumed control of the investigation. A go-team is en route from Washington DC, accompanied by Member ______, and is expected to arrive here at 0:00. Pending their arrival, we have closed off the site to preserve evidence. No press access will be granted until the go-team is here and the NTSB's public affairs staff member who is traveling with the go-team can work out arrangements. In the meantime, direct any questions about procedures to the NTSB Public Affairs Office in Washington DC at (202) 314-6100."*

Do not promise when or where the first press briefing will be or when or where press access to the site will be granted. Under NTSB policy, only the Board Member, public affairs representative, or IIC can speak to the media beyond what has been suggested above.

When a Board Member is present at the scene of an accident, he/she is the official spokesperson for the NTSB. When a Board Member is not present or leaves the scene, the representative from the Office of Public Affairs and the IIC will serve as the spokespersons.

2.2 Preparations Before Departing to the Accident Scene

After being notified of an accident and its approximate location, the IIC should notify his or her supervisor[7] with the preliminary information. The IIC should not launch until the following actions have been completed.

a. Get the exact location of the accident site: city, town, county, lot and block number, street address, and geographic coordinates. The location of the accident will dictate the mode of transportation and arrangements required.

b. Check the location of the accident with a current map.

   (1) Take the map with you.

   (2) If you do not have access to a map, the FAA coordinator, or local official, may be able to obtain a map in sufficient detail to find the location and all features that may have played a factor in the accident. Ideally, a 1:63,620-scale map of remote sights and city maps depicting street names is useful. Useful maps are also available on-line.

c. Make arrangements for travel to the accident site by any of the following means:

   (1) Jump seat authorization (NTSB Form 7000-5).

      (a) Ensure you have sufficient jump seat forms to complete your travel to and from the accident site.

      (b) Operations Bulletin AS-INT-005 specifies procedures to be used when riding in a jump seat.

[7] RCs may have specific procedural guidance for IICs prior to traveling to an accident scene.

(2) Commercial Air. Use only the approved agent for all official use ticket purchases. Only coach class is authorized.

(3) Government car. Do not use a government car if traveling to Canada or Mexico. There is no insurance coverage outside of the United States.

(4) Rental car. Rent a compact unless unavailable or circumstances justify otherwise. Purchase additional insurance if traveling outside the United States.

(5) Privately owned vehicle.

d. Contact the FAA Coordinator. During your initial conversation with the FAA coordinator, you should be able to determine the coordinator's experience level. You may have to give the FAA coordinator specific instructions and guidance. The FAA coordinator becomes doubly important if he or she is very familiar with the area of the accident. A telephone call to the FAA coordinator may solve many logistical problems. However, even when you have the FAA coordinator make local arrangements for you, a call to the local authorities is prudent.

(1) Confirm the site location.

(2) Confirm access to local and appropriate forms of transportation and any special clothing/equipment/survival gear considerations for the site.

(3) Survival Requirements and Precautions in Remote Locations. Carry enough survival equipment that is compatible with the location and climate of the accident site to ensure your safety. Be aware of any local or state regulations requiring survival equipment.

e. Contact Local Authorities. Local law enforcement/rescue officials may never have seen an aircraft accident, and they may not be familiar with the NTSB or be aware of the NTSB's jurisdiction over the accident investigation. Your job is to promote the NTSB; you are the NTSB's direct representative. If the local agency is not familiar with the NTSB, educate the agency directly, politely, and in a business-like manner.

(1) Local authorities may include local police, sheriff's deputies, state troopers, the military, or other appropriate agencies.

(2) Identify yourself, and explain your mission.

(3) Explain the function of the FAA coordinator and what the coordinator is allowed to do before your arrival.

(4) Politely make officials aware that site security and site safety is imperative. Be sure they understand that no unauthorized individuals should be allowed into the accident scene.

(5) Emphasize that some general aviation and commercial aircraft have explosives and ballistic parachute rockets on board, which makes it imperative that the local authority does not disturb the wreckage until the status of any pyrotechnic ordinance is confirmed. (Refer to Section 3.10.2 for additional information).

(6) Emphasize that air-bag seat belts are becoming more common in all airplanes and that the first responders need to be aware of the seat belts and that they have a triggering explosive installed.

(7) Emphasize that some composite materials, especially those used in general aviation airplanes, may produce toxic fumes when burned.

(8) Determine whether wreckage may be moved before your arrival. Be sure to alert the officials that they may do anything necessary to rescue survivors. However, when human remains must be removed before the investigator's arrival, instruct them to document the wreckage with photographs before any disturbance. If you are in doubt about movement of the wreckage, contact your supervisor.

(9) If there were witnesses, ensure that the officials record at least their names, addresses, and phone numbers. Witnesses may be transient and, depending on your arrival time, may not remain at the accident site. Witnesses may be the only clue about what occurred. If the authorities are in a position to take a basic statement, have them do so because it may have a bearing on the direction of your investigation.

(10) Arrange for transportation to the accident site.

(11) Once you have local transportation to a remote accident site secured, you may want to keep the transportation means available and at your disposal for the entire time you are on-scene for the accident team's safety and emergency use.

(12) Be sure that, when arranging for services, you agree upon a price before hiring those services. These prices should be representative of the local area. The IIC is authorized to spend up to \$2,500 per item maximum for the direct expenses of an accident.[8] Although the Office of the Chief Financial Officer directives and operations bulletins specify a \$2,500 per item limit, make sure you understand any limitations or consultation requirements that your supervisory chain may impose. Any item or service over \$2,500 requires specific management approval before committing the funds. ***Do not require the party members to share investigation expenses.***

(13) Determine if special equipment may be needed and its availability.

[8] See Operations Bulletin ACQ-GEN-005.

(14) Determine the disposition of bodies and request autopsies with split samples, if necessary. You may have to carry your own toxicology kit.

(15) Ensure that you have the information needed to notify headquarters about the accident, and follow your office procedures for providing this information to the NTSB Communication Center.

f. Contact your supervisor or designated supervisor/backup and provide the following:

(1) Known circumstances of the accident

(2) Your preliminary risk assessment

(3) Your travel arrangements

(4) Assistance needed from headquarters, if any

(5) Direction of the investigation

(6) Discussion about whether headquarters should be notified

(7) Point of contact at or near the accident scene

g. Coordinate with the appropriate AS division if issues arise in that division's area of expertise. If, for example, you have a midair collision on a federal airway with known ATC involvement, make sure that AS-30 receives information, along with any request for air traffic assistance.

h. Be sure to have the following forms available, as applicable, to the investigation:

(1) Parties to the investigation forms

(2) Witness statements

(3) Pre-addressed envelopes/labels

(4) NTSB Form 6120.1

(5) Passenger statements

(6) Wreckage release forms

i. Contact or arrange to have someone contact the airframe and engine manufacturers as soon as possible to convey the available information regarding the event. Also, notify other manufacturers of significant components if the available preliminary information indicates their product may have played a role in the event. It is important that all regional offices have an up-to-date notification list of all common industry manufacturers.

j. If the airframe or engine is of foreign manufacture, the aircraft is of foreign registry, or the operator is based in a foreign country, make sure that the appropriate foreign government has been notified, in accordance with the provisions of International Civil Aviation Organization (ICAO) Annex 13, as soon as possible.[9] The recognized states that have rights to participate and that may require notification are: State of Design, State of Manufacture, State of Registry, State of the Operator, and the State with predominate citizens on board. If the aircraft is multi-engine and over 2,250 kg (~4,950 pounds) gross weight, a separate notification must be made to ICAO.

2.2.1 Accident Scene Security

An initial duty of the IIC, following the notification of an accident, is to ensure that the accident site and wreckage are properly secured in accordance with 49 *Code of Federal Regulations* (CFR) 830.10. The twofold purpose of obtaining early scene security is to preserve evidence and to prevent injury to inexperienced personnel. As noted, initial arrangements for security should be made upon notification of the accident and before the investigator's arrival. Give those securing the wreckage clear and explicit instructions about who is allowed access to the accident site. Typically, local or state law enforcement agencies will provide, at least, the initial site security until the investigator arrives. At rare times, the location of the wreckage or the situation surrounding the site will require consideration for the immediate movement or removal of the wreckage. The IIC is responsible for coordinating the removal of wreckage with local authorities in a manner that will preserve evidence to the maximum extent.

Upon arrival at the scene, the IIC should contact the local authority responsible for the personnel providing security for the wreckage. The police, coroner, etc., should reach an understanding about the division of duties, and the responsible local authorities should be identified. In most cases, local/state police, local sheriff's office personnel, or the Civil Air Patrol members will secure the wreckage. Assistance may also be obtained from military units near the accident site or from local disaster and civil defense units. Occasionally the need will arise to employ civilian guards. In this event, the hourly wages to be paid must be agreed upon before services are rendered. For all cases in which payment for guard services is authorized ahead of time, the administrative details for payment should be arranged when arriving on scene. Payment for security personnel can be billed to the employee's office or paid directly with a purchase card. An invoice showing cost per hour and number of hours worked must be obtained in either case.

The NTSB is responsible for providing/arranging security for the wreckage until the on-scene investigation is complete. Once the on-scene phase of the investigation is complete, wreckage security becomes the responsibility of the owner, operator, or insurer. Before departing the site, the IIC should make every attempt to contact local authorities to inform them of the wreckage location and that the NTSB, having completed its investigation, is no longer responsible for the wreckage.

---

[9] It is recommended that someone other than the IIC, such as the RC or the duty officer, perform this task, so that the notification is not delayed.

2.2.2 Wreckage Documentation if IICs do not Travel to the Accident Scene

Ideally, the wreckage should be documented at the accident site. However, regional investigators cannot launch to all of the general aviation aircraft accidents that occur in the United States each year. Therefore, the NTSB relies heavily on the FAA's cadre of aviation safety inspectors located throughout the country for the on-scene documentation of many aircraft accidents.

When the NTSB does not travel to the accident site, the following guidance will help IICs direct the efforts of the FAA, manufacturers, other government agencies, local law enforcement, and salvage operators to ensure that aircraft wreckage is adequately documented at the accident site and during follow-up examinations after the wreckage has been removed. Preservation of perishable evidence is a priority and is critical to the proper conduct of an investigation.

Except under rare occasions in which wreckage must be removed immediately for safety/security reasons, the IIC should ensure that a comprehensive wreckage examination suitable for the accident circumstances is performed before authorizing the removal of wreckage from the accident site. The IIC should accommodate, within reason, requests from the FAA and manufacturers to participate in the on-scene documentation of aircraft wreckage when the NTSB does not launch. Airframe, engine, and component manufacturers typically prefer documenting the wreckage at the accident site to ensure that their responsibilities are met. This is especially true for fatal accidents, serious accidents, and special interest accidents such as a new product line, new avionics, airbags, etc.

The IIC should ensure that the FAA representative on site is familiar with the party system, the role and responsibilities of the parties, and how the parties relate to the IIC and the FAA inspector who is conducting the on-site examination. The IIC should make reasonable attempts to have the wreckage documented as thoroughly as possible on scene, and with all resources available, to prevent potential loss of information and to avoid additional examinations at a later date that would involve repetitive travel by the FAA and parties.

If the power plant has not been clearly eliminated as a potential cause or factor in the accident, the IIC should not authorize disassembly of the engine or any associated components in the field if there is a possibility of doing a functional test or engine run with the intact components. Disassembling a component makes later testing much less valuable because critical settings or conditions may be lost or altered.

Should a separate wreckage, engine, or component examination be required to ensure that potential safety issues and causal factors are determined, the examination should be conducted at the earliest practical time after the accident, and no more than 30 days after the initial on-scene examination, and the following guidelines should be followed:

a. The IIC will determine as soon as possible if the wreckage examination will be done on site or at an off-site facility. The IIC should then immediately communicate the determination to the FAA, the party participants, and the manufacturers. This will assist the NTSB, FAA, and all other involved parties in managing resources while enabling manufacturers to make an informed decision about traveling to the scene.

b. The IIC should evaluate the competency, resources, and experience of salvage operators and provide appropriate guidance about the proper documentation and preservation of the wreckage.

c. When multiple aircraft are scheduled for examination, the parties and FAA should allot, within reason, adequate time for a thorough examination. The examination of more than two aircraft in one day needs to be scheduled and managed carefully by the IIC. Avoid the "assembly line" mentality of wreckage examinations.

d. If a wreckage exam is required, the IIC should ensure that the wreckage is made accessible for the exam to avoid wasted time in removing wreckage from a trailer or box after the beginning of the allotted exam time.

e. Before the start of the wreckage exam, the IIC and/or FAA should ensure that all paperwork (log books, etc.) has been collected and made available to the parties.

f. In the event that the wreckage must be removed/recovered before an adequate examination by the NTSB, FAA, or the parties, the IIC should ensure that the salvage operator and FAA are provided with a list of guidelines and best practices for initial documentations, as per Appendix 10, and that all documentation is provided to the parties to the investigation.

g. The IIC should prohibit any attempt to power up and download non-volatile memory from aircraft with advanced (digital) avionics because this could result in loss of information. Digital avionics that could lose information when powered up include, but are not limited to, the enhanced ground proximity warning system/ ground proximity warning system, the flight management system, the flight data recorder (FDR), the cockpit voice recorder (CVR), full authority digital engine control, the vehicle and engine monitoring display, the multifunction display/cathode ray tube, and engine trend monitors. After proper inspection and documentation, the non-volatile memory components should be carefully removed utilizing recommended guidelines and procedures, where available. If there is any question about how to remove, package, or ship components with non-volatile memory, the devices manufacturer should be contacted.

2.2.3 Autopsies, Toxicological Testing, and Other Medical Information

Autopsies must be requested on the pilot, co-pilot, and/or any passenger who may have had access to the flight controls. In survivable accidents, autopsies should also be requested on fatally injured passengers.[10] Many states will automatically perform autopsies in accidental death cases. However, the IIC is responsible for ensuring that an autopsy is performed when appropriate. This should be accomplished through coordination with the FAA, local law

[10] Contact the Survival Factor Division (AS-60) for additional consultation regarding passenger injuries.

enforcement authorities, and/or the medical examiner/coroner's office. Jurisdictional issues and conflicting investigative priorities may occasionally result in disagreements between the investigator and the medical examiner or coroner. It is important that the investigator recognizes and respects the local authority of these individuals in order to most effectively coordinate appropriate post-mortem examinations. Because many local authorities will have limited experience with aviation-related autopsies, it may be useful to contact the NTSB's medical officer for additional guidance before the autopsy is conducted. The FAA will pay reasonable costs for autopsies on flight crewmembers when those autopsies would not otherwise be performed by the local medical examiner/coroner. Before ordering an autopsy in this situation, make sure you understand the costs that will be billed by the medical examiner/coroner for the procedure and that those costs are within the amount that the FAA will pay for the service. In this situation, the NTSB may be asked to pay for any excess charges above what the FAA will contribute.

The IIC is responsible for obtaining a copy of the autopsy report. Procedures for obtaining the reports vary among states. Some medical examiner/coroners' offices will mail the reports with just a telephone request, and others will require a more formal written request. If any cost is involved in obtaining the report, the fee can be paid by the investigator with a purchase card or can be invoiced to the investigator's office for later payment by purchase card.

The NTSB's medical officer can be helpful in interpreting autopsy protocols, especially in cases where incapacitation or impairment may be suspected. If medical certification questions arise, the medical officer may suggest a subpoena of personal medical records for pertinent conditions or current treatment regimes. In cases where very early evidence (erratic flight track, strange speech patterns, or unusual preflight behavior, among other possible indicators) suggests potential impairment or incapacitation, the medical officer ideally should be contacted early enough in the investigation to consult with the pathologist performing the autopsy about desirable pathology protocols to follow. The NTSB's medical officer should be consulted for interpretations and explanations of positive toxicological results.

Toxicological tests should be performed on suitable specimens from all crewmembers and on other individuals of interest (passengers, ATC personnel, airport personnel, mechanics, dispatchers, etc.) when appropriate. Detailed guidance on the appropriate collection and transportation of specimens can be found in Operations Bulletin RE-GEN-001 (Procedures for Securing Samples for Toxicological Testing).

A situation may arise where a crewmember/passenger/ground fatality is from a religion that does not believe in autopsies or that specifies expeditious burial practices, which may be in direct conflict with the needs of the investigation. The IIC should exercise diplomacy in a sensitive situation such as this and strive to achieve a reasonable balance between the religious beliefs of the families and the needs of the investigation. Although Section 1134 of the Independent Safety Board Act states that the NTSB "may order an autopsy to be performed and have other tests made when necessary to investigate an accident," the act's provisions also note that "local law protecting religious beliefs related to autopsies shall be observed to the extent consistent with the needs of the accident investigation." The most prudent course of action may be to get the Office of Transportation Disaster Assistance involved to assist the IIC in brokering an outcome acceptable to everyone.

2.3 Local Authority Relations

The NTSB is required to perform a complex and demanding mission critical to public safety. Much of the NTSB's mission is accomplished through the contributions of outside local and state agencies and, to some extent, other entities through the party system. Over the years, these local and state entities have helped with everything from four-wheel drive trucks to wilderness guides. They have provided extra manpower for security and helicopter airlifts, assisted in photographic documentation, and provided boats and divers, all at little or no charge. Without the help of the local and state agencies augmenting its resources, the NTSB would have difficulty accomplishing its mission. Establishing and maintaining an excellent rapport with these local entities is important to the overall success of the agency and can make the job of the regional ASI much easier. Soured relations with these local agencies can also make the job nearly impossible.

Always use an appropriate professional and courteous demeanor with local authorities. Rarely will a local authority challenge your authority. Especially in the more rural areas, this may be the first aircraft accident they have experienced, and they may not be sure how to proceed. They are usually grateful that someone has arrived to take responsibility for the investigation. Approach the local authority as you would wish to be approached, with professionalism and courtesy. Take the time to understand any concerns or questions that local officials have and provide what help you can to address those concerns. Educate them about the NTSB's mission, goals, and procedures. Take the time to debrief the jurisdiction's command structure and thank them for their assistance.

2.4 Deliberate Acts

No NTSB investigation will be initiated into any occurrence involving a fatality or serious injury in which it is obvious that the occurrence was a result of a deliberate act in which an individual acted to take his or her life. This includes occurrences involving death or serious injury of occupants that egress the aircraft during flight. The exception to this is for deliberate acts that involved *substantial damage* to the aircraft during the time any person boarded the aircraft for the intention of flight. In these cases, and in accordance with ICAO Annex 13 guidance, a limited accident investigation will be initiated. The probable cause determination for these accidents will typically be: "the deliberate act by the pilot in command."

In the event of any occurrences listed above that involve high national public visibility; the Deputy Director for Regional Operations (AS-2R) should be notified immediately for consent and guidance before any NTSB participation.

3 On-scene Activities

3.1 Overview

No two accident investigations will be exactly the same. Environmental factors, accident site locations, and technological advances will continue to challenge investigators. No procedures manual can anticipate every condition or keep pace with the aviation industry's rapid development of technologies and materials. Thus, the following guidelines should be considered general guidance. Investigators should take these general guidelines and apply them to the unique situations of each investigation.

3.2 Investigation Organization and Planning

Most of the procedures contained in this manual apply to investigations where a single investigator is present, although some may involve NTSB group chairmen and numerous parties. When the investigator or the investigative team arrives at the scene of an accident, the situation is often one of great confusion. Therefore, it is important that investigators gain the active support of local authorities and others involved in the investigation. Cooperation between investigators, local authorities, and others will greatly facilitate the work to be accomplished.

Regional investigations can range in size and scope from just the IIC and the FAA coordinator at the site of a small, two-place airplane accident to a field major investigation with several NTSB group chairmen and numerous party participants. Regardless of the complexity the investigation, good organization and skillful people management tools are the keys to success.

Careful and thoughtful organization is the foundation of every successful investigation, and good organization begins with planning. A plan provides vision and direction and sets the goals and objectives to attain within cost and time limitations. The plan is developed from the information available about the known circumstances of the accident, which defines the investigation's scope and initial direction. In the early stages, planning may only mean developing a broad overview of the investigation, steps foreseen in the investigative process, logistical requirements, anticipated investigative groups, and each group's goals. As the investigation progresses, the planner and the plan must be flexible enough to adopt necessary changes as information develops and the investigation's focus and direction become clearer. An initial organizational meeting, daily progress meetings, and a final debriefing meeting are critical elements of the plan.

Organizational meetings provide the IIC with the opportunity to share his/her vision of the investigation's planned scope, to disseminate information about the accident, and to gather background information on problems or issues with manufacturers' components. Investigative groups should be formed with goals and objectives clearly defined. This sharing of information and expectations can be critical. For example, the power plant group may need to be careful in handling the vacuum or electrical components that the airframe or systems working group may need to examine. It is important that work product expectations be clarified early so participants understand what is expected of them and the organizations they represent. The organizational meeting introduces the participants to the NTSB's procedures and to each other.

In regional investigations involving additional NTSB specialists, a work planning meeting should be held at the beginning of each on-scene investigative day to discuss the day's objectives and any changes to the investigative plan. Work planning meetings[11] are also important to the investigation's overall quality. These meetings allow the IIC to keep fully abreast of each group's progress and to alert the IIC if the investigation plan needs to be modified. Information should be shared freely during these meetings. Sharing information keeps the groups informed about the evolving direction of the investigation and allows the participants to contribute important information and ideas for potential changes to investigative protocols. The meetings can be a quick gathering during a rest break, a discussion over lunch, or a more formal meeting at the end of the day.

A debriefing session should be held before the participants' release at the conclusion of the on-scene investigation. Information developed during the on-scene phase, usually group field notes, is shared among the participants, and follow-on investigative actions are identified and coordinated. Findings determined during the investigation are discussed. Members of the investigative team should be cautioned about speculating about the causes of the accident outside of the investigation. It is imperative that a consensus be reached among all participants on the factual evidence observed and the evaluation of that evidence. Disagreement resolution should occur at the time that the evidence is accessible, instead of several months later when memories have faded and the wreckage is no longer available. The debriefing session is also an excellent time to reaffirm a clear understanding of the work product requirements that the IIC expects the participants to deliver and completion deadlines for any follow-on assignments. As in the major investigations, all factual information, notes, and photos should be shared among the parties and the NTSB IIC.

3.3 Conveyance of NTSB Investigation Procedures and Regulations

The IIC must ensure that all participants understand the procedures and regulations under which the investigation will be conducted. Procedural guidelines, which should be clearly discussed in any organizational meeting, are based on NTSB policy and apply to every investigation. Upon arrival at the accident scene, organize a meeting to convey how the NTSB investigation will be conducted. At a minimum, the IIC will:

- Determine whether members of the news media, attorneys, insurers, or persons representing claimants are present at the accident scene or organizational meeting. These entities cannot participate in the investigation.
- Introduce all NTSB personnel.
- Identify which organizations are parties to the investigation and their representative(s). All party representatives[12] shall sign an attendance roster and the "Statement of Party Representatives to NTSB Investigations." If group chairmen are present, persons from the parties should be assigned to these groups depending on their areas of expertise. If more than one representative from an organization or company is involved in the investigation, one person must be designated as the coordinator for that party.

[11] Work planning meetings are internal to NTSB staff and management.
[12] FAA personnel do not have to sign the Party to Investigation Statement.

- Convey to the parties to not release information to the public or media about the NTSB investigation. Any information released to the public will come from the IIC, with the exception of communications between party members and their respective companies, agencies, or organizations. If a Board Member is present, he or she will generally conduct media briefings. Public affairs officers normally will not conduct press briefings for the IIC.
- Take precautions to avoid discussions regarding the investigation when members of the public or the media are within hearing distance of the investigative team.
- Clearly state to all involved that the purpose of the on-scene investigation is strictly to determine the facts and circumstances surrounding the accident/incident.
- Emphasize on-the-job safety. Accident sites are full of dangers and can be hazardous to those who are not accustomed to working in these environments. If an unsafe condition is observed, the IIC should be informed.
- Explain that all information about the accident/incident will be shared among the investigative team and no information will be withheld from any members. A copy of each group's field notes and photos will be distributed to other members of the investigative team at the conclusion of the on-scene investigation. Copies of all photographs taken will be made available to the IIC.

3.4 Party Relations

The NTSB has found the party system to be a valuable and useful technique to enhance investigation capabilities and to gather facts efficiently. The NTSB allows participation by various interested parties in investigations for two main reasons. First, parties, whether they are operators, manufacturers, unions, or other groups, assist the NTSB by offering technical expertise. All persons participating in the investigation must be in a position to contribute specific factual information or technical skills that would not otherwise be available.

Second, party participation is solicited by the NTSB because it enables a company or organization to have immediate access to facts concerning the accident; the company or organization can use these facts to immediately initiate preventive or corrective action should a product or procedure be found lacking. The NTSB does not want companies to wait for recommendations. If a problem is discovered, the NTSB prefers that the company initiate remedial actions immediately. Although this does not always happen, this is the reason that the FAA is, by law, always a party to NTSB investigations. The FAA can mandate immediate fixes, when necessary, to prevent another accident. However, the primary role of FAA party representatives is to support the NTSB's investigation, not to use their participation to develop information for punitive actions or to issue violations.

The IIC's careful selection of parties on a case-by-case basis is an important step in the overall success of the investigation. Regulations do not require the IIC to designate interested parties to participate in the NTSB's investigation - they only grant the IIC the authority to do so in the interests of the NTSB's mission.[13] At any time, the IIC may remove designation of party status and investigation participation privileges for failure to comply with assigned duties or for

[13] See 49 CFR 831.11

acting in a manner prejudicial to the investigation. If this is necessary, AS management should be immediately notified of the action.

Parties are limited to persons, government agencies, companies, and associations whose employees, functions, activities, or products were involved in the accident, and/or those which can provide expertise that the IIC determines is required. Private persons, companies, and associations have no right to participate in the investigation; only the FAA has a legal right and entitlement to participate in the investigation.[14]

When talking to the potential party representatives, the IIC should bear in mind the obligation to make a decision about what type of expertise should be provided. All parties must show the IIC that their personnel are suitably qualified and will actually be of assistance. Approval is not automatic. If, for example, a potential party chose to be represented by a specialist and the need is for a different type of expertise, the potential party should be advised accordingly. If the entity is unable or unwilling to provide the desired expertise, the IIC should decline to designate that entity as a party. Similarly, if an individual has demonstrated, in the past, an inability to follow NTSB direction or makes no contribution to the NTSB's investigative effort, the IIC should either not invite the entity that he/she represents to participate or should seek the designation of someone else to represent that party. It is important to remember that the NTSB does not need to designate an organization as a party just because that entity has information vital to the investigation—the NTSB has a statutory right granted by Congress to obtain information from any source. Thus, determinations about whether to have any parties other than the FAA and, if so, what organizations are to be granted party status and are based on the needs of the NTSB, not the needs or interests of private persons or companies. Parties that do not follow the rules may lose party status.

The NTSB's rules of procedure, 49 CFR 831.11(c), prohibit participation of a party being represented by any person who represents claimants or insurers. To prevent such representation, all non-FAA party representatives must sign the "Statement of Party Representatives to NTSB Investigation Form."

In cases where multiple individuals are present from one party, a party coordinator should be identified as the spokesperson for the party who will be responsible for managing the conduct of each individual from that organization. The party coordinator will be the IIC's direct and official point of contact for the party and should be available to the IIC for the duration of the investigation. In no case should an individual whose interests lie beyond the basic safety objectives of the investigation represent a participating organization.

The purpose of permitting the participation of organizations is to assist the NTSB in developing a complete factual record. The free flow and exchange of information is key to the successful implementation of the party system. The IIC should foster a climate of trust and respect within the investigation, which encourages frank and open information exchange. All participants should understand that no one will be allowed to withhold information. All

[14] In accordance with Annex 13 of the ICAO treaty, certain foreign states have participation rights in investigations involving foreign designed, manufactured, registered, or operated aircraft. See the Major Investigations Manual for further details.

information obtained by group members will be brought to the attention of their respective group chairman, if applicable, and to the IIC. Information exchange by definition is a two-way street. To cultivate this type of professional collaboration, which makes the party system work long term, the IIC must ensure that all parties have access to all relevant information. With the exception of classified, export-controlled, proprietary, or Privacy Act material, the IIC should make sure that copies of group field notes and other relevant background material are made available to the parties.

By design, the party system enables responsible safety officials whose products or services might be involved to have immediate access to facts regarding the accident; the company or organization can use these facts to initiate preventive and/or corrective action. To facilitate this, and after consultation with the IIC to ensure the information shared is consistent with procedures contained in 49 CFR 831.13, party participants/coordinators may relay IIC-approved information to their respective organizations.

Police, firefighters, the National Guard, Department of Defense (DoD), Federal Bureau of Investigation (FBI), Federal Emergency Management Agency, National Disaster Mortuary Team, the Red Cross, the Salvation Army, and other agencies can provide assistance at the scene but generally are not made parties to the investigation, unless their organization meets the established party criteria. This includes insurance adjusters who may be present at the accident scene. The IIC should ensure that insurance adjusters ***do not*** participate in the NTSB's documentation and investigation of the accident scene, nor should they be involved in any deliberations regarding the investigation. However, adjusters may be allowed to briefly document the scene immediately following the NTSB's documentation to prepare for the disposition of the wreckage after the IIC has completed his/her on-scene work.

3.5 Wreckage Security and Evidence Preservation

As noted, an initial duty of the IIC following an accident notification is to ensure that the accident site and wreckage are secured in accordance with 49 CFR 830.10. Initial arrangements for security should be made upon notification of the accident and before the investigator's arrival on scene. The IIC should keep in mind that some local jurisdictions now charge other agencies mutual aid fees based on services rendered, so the IIC should not assume that the local police jurisdiction would guard the wreckage for free. Find out what the costs are before asking a jurisdiction to "watch the wreckage overnight" until the investigation team arrives.

In rare cases, the location of the wreckage may require movement or removal before the arrival of NTSB personnel. In addition, disturbance of the wreckage by the local coroner/medical examiner during removal of victim remains may also be necessary. The IIC is responsible for coordinating such removal or disturbance with the local authorities to ensure that critical investigative evidence is not compromised. Efforts should be made to have a knowledgeable person, such as an FAA inspector or a local aircraft mechanic, document the critical areas before wreckage is moved or disturbed.

Most large police jurisdictions and many state police agencies have aviation units that might be willing to supply knowledgeable officers for this documentation. Remember, to police jurisdictions, an aircraft accident may seem like a routine traffic accident and will not have the same significance for them as it does for the NTSB. Experience has shown that they provide better documentation results if they are asked to document the site like a "crime scene" before any disturbance. Useful documentation includes still photos and/or video footage taken before, during, and after movement/disturbance.

Ask the police/coroner to tag any switch or lever that had to be moved with the location/setting before disturbance. Measured diagrams showing the wreckage location and orientation from fixed reference points, size and shape of ground scars, and any objects contacted by the aircraft will be invaluable in reconstructing the site later. In these cases, it is important to arrange for personnel who responded to the accident and/or who performed the move (i.e., the coroner's investigator, officers, fire personnel, and municipal workers) to be available for interviews after the investigative team's arrival so that the team can gain firsthand knowledge on what was disturbed. They will also be able to assist in reconstructing the wreckage to its condition before the disturbance. Do not expect law enforcement personnel on scene to be familiar with aircraft or aviation-related issues. You may have to spend some time explaining what components are of critical evidentiary value.

Upon arrival at the scene, the IIC should contact the local jurisdictional authority responsible for incident response and management. This also includes the fire/rescue, coroner/medical examiner, and the police personnel providing initial security for the wreckage where an integrated incident command structure is not used. Beyond common courtesy, important benefits can be obtained from the timely and courteous interface with the local jurisdiction. The police agency will typically have identified and interviewed witnesses and, most likely, will have photo documentation of the scene before it was disturbed for victim extraction. The fire/rescue entity can provide information on response times, extinguishing agents used, initial fire locations, dangers still present, and the specific parts of the wreckage disturbed while securing the scene and extracting the victims. Fire department personnel frequently turn off fuel valves and master switches, disconnect batteries, and fill fuel tanks with water. It is, therefore, good investigative practice to determine what, if anything, was disturbed during the initial response.

Coordination with the coroner/medical examiner can quickly provide the victim identities, next-of-kin information, location in the wreckage, personal property of interest taken into custody (log books, certificates, chart cases, medications in personal possessions, fuel receipts, etc.). This is also a good time to make clear the need for crew autopsies and to ensure that toxicological samples have been secured and instructions provided for shipment to the appropriate testing facilities. Likewise, a request can be made to the medical examiner/coroner to look for bruising or other injuries consistent with the use of seat restraints and flight control usage, as part of the medical examiner/coroner's examination of the victims.

In cases where an on-scene investigation is performed and the NTSB has assumed custody and control of the wreckage, the NTSB is responsible for providing/arranging security for the wreckage until the on-scene investigation and any follow-up wreckage examination is complete. This responsibility also extends to parts/components retained for follow-on testing. Once the on-scene phase of the investigation is complete, wreckage security becomes the responsibility of the owner, operator, or insurer. In cases where the wreckage is not being moved for further examination, the IIC should contact the operator, owner, the owner's representative, or local authorities to inform them of the wreckage location and that the NTSB, having completed its investigation, is no longer responsible for the wreckage. When follow-on component testing is completed, components should be shipped to the owner or designated owner's representative with proof of delivery. Execute a wreckage release form (NTSB Form 6120.15) as soon as possible after completion of the examinations. The NTSB is responsible for security of the wreckage or components as long as they are in our custody, and technically they remain in our custody until we have formally released the items back to the owner or the owner's agent.

Accidents where NTSB investigators are not present at the site pose special security problems and pitfalls. The IIC should be careful using the terms "custody" or "control," both of which imply an obligation to secure and protect the wreckage. Taking "custody" or "control" of wreckage that has not been observed firsthand exposes the agency to the potential for spoliation of evidence damages if parts are later found to be missing. Remember that by statute the NTSB can examine any wreckage or component from an accident or incident of interest at any time. The safest course of action is to make it clear that the owner/operator is responsible for securing the wreckage, that certain parts or components are not to be materially disturbed without authorization, and that the NTSB will exercise its right of examination at a date and place to be determined.

Once security has been arranged for the on-site phase, explicit instructions should be given to the security provider about who is allowed access to the accident site. Depending on the size of the investigative team and the location of the wreckage, it may be necessary to supply the group chairmen, parties, and participants "access to wreckage" identification. Use identification badges if they are available. If not, a roster of approved names should be developed. This information should be coordinated with personnel who are supplying security at the site.

Retaining security personnel for the duration of the on-site phase can be costly to the agency and should be undertaken only after considering the costs versus need and after exploring alternatives. After arrival on scene, the IIC should assess security needs. On-scene investigations of many accidents in rural or remote locations can be completed in one day, and the investigative team can provide the required security. Other cases where security may not be needed include wreckage on secured private property or in inaccessible remote locations. Wreckage in an easily accessible public place in an urban setting will have to be guarded for the duration of the on-scene phase to prevent theft of wreckage or injury to unauthorized personnel and for crowd control. In accidents involving moderately sized commercial operators, the company may be able to supply personnel to provide security. In each case, the IIC should use forethought and discretion to balance the needs of the investigation versus cost.

3.6 Witness Interviews

Interviews with witnesses, crewmembers, and passengers should be conducted as soon as possible after the IIC's arrival at the accident site. Long delays between the witnesses' observations and the interviews increase the potential for inaccuracies in their statements. What may seem like insignificant information may become important when combined with facts discovered during the investigation.

The task of locating witnesses may vary from an overwhelming number of people volunteering statements to witnesses found during a door-to-door search. Typically, witnesses will make themselves known to someone. However, this is not always the case. Local authorities, newspapers, news media personnel, local residents, airport personnel, and passengers and crewmembers of other aircraft may be valuable witnesses or may aid in locating witnesses. In addition, local news coverage may contain detailed witness observations and other important background information.

When conducting an interview, introduce yourself and the agency, stating the NTSB's mission. The interview should be conducted on a basis of courtesy, cooperation, and neutrality. Witnesses should be encouraged to freely relay everything they may have seen or heard regarding the accident before you begin to ask questions. The witness should be urged to relate only their own observations and not those of other witnesses. It should be made clear to the witnesses that the purpose of the interview is to gather information about the accident/incident to prevent similar occurrences in the future.

Do not just hand witnesses a piece of paper and ask them to write a statement about what they saw. For many people, writing is a chore, and they will hurry to finish it, often leaving out pertinent details. For example, if you ask for a written statement, a witness may just write, "I saw it hit a tree and the engine sounded funny." However, if you have established good rapport with witnesses, in an interview they might go on at length about events and sounds they observed and heard *before* the aircraft hit the tree.

During regional investigations, the formality of conducting interviews will vary. Witnesses will often show up at the accident site during the on-scene phase of the investigation. In these cases, the IIC will have to conduct a very informal interview. During field major investigations or when a large number of witnesses are available, a more structured setting for conducting interviews may be appropriate. Regardless of the circumstances, the following guidelines will help achieve a successful interview.

a. The IIC should visit the accident site before interviewing witnesses. This will help the IIC to develop a list of areas to be covered during the interview and will familiarize the IIC with the wreckage and topography that the witnesses will discuss.

b. The IIC should attempt to develop a positive rapport with the witness. The interview should not come as a surprise to the witness. If possible, prior arrangements should be made about the time and place of the interview.

c. Witnesses should be qualified regarding their aviation knowledge and experience.

d. If a group interviews witnesses, one person (either the group chairman or the IIC) should act as the spokesperson and take control of the interview. The spokesperson should brief the group before the interview on how the interview will be conducted.

Other members of the group should pass the interviewer questions to ask and not interrupt the interview.

e. Model aircraft, maps, and charts are valuable tools that can be used during witness interviews. Many witnesses who find it difficult to describe the aircraft's movements will be able to show the IIC by using models and maps.

f. Encourage the witness to share his/her recollections *without interruption*. Periods of silence while the witness collects his/her thoughts have been found to encourage the witness to expound more fully and avoid omissions. The interviewer's ability to be a good listener is essential in this phase.

g. After the witness has completed his/her narrative, the interviewer may ask specific questions. In forming questions, keep them simple and avoid aviation jargon or terminology with those not familiar with aviation. Specific questions from others in the group should be channeled through and asked by the spokesperson. Ensure that questions are not presented in a leading manner.

h. Note taking during the interview is advisable. However, it should not be distracting. Audio recorders may also be used with the witnesses' consent.

i. When interviewing a witness under a doctor's care, always obtain permission from the attending physician before the interview. In these cases, limit the number of questions and the size of the witness group.

j. Following the interview, ask the witness to prepare or permit you to prepare a written statement including all the pertinent information given during the interview. Provide the witness with a "Statement of Witness" form and a self-addressed, stamped envelope. Encourage the witness to use sketches, drawings, photographs and maps to supplement the statement. If a witness refuses to sign a statement, don't press the issue. Indicate on the statement in whose presence the statement was made and that the witness did not wish to sign it. If a witness account is critical to the investigation or eventual cause determination, write a summary of the interview for the witness's review and signature.

k. Always be courteous to the witness and treat him/her with the same considerations you would desire in his/her position. The investigator should leave a telephone number and an address where he or she can be reached should the witness recall additional information.

3.7 Accident Site Planning and Wreckage Recovery

Planning in the early organizational stages of the investigation is the proper time to consider the majority of the logistical concerns. However, an early plan may have to be adjusted before arrival at the site and modified several times during the investigation due to new information or changes in conditions. The more information the IIC has, the better the logistics plan.

The type, size, and complexity of the aircraft involved and the accident site will determine the right size of the investigative team required and the skills necessary for proper documentation. For example, a corporate turboprop accident involving wreckage scattered over a wide area may be more labor intensive, than a two-seat trainer with the wreckage confined to a small area. If more labor or certain unique skills are required, the investigator can solicit extra inspectors from the involved FAA office or consider contracting with a local fixed-base operator (FBO) to supply the additional workers needed.

The key element of logistics planning is to anticipate the on-site tasks to be accomplished and the skills required. The first step is to relate the size/complexity of the aircraft type to the accident scenario and then factor in the nature of the terrain and any access limitations. Whether the wreckage will be recovered and the type of follow-on examinations that may be necessary (depending on the aircraft and the scenario) will determine what documentation tasks will have to be accomplished at the site and will also determine the number of people and the special skills required.

For example, consider an accident scenario that involves a cabin class corporate turbine-powered airplane on a night instrument approach. Turbine engines require special tooling and fixtures to disassemble and often require special test rigs to determine the integrity of the fuel control units. This requires highly specialized knowledge. If it was a turboprop, valuable information regarding power produced at time of impact is available in evidence inside the propeller hub, and this will also require very specialized tooling and knowledge. The nature of the event (instrument approach) suggests that the avionics/autopilot and the electrical system will be of significant investigative concern. Thus, parties representing investigative specialties (implying, perhaps, one or more people per specialty) will be anticipated in airframe, power plant, propellers and avionics, plus one or two FAA representatives.

Whether or not specialized skills will be needed at the accident site depends, in part, on the following:

- The limitations imposed by the terrain/environmental conditions at the accident site, including the time available and whether the wreckage is readily accessible.
- Transportation and equipment requirements.
- Whether full access to all wreckage components of interest can be obtained at the site.
- The nature of the anticipated detailed component/wreckage examinations, including any special tooling or facilities needed.
- Likelihood of wreckage recovery.

Experience has shown that the accident site is, in most cases, a very poor place to conduct detailed teardowns of intricate or sensitive components, especially if the investigation is concerned about the potential of contamination inside the components. In the case of the cabin class, turbine-powered airplane example, the very size and weight of the wreckage would make access to all parts of the structure and the components inside nearly impossible without heavy equipment to lift and move the pieces. The specialized tooling and fixtures necessary for teardowns of turbine engines would make a field examination almost impossible. The internal design of most propeller hubs makes field disassembly very dangerous and extremely unwise. The sensitive nature of most system components, especially the digital ones, requires bench test equipment and relatively sterile environments for examinations.

If most of the detailed follow-up component investigations need to be performed in manufacturers' or overhaul facilities, then the question is whether all of the related party participant technical specialists are needed in the on-site documentation efforts. This is especially true in those cases where the location and/or environment of the site impose transportation limitations.

One of the keys to efficient accident site planning is the likelihood of whether the wreckage can be recovered for further examinations. In cases where the wreckage will not be recovered from the site, the investigative activities will have to be completed on the scene. In the majority of the cases where recovery of the wreckage will occur, the investigator has many more options concerning the time and place of any detailed follow-on examinations. Early contact with the operator to determine if the aircraft is insured and then contact with insurance company representatives will help the IIC to coordinate wreckage recovery to a location where detailed follow-up examinations can be accomplished while the wreckage is still in the NTSB's custody and control.

If the accident site has easy access, such as on an airport with testing facilities, then all the specialties would be useful on scene and, perhaps, some workers to assist with the physical labor involved in wreckage movement and access. On the other hand, if the accident site is on the side of a mountain in the winter where helicopter lifts or a trek by snow cat are required to get the team to the site, prudence and the limitations imposed by site access may dictate that only the airframe and maybe the power plant specialties would be of use, with the balance of the detailed system examinations performed after wreckage recovery.

On occasion, there may be more participants than tasks to accomplish at the site, which can cause management problems and inefficiency. Because transportation and supply issues increase with the number of people involved, consider assigning remote tasks (witness interviews, log book reviews, fueling documentation at the airport, etc.) to the other members of the investigative team if adequate FAA or NTSB supervision is available. Again, the nature of the site, its relative remoteness, transportation and supply issues, and equipment required will dictate the appropriate size of the investigative team at the accident site. In a worst case scenario, the accident site may be in a body of water – ocean, lake, or river. Having the entire accident investigation team arrive prior to the wreckage being recovered would not be a good use of time or resources.

3.7.1 Underwater Recovery of Wreckage

Locating and recovering aircraft wreckage in the water requires a well-coordinated plan that varies in scope and magnitude, depending on the nature of the body of water in which the accident happened, i.e., open ocean, lake, or river. Depending on the circumstances of the accident, locating wreckage might require that the NTSB obtain such things as witness statements, weather data, and radar tracking data for the accident aircraft. Trajectory analyses may also be necessary to aid in locating the wreckage.

One of the most important steps that the regional IIC must undertake is to locate on a chart, and mark with buoys, the estimated position where available information indicates that the aircraft disappeared. Although recorded radar data can be extremely useful in finding a likely location of the water impact and the subsequent wreckage location, remember that the ATC radar system will disregard secondary beacon targets that do things that airplanes are not supposed to do (i.e., excessive rates of descent beyond the programmed maximums for that type of aircraft); the initial request should include the known secondary beacon code assigned (1200 codes for VFR aircraft) *and* all primaries. The Civil Air Patrol may have already initiated a radar track evaluation in the case of missing aircraft, and it may be able to provide useful information. All information obtained during this initial phase should be relayed immediately to local authorities or the U.S. Coast Guard to assist them in locating the wreckage. ATC specialists from NTSB headquarters should be contacted, if necessary, to determine whether they can supply help for this effort.

An immediate effort must be launched to locate and interview witnesses who might provide information about the aircraft's flightpath before impact with the water. In the event that the main wreckage area is not identified, the exact location of floating debris, bodies, or petrochemical slicks must be documented without delay. It is also extremely important to document the time the floating debris was first sighted at the noted location. When combined with local tide and current data, this information may prove invaluable in the subsequent location of the main wreckage mass.

Once the suspected position of the wreckage is determined, there are many ways to locate the wreckage, depending on the circumstances and the body of water involved. Larger aircraft with CVRs and FDRs can be located by using sonar to home in on the ULB or pinger, which activates when submerged and operates on a frequency of 37.5 kHz. The ULB battery is designed to last 30 days. Many U.S. Coast Guard facilities have portable equipment or know of commercial vessels so equipped. Side-scanning sonar can be used to map the bottom of the suspected area to look for wreckage. Small recovery submarines or remote vehicles equipped with cameras and high-intensity underwater lighting can assist in locating the wreckage and developing a recovery plan. Investigators must be extremely cautious in authorizing or committing funds for this search effort because the daily costs can be very expensive for suitably equipped vessels to conduct side-scan sonar grid searches. Even in cases where numerous witnesses have pinpointed a probable location where the aircraft splashed down, it has taken days of searching to finally locate and verify the wreckage position. The costs for this type of process can mount very quickly.

To assist in quickly and effectively locating and recovering aircraft wreckage in the water, the NTSB has a memorandum of agreement (MOA) with the DoD. The DoD tasks the U.S. Navy Office of the Supervisor of Salvage to assist in developing recovery plans for ocean-submerged wreckage. The MOA provides for a no or small fee consultation on the practicality of the recovery; however, the NTSB must reimburse the Navy for the costs of any recovery effort it initiates, which can be significant amounts of money per day. Use of this MOA should be coordinated through NTSB management.

Divers should not be employed without first having a very good estimate of where the wreckage is located. Free diving is still mostly limited to depths to 150 feet and hardhat divers must be contacted on an individual basis for their limits. based on equipment and experience.

In many cases, local law enforcement agencies, lifeguard units, or fire departments will provide divers for recovery of bodies. Many times, these organizations will remove wreckage that is in shallow water to eliminate a public hazard or as a training exercise. In the case of wreckage in shipping channels of navigable waterways, the Army Corps of Engineers may remove the wreckage to eliminate a hazard to navigation.

In the event that it becomes necessary to employ commercial divers, negotiations relative to their employment should be handled with caution. Many commercial divers do not own all the equipment required for a diving operation. The IIC may find that, even though he or she has contracted for the services of the divers, additional equipment contracts for boats, compressors, barges, cranes, and float equipment may be required. Again, make sure you are very clear in the services contracted for and the costs involved. In no case should the NTSB take on the responsibility for the safety of the operation. This is the responsibility of the contracted persons or company.

Before the initiation of any recovery, make sure any documentation of the wreckage that you may need, such as underwater still pictures or video/digital documentation, is accomplished. Irreplaceable evidence can be destroyed or damaged in any recovery operation. As the wreckage is lifted from the surface, trapped water in the structure can induce structural bending or deformation, and pieces can fall back into the water. It is highly desirable for someone to be on scene during recovery to photo document the wreckage as it is lifted onto the barge.

When divers are employed, discuss with the divers the best method of recovery to ensure maximum safety and minimum damage to the evidence. It is helpful to use aircraft manuals, models, and/or a full-scale aircraft to familiarize the divers and establish the best recovery plan. Be certain that all personnel not absolutely necessary to the recovery operation remain clear of all equipment and staging areas on vessels. It may be necessary for Safety board personnel to be on board recovery boats for several hours. Therefore, proper attire should be packed.

3.8 Specialized Equipment and Tool Requirements

An important part of investigation planning is to determine what specialized tools and equipment will be required for the on-site wreckage documentation and how to get them to where they are needed.[15]

As investigators gain experience with different types of aircraft and accident scenarios, decisions about what tools will be needed become second nature. A list of generalized tools and equipment typically useful for on-scene investigative purposes is included in Appendix 1. The

[15] A complete list of recommended tools and equipment can be found in Appendix 1.

list is not all-inclusive, but is a good starting inventory, which can be modified as conditions require.

In the initial coordination efforts with the airframe and engine parties, a good practice is to ask the manufacturers' representatives about the special tools that might be needed for the specific aircraft type. The coordination of who will bring what to the scene is important so that valuable space and effort is not wasted in duplication. If you have party participants from the airframe and engine manufacturer who are bringing a fully stocked toolbox, there is less reason to try to carry your tools when the space may be better used for other investigative equipment. However, for certain types of teardowns, although the party may provide the necessary tools on site, it may be more appropriate to conduct the investigation off site where additional support and facilities provide for a more detailed and comprehensive investigation and where the risk of losing important evidence is less.

Investigators should not forget to include pertinent parts/maintenance manual publication pages in the tools and equipment requirements list, especially if the involved aircraft type is unfamiliar. Diagrams and three-view drawings in these manuals can identify the locations of critical components, and fuel and control lines within the structures, and show how the systems are supposed to operate. The three-view drawings can also serve as a handy note pad to document damage or missing components in a pictorial way. If the office library does not contain the appropriate publications and the airframe or engine participant does not have them, consider stopping by a local airport FBO to see if you can copy some pertinent pages from its manuals.

Consideration must also be given to the need for equipment to excavate or move wreckage components during the on-scene phase. In the case of an aircraft that crashes nose-first into a freshly plowed farm field or muddy pasture, a backhoe or other digging equipment may be necessary to excavate the wreckage to document the areas. In-flight breakups or midair collisions almost always require a two-dimensional reconstructive layout of the wreckage(s) to understand the sequence of failures or impact geometry. This also necessitates some means of lifting and moving the wreckage components to a centralized point for the documentation to occur.

Think critically about what you will need at the site for the given accident scenario. If you do not have it, how are you going to obtain it? How are you going to get it where you need it?

3.9 Site Access and Transportation Needs

Although the limitations of site access can often dictate to a large measure how the on-scene phase of an investigation is accomplished, NTSB investigators have used ingenuity and persistence to overcome site-access limitations and accomplish the mission. Over the years, NTSB investigators have probably used every conceivable means of transport in getting to the site; from shoe leather to snow cats, and snow mobiles to helicopters. They have used rental cars, trucks, farm tractors, crane winches, ladders, boats, airboats, horses, and even mule teams. Clearly, ingenuity is often required to get to the locations of accidents.

Before responding to the accident site, the investigator needs to take a few moments and add transportation/site access to the logistics plan of action. To have the information to make the appropriate choices for transportation, the investigator needs to ask several questions. What are the expected and possible worst-case weather conditions for the anticipated duration of the on-scene phase? What tools, equipment and supplies will be required for the work on scene and how will they be transported? If heavy equipment is necessary, can it get to the site? How many people are anticipated to be on the investigation team, and is there enough transportation (too many people for the available seats)? Is the site drivable to within a reasonable distance and is a four-wheel drive vehicle required? If a helicopter airlift is necessary, what load limitations will be imposed by the altitude/temperature? If a hike or mountain climb is required, what is the exact nature of the terrain, and will special equipment and supplies be needed? Are the physical skills and experience of the investigative team up to the challenge of the terrain and environmental conditions? If there are unique weather/environmental conditions, are any special items of equipment necessary?

This information is best obtained from a source close to the accident site area with detailed knowledge of recent changes in the terrain or conditions. Usually, the local police jurisdiction has participated in search, rescue, and body-recovery operations, and a phone call to a member who has been on scene can resolve many of the questions. In the case of public lands (national forest, national park lands, wilderness areas, or state/local preserves), coordination is required with the appropriate agency involved anyway, and the investigator need only remember to ask the appropriate questions to help make the best transportation/site-access decisions. If the accident occurred on private land, coordination with the landowner is a must. The public entity or private landowner frequently offers to assist with the team's transportation needs.

Recent environmental legislation has resulted in laws and regulations that forbid mechanized travel in any form in some wilderness areas and wildlife preserves, so the IIC should contact the responsible agency to determine what, if any, restrictions will be imposed on site. Although it may be possible to receive one-time exemptions for the accident investigation, detailed negotiations will be necessary to coordinate site access and the needs of the investigation.

Helicopter operations also require careful preplanning. Local police, the National Park Service/Forest Service, and even the military will often supply a helicopter for the airlift of personnel and equipment into remote sites. However, most of the agencies now require passengers to wear full Nomex flight suits, special boots, and helmets, and most of these agencies do not have spare equipment to loan. The altitude and outside temperature may also limit helicopter performance and the load that can be lifted into or out of the site. Again, proper and timely coordination will eliminate many problems and lead to a smooth, efficient investigation.

3.10 Accident Site Safety Precautions and Planning

Aircraft wreckage sites may expose investigators to certain risks, including biohazards, airborne hazards, adverse terrain, and adverse climatic conditions. Personnel involved in the recovery, examination, and documentation of wreckage may be exposed to physical hazards from such things as hazardous cargo, flammable or toxic materials and vapors, sharp or heavy objects, pressurized equipment, and disease. A key part of logistics planning includes the safety and protection of the investigative team members. In accordance with NTSB Order 11A and AS policy, all IICs must complete the Risk Management Worksheet before going on scene. An expanded list of on-site safety hazards and precautions can be found in Appendix G of the Major Investigations Manual. It is important that the IIC become very familiar with Appendix G and act accordingly. Although not all of appendix G is directly applicable to smaller, two- or three-person investigations, much of it is, and the sections designed to provide directions/guidance for the larger investigations can usually be adapted to the smaller regional investigations.

The IIC should ensure that all investigative team members are properly equipped and supplied for the anticipated environmental and working conditions. The weather conditions expected to be encountered are pivotal in this planning. If extremes of temperature are predicted, some form of shelter might need to be added to the list of equipment so that team members can get out of the sun, rain, snow, or cold for rest breaks. Enough fluids should be available at the site to prevent dehydration and exhaustion. The investigator should determine beforehand if any wildlife is likely to be present, the degree of threat posed, and means to minimize or eliminate the danger.

3.10.1 Accident Site Hazards

The scene of an accident may contain bloodborne pathogens. Bloodborne pathogens are viruses, bacteria, and parasites that are present in the blood, tissue, or other body fluids of infected persons. They could include, but are not limited to, the hepatitis B (and C) virus (HBV) and the human immunodeficiency virus (HIV), which causes AIDS. Some of these viruses do not die upon contact with oxygen or when the fluids dry out. Studies show that certain climatic conditions may prolong the infectiousness of HIV. Those who work in or around the wreckage must use extreme caution to minimize direct contact with bloodborne pathogens. At a minimum, heavy leather work gloves over nonpermeable rubber gloves should be used when touching the wreckage. Under certain conditions, such as within the wreckage where investigators may come into contact with blood or human remains, full face masks, protective goggles, and disposable overalls and booties must be worn.

OSHA requirements concerning training and on-scene protection procedures and equipment are included in the NTSB's Exposure Control Plan. The NTSB's OSHA coordinator is responsible for maintaining the plan and ensuring that it is updated annually. Additional copies of the plan can be obtained from his office or can be accessed through the NTSB's internal e-mail system. Managers must ensure that each investigator has appropriate biohazard and protective equipment readily available to use on the accident site.

The IIC will inform party participants that the NTSB will not assume responsibility for any personal injuries incurred during the course of an investigation nor will the NTSB provide protective equipment to any participants. Any safety concerns should be promptly communicated to the IIC, so that appropriate action may be taken. Participants not properly protected will not be allowed on the accident site. The party participants are responsible for ensuring that they have received the appropriate on-site safety training and are familiar, and in compliance with, all applicable OSHA requirements.

3.10.2 Explosives and Ballistic Recovery or Ejection Systems

Investigators should be alert to the potential for explosives and explosive devices on aircraft before examining the wreckage. Pyrotechnic devices can include anything from firearms ammunition for a hunting trip to undeclared hazardous materials in cargo to flares in survival kits all of these devices are potentially dangerous, especially after exposure to a severe impact or postimpact fire. Ballistic recovery or ejection systems pose similar risks.

During the investigation of an accident involving an aircraft with ballistic systems installed (ejection seats on former military aircraft, ballistic recovery systems on civil aircraft, or any other types of known on-board explosive devices), NTSB personnel should exercise extreme discretion and caution. Investigators working in and around the wreckage could be killed if the explosive charge in these systems is inadvertently triggered. Per FAA Order 8130.2E, paragraph 124e, the certificated aircraft's operator must have provisions that provide for clear marking and identification of all explosive devices. These markings may not be visible or may have been obliterated. Extreme caution should be exercised when looking for markings.

If the presence of explosives or ballistic devices is suspected or confirmed:

a. ***Always*** inform the RC of potential on-scene safety hazards.

b. Allow no personnel to go anywhere near the wreckage until it has been established that there are no unaccounted-for live explosive devices.

c. Provide similar warnings to FAA inspectors and first responders.

d. Emphasize to all present that ballistic systems should be treated as if there is a "live" charge present.

e. The IIC will arrange to have an expert disarm and remove the ballistics from the site. Experts may include the system's manufacturer or DoD explosive specialists.

3.10.3 Remote Site Considerations

Operations at remote accident sites present special problems and concerns that need careful thought and planning. Failure to adequately address these areas can result in inefficiency and nuisance difficulties, or even dangerous situations that put investigative team members at risk. Remote locations are generally defined as those sites that are physically isolated in relatively uninhabited areas, such as mountains, deserts, forests, and swamps. But the term "remote" can also include the concept of distance *in time* from necessary assistance in an emergency situation. Some locations are remote in clearly obvious ways, such as the side of a mountain or several miles from the nearest highway. Others are not so obvious but are remote nonetheless. Time from the nearest help location, considering normal transportation means, should be a criterion of remoteness in addition to the more obvious locations. Regardless of the nature of the remote site location, the investigator must consider the ramifications of remote sites when planning logistics for site operations.

In most cases, remote accident sites will require some form of unique or unusual transportation arrangements. As noted, typical examples of these transportation forms might include helicopters or other float/ski equipped aircraft, snow cats, snowmobiles, and pack animals. These unique transportation modes almost always increase logistics complexity by imposing limitations on the number of people and the amount of equipment or supplies that can be taken into the location. When coupled with adverse environmental conditions, or its potential, what was at first an inconvenience can become a dangerous situation that requires thought and planning for hazard mitigation.

Transportation issues will manifest themselves mainly in finite time limits for wreckage documentation. The helicopter may have to come get you early because a frontal system is suddenly moving into the area or the 3-hour snow cat crawl into the site may mean that you have to leave 4 hours before dark to allow time for the trip. Whatever the cause, the investigator needs to forecast the amount of time on scene and prioritize the documentation tasks, from most critical at the top of the list to nice to have but unnecessary at the end. The prioritization can easily be done based on the accident scenario, modified by the initial viewing of the site and a walkthrough of the wreckage. Stick to the list. Changes in environmental conditions may require an earlier-than-anticipated departure, and circumstances may preclude another chance at the wreckage for some time.

The potential injury/illness hazards inherent in remote site operations are obvious. Maintaining communications capability with the outside world is a must in hazard mitigation. A suitable first-aid kit for the immediate treatment of injuries, including snake and insect bites, is essential. Areas with the potential for other wild animal hazards also require forethought. Before going on site, the investigator should contact the appropriate local authority and ask about potential wildlife hazards. When appropriate, the IIC should encourage local law enforcement or other designated agencies to accompany the investigative team to provide protection. Investigators should also be aware that the Endangered Species Act and other similar laws impose civil and criminal penalties for the harming or destruction of certain protected species.

Just as safety-conscious pilots would not consider embarking on a flight over environmentally hostile terrain without filing a flightplan or using flight following, the investigative team should never go to a remote site without first filing the terrestrial equivalent. Always make sure someone knows where you will be, the routes and transportation means in and out, the estimated times of departure and arrival, and what course of action you plan to take if delayed or if equipment failure precludes normal extraction. Personal locator beacons may be available in your region and are useful in summoning aid in remote locations.

Knowledge and planning are the keys to preventing trouble, especially in mountainous terrain, where the weather can go from benign to inhospitable in a short time. Plan on the worst-case scenario (how cold could it get if the team is stuck there overnight) and equip the team for that eventuality. It is generally *not* a good idea to have more people at the site than the available vehicles can extract in one load.

Machines break down and often do so at the most inconvenient time and worst possible place. Think about what will happen if the vehicle(s) break down given the weather, distance to civilization, and terrain conditions of the particular accident site. Are alternative backup transport means available? If not, then you should definitely equip the team members for the possibility of an overnight stay at the site.

Careful consideration of the possible "what if" scenarios for the particular accident site and of the anticipated environmental conditions makes good procedural sense. Always make sure that basic survival equipment and supplies are available for the worst-case situation.

3.11 Preliminary Survey of the Accident Site

Shortly after arrival at the site and after any preliminary meetings are completed with the party participants and/or local authorities, the IIC should make a preliminary survey of the total accident site, focusing first on a total assessment before moving to the detailed documentation and study phases.

First, look around at the surrounding terrain and the obstacles to get a comprehensive view of the site. Look for and secure any immediately perishable evidence, such as charts or other documents that may blow away, etc. Identify the energy path of the aircraft. This may include ground scar bearings and/or a line through the median wreckage distribution bearing. The reciprocal bearing of the energy path will be a close approximation of the vehicle's approach path. This bearing should then be walked, paying close attention to any signatures of aircraft contact. The distance covered is left to the IIC's discretion. However, remember that, even at typical approach speeds, aircraft are traveling at 60 to 100 feet per second, with up to 200 feet per second or more for moderate cruise airspeeds. The first contact with any obstacle may be some distance away from the initial ground contact point.

Once this first contact point is established, walk back to the wreckage noting probable flightpath angles and aircraft attitude. The temptation will be very strong to begin a detailed analysis of one or more components in the ground scar and wreckage distribution areas of the site, but completing the whole view survey is important to the overall efficiency of the investigation. Note the ground scars, estimating the part of the aircraft that may have created the scar. View the pattern of debris distribution as another means of solving the attitude and energy state questions. The wreckage patterns are also important in determining the key question of whether all the aircraft is present at the site or whether there was an in-flight breakup.

In-flight breakups and midair collisions pose significant challenges to the completion of this initial survey. In these cases, the wreckage debris may be scattered over a wide area measured in miles. The initial survey may have to be accomplished from the air to identify the location of all components. No matter how difficult the task, it is critical to the investigation to complete this overview survey to determine what you are dealing with and the best investigative protocol to employ for the efficiency of the investigation.

Determining whether the entire aircraft is present can be a daunting challenge, especially with extensively fragmented structures or ground fires that have reduced parts of the wreckage to ash and molten globs of metal. Determining whether the entire aircraft is present may have to be inferred. For example, the intermediate portions of the left wing span may not be obvious in the debris, but fragments of wing tip cap, navigation light lens, or structure known to be outboard of the missing section may have been observed in the initial ground scar areas, establishing that the entire span was intact at impact.

3.12 Wreckage and Site Assessment

Many clues about the circumstances of the accident or incident can be obtained during the initial assessment of the accident site. Initial impressions and observations about impact attitudes and terminal energy can greatly assist the investigator in determining the most important aspects of the wreckage to document and the need for follow-up component investigations. The majority of regional office investigations will involve wreckage sites that remain relatively intact until the investigator's arrival.

A thorough viewing of the entire accident site, including all obstacles and terrain along the direction of approach to the first contact point, will give the investigator an idea of the type of accident he or she is dealing with. Questions that should be answered during the initial scene viewing include:

- What is the type and height of terrain, and are obstacles involved?
- What was the flightpath angle at impact?
- What was the approximate airspeed at impact?
- What was the aircraft attitude at impact?
- Is the entire aircraft there?
- Was the aircraft under control at impact?
- Was there a fire? If so, was it in-flight or postimpact?
- Was there engine power at impact?

Aircraft accident investigation protocol is analogous to fault tree analysis used in modern engineering problem-solving, where "yes" or "no" decision points lead to certain branches of inquiry deemed significant, while others are determined to be of lesser importance. As the decision points are reached, the investigation continues to focus on the root causes.

Distinction between controlled and uncontrolled flight can be derived from the normal range of expected flightpath angles and pitch and roll attitudes for the type aircraft. For most general aviation aircraft, the average maximum pitch attitude range used in normal maneuvers is $\pm15^\circ$, with a flightpath angle of 10° or less (turbine-powered aircraft may have slightly higher normal values, while helicopters are capable of much greater operating angles). For most pilots, 35° to 40° in any flight attitude is the maximum comfort range.

Impact geometry can be derived from careful observation of the accident site and the wreckage itself. Comparing the height of any obstacles along the approach flightpath with the resultant angle from the first impact point will yield the minimum possible flightpath angle. Pitch and roll attitudes can be derived from the crush line angles on the fuselage and wings, allowing for the slope of the impact point terrain. If the engine or other object of mass is buried in the soil, the longitudinal axis can generally be taken as a close approximation of the pitch attitude.

Ground scar patterns and the wreckage distribution pattern can also be important in reconstructing the impact attitude. The size and shape of the scars, in context with the identity of the wreckage debris associated with them, can yield a possible range of pitch and roll. For example, two parallel ground scars, one with wing tip debris and the other with landing gear components, coupled with the wing span distance from gear to tip, will give a geometric solution to roll attitude. If colored light lens fragments are also found in or near the scar associated with the wing tip, then the identity of the wing is clear. Tree strike scars are also important, but when attempting to determine flightpath angle, the investigator needs to be aware of the loss of vehicle energy during a tree strike sequence. The flightpath will become steeper with each succeeding tree strike.

Symmetry is also important beyond the scope of impact geometry. Symmetry in the wreckage and in all components on each side of the fuselage is good. Lack of symmetry always has to be explained. For example, more damage on the left side components (of course, taken in context with the terrain slope and direction) implies a left wing down attitude. Symmetry in the damage to each side would correspondingly indicate little or no roll at impact.

When determining power on a multi-engine airplane, symmetry in propeller damage would point to each engine producing a like amount of power at impact. Lack of symmetry means the side with less damage is immediately suspected in terms of engine power capability. This, of course, has to be read in the context of the impact geometry for it to be of value (i.e., was one side shielded from any significant ground contact early in the sequence?).

Reading engine power level from propeller damage and other internal signatures within the engines can be difficult and misleading. More than one investigator has been fooled when they relyied completely on propeller signatures in determining power output. Variables in the viscosity of the medium propeller strikes, the time exposure for blade damage, and the impact geometry are all factors. Propeller damage must be placed in context with the accident sequence. The classic propeller damage signs, which can equate to engine-driven power, include:

- Leading edge gouging and damage.
- Chordwise scratches perpendicular to the span axis (diagonal scratches are secondary events).
- Tip end polishing, where the paint is smoothly worn off over the width of the blade.
- Tip end torsional twisting opposite the cambered side.
- "S" bending
- Trailing edge spanwise compression sine wave pattern deformation.
- Blades broken out of the hub in a direction opposite the direction of rotation.

As noted, the key to understanding propeller damage is to relate it to the context of the impact sequence and the nature of the medium. Propellers are really rotating airfoils that generate lift parallel to the crankshaft (thrust), and they will behave like an airfoil in any medium they pass through. Propeller rotational speed versus time must be understood when attempting to correlate impact sequence to damage. For example, assume a cruise revolutions per minute (rpm) of 2,400, which equates to 40 revolutions per second, 4 revolutions per 10th of a second, and 0.4 revolutions per 100th of a second. Multiply these numbers by the number of blades in the propeller, and you have the total blades with opportunity for damage in the listed time intervals. Now compare two extremes of impact geometry: a low angle high-speed trajectory and a CFIT straight into a vertical rock face. In the low-angle example, the time line of the sequence is relatively prolonged, perhaps over several seconds, resulting in 80 or more opportunities for blade damage. One would expect to see the propeller blades twisted into pretzel shapes if at cruise rpm. On the other hand, the vertical rock face impact would be measured in a time frame of less than a 100th of a second, with maybe a quarter of a propeller revolution. Correspondingly, one might not see much propeller damage even at full power.

It is also necessary to factor in the possibility of secondary bending deformation and damage in the impact sequence, which masks the primary power deformation signatures. In the final stages of the impact sequence, the blades tend to be bent back and formed around the cowling or engine, and sometimes this tends to undo the primary power signatures. Backing out from the potential secondary bend deformation and scratch patterns to arrive at the power deformation signatures takes judgment and careful study.

Finally, the more viscous the medium the blades are forced through (water, soft sand, mud), the more pronounced the blade twist deformation, polishing, and trailing edge compression signatures. Do not be surprised to find unusually large pitch angles on one or more blades of a constant speed propeller; the twist forces generated as the blades enter the medium may break the internal hub pitch change mechanisms, allowing the blades to rotate freely in their clamps. One or more blades of a slowly rotating propeller that enter rock strewn desert soil or contact a rock outcropping may also exhibit tremendous leading edge damage when the engine power output was low.

3.13 Media Relations

The NTSB is a public agency engaged in the public's business and supported by public funds. The NTSB's work is open for public review. The NTSB has established policies and procedures dealing with employee contact with representatives of the news media. These procedures are designed to assist employees during and after an investigation, while also ensuring that the NTSB speaks with one voice when releasing factual information on its investigations, which is, by its very nature, sensitive and can involve the reputations of individuals and organizations. The NTSB's Public Relations Policy and Procedural Guidance is covered in full under NTSB Order 6A, Media Relations, dated June 13, 2007.

3.14 Media Policy in Regional Investigations

Press interviews at the accident site present a timely opportunity to disseminate factual information on the progress of the investigation and to inform the public about the NTSB and its mission. Because the amount of media coverage on each accident varies, the IIC must be flexible in dealing with the media. The majority of regional accidents will involve local news reporters. In cases where the amount of media interest is small, the IIC can easily brief reporters on an as-needed basis while on scene.

Regional IICs may, however, become involved in accidents/incidents that attract a great deal of media attention, and a large number of reporters. In these cases, media briefing times may need to be scheduled and group briefings conducted. You should allow time and plan to speak to the media while on scene, but do not allow media briefings to consume a lot of time away from the investigation. Public affairs can assist with media calls for regional investigations. If you ask Public affairs to handle media calls, please keep the public affairs office advised of developments in the investigation. If you plan to hold a media briefing, advise your RC and the public affairs office of the time and location so that media can be alerted accordingly. Be sure to provide the RC and public affairs office with sufficient lead time. If you get inquiries from major national media outlets, you are required (as per AS and public affairs policy) to alert your RC and public affairs before giving any interviews. Once your factual report has been released, it is often the best practice to refer future calls to the public affairs office. However, if you wish to continue to speak to the news media about your factual report, you may do so, provided your RC approves.

3.14.1 Press Briefings

- Give ***factual*** information.
- Explain the comprehensive nature of NTSB investigations:
    - On-scene.
    - Lab work, record procurement, interviews.
    - Factual reports (i.e., preliminary, factual).
    - Final report.
    - Safety recommendations are always possible.
    - Explain the party system.
- Explain what you are looking at and why, but don't get analytical.
- Listen to the Question!
- Don't use jargon   be professional and clear.
- Choose your words carefully, and don't use colloquialisms.
- Don't be in a rush or lose your composure.
- No exclusives. Share the information equally.
- Do not release names of anyone involved in the accident.

The NTSB Basic Accident Investigation course contains a segment on media relations and press conferences, and the resource material provided during the course may assist you in dealing with the media. You can always contact a public affairs officer through the NTSB communications center 24 hours a day, if necessary.

4 On-Scene Investigation Methodology

4.1 General Methodology

The following is a general discussion of guidelines for on-scene investigation protocols. A list of recommended tools useful for on-scene investigative wreckage and component examination work, a detailed investigation guide checklist covering most aspects of the on-scene wreckage work, and a glossary of terms for describing damage and component anomalies are provided as appendixes to this manual (see Appendices 1, 2, and 3). Additional guidance for the documentation methodology of structures, power plants, systems, and components can be found in the group chairman checklists for the appropriate specialty in the Major Investigations Manual.

4.2 Documentation

Keeping up with the documentation requirements during the on-scene investigation of the wreckage can be difficult. Many details need to be recorded, and the IIC will often be engaged in many other tasks, including management functions and coordinating party representatives. Although it may be tempting to think that you can simply remember most of the details and can write it all down when you get back to the office, this is rarely the case. An IIC can easily be launched to another accident or be assigned another higher-priority project. Months later, it will be nearly impossible to reconstruct what you saw on scene from memory and photographs alone. Investigators should always make the time during the on-scene phase of the investigation to thoroughly record factual information and observations.

4.3 Detailed Assessment of Wreckage

So far, the discussion about wreckage has focused on the importance of the initial survey to determine flightpath angles and impact attitudes, or "how the aircraft arrived at the site." With the protocols and priorities thus established, the investigator must begin the detailed examination of the wreckage to complete the documentation. Many investigators favor a generalized "walk around preflight-style" first look at the wreckage to document the context of the whole vehicle. This methodical preflight style (where you have a start and end point that is always the same) is also helpful in ensuring that you look at the whole without overlooking one or more components. Make sure the entire aircraft is accounted for in the wreckage distribution. This is also a good time for the IIC to asses what hazards (biohazard, ballistic materials) might be encountered at the site. The focus can then shift to the detailed examination and documentation of the various components.

As the detailed systems documentation begins, it is important to remember that things may not be what they appear to be. Anyone who has seen films of real accidents or survival factors crash tests will recall that significant collapse and rebound of structure occurs during the impact sequence. As a general rule, the higher the energy and angle of impact, the more the structural collapse. In extreme cases, a 30-foot long fuselage may see a 50 percent or more collapse in the impact, then rebound to about its normal length. Thus, the investigator cannot take at face value the postimpact position of any component or control. This is especially true in cable-driven or actuated systems/components as the cables slacken or become trapped in wreckage folds during the impact structural collapse. Hydraulically driven components can also change position once the lines are ruptured and the system pressure depletes. A thorough investigator *always* looks for preimpact corroborative evidence of the position in the form of witness marks or color transfers between adjacent components to confirm the positions observed. This is especially true for any component found at some extreme of travel inconsistent with the flight regime associated with the accident sequence. For example, although jackscrew actuators are typically more reliable, cable-driven jackscrews of the type associated with trim tabs can be affected by cable movement during the impact sequence.

It is also important to determine the locations of victims in the wreckage and to compare these positions to where the occupants should have been in the airplane. Several cases have been recorded in which a pilot was not in a pilot station seat when the accident occurred. As in all good investigations, the evidence has to be logically consistent in the context of the accident: wreckage, victim locations, and crew/passenger functions.

4.4 Photographing and Documenting the Scene

Following the initial survey of the accident site and wreckage, detailed scene documentation should be accomplished with both photographs and a wreckage diagram before disturbing the accident scene.

Photographs are invaluable in documenting the original condition and position of the aircraft and its components. They are also critical in documenting the nature of the accident site terrain, obstacles involved, and ground scars. Good on-scene photographs should allow you to reconstruct the accident site and any critical evidence. Accident site photographs should document the overall nature of the site, the generalized wreckage distribution patterns, and the key components and evidence of value.

Photographs should be taken from the initial point of impact along the wreckage path to the area at the final point of rest. Included in this overall category are photos showing the surrounding terrain and obstacles. Consideration should be given to incorporating some frame of distance and/or height measurement reference in the overall wreckage distribution photographs and in detailed close-ups of components. Routine everyday objects (pens, pencils, coins, etc.) can provide a size measurement in detailed close-ups and in some general overview shots. At other times, especially where photo documentation is being made of a critical actuator measurement or other detail, the use of a ruler will be necessary. Be cautious about the type of measuring device you use, and make sure there is enough contrast and visibility of the rule's divisions to be seen in the finished photograph. A standard carpenter's tape rule will not be distinct enough for the divisions to show up well in anything but a detailed shot of some component. For the overall shots, obtain a tape measure like those sold in stores that stock surveying equipment; these tape measures generally have large easily seen numbers and inch lines, and the foot markings are usually in alternating contrasting colors.

Plan your shots. For example, a shot of a crumpled piece of metal will be meaningless a week later without some type of identification or label. Photos of each blade of a three-bladed propeller are meaningless unless the blades are numbered or labeled. A separate photo log noting what photographs were taken is useful. Digital cameras assign a unique number to each photograph. You can reference this number in your log. Some digital cameras can be set to reuse numbers if a picture is deleted. Make certain that your camera is not set up in this mode. Make plastic tags with letters representing the cardinal directions (left, right, up, down, plus numbers 1 through 6) with some means to clip them onto the wreckage bits. Avoid the use of white plastic card stock because most airplanes are painted white overall and a white card on a white paint job does not show up very well.

Another way of accomplishing the labeling task is to carry and use black and white paint marking pens. Think of two different photos of a wing, one without a label in the view and one clearly marked with a tag. In the first, it is hard to identify the wing without a lot of looking to locate recognizable characteristics. A labeling tag in the photo makes the wing, and its position, immediately recognizable. This technique is particularly useful when documenting components that have come to rest in an abnormal attitude such as a wing or horizontal stabilizer section that has separated and come to rest inverted. When viewing the photograph weeks later, it will be very helpful if you have identified (and labeled) which side of the aircraft the wing is from and which side is up.

Sufficient contrast to distinguish important objects from the background is another often overlooked problem in accident investigation photographs. A photo of a white painted wing in a snow bank will not show up very well. Burned wreckage is problematic because of the subtle shades of gray represented by the burned remnants. You may have to wait for better light conditions or adjust the camera's contrast setting. Also, be careful using flash, particularly the built-in flash on your camera. The reflection of the flash may overexpose, or "blow out," areas of your photograph. This is most common when photographing light-colored items and any item where the angle allows a directional reflection from the flash to the lens. Experiment with different shooting angles until you get an acceptable picture.

When taking very tight close-ups of components, make sure to use a label or some other means of determining identity and context. If a label is not practical, consider taking two shots, one overall view showing the part in the wreckage context and one detailed close-up. A nicely composed photo of a hydraulic actuator arm is good, but it may not be helpful later without context information. Is it the landing gear actuator or flap extension mechanism? Which side of the aircraft is it on? Again, using your log and the number of the digital photograph is helpful.

In some cases aerial photographs may be desirable to obtain an overall view of the accident site, its relation with the surrounding area, and the impact sequence. Infrared photos can help identify the locations of scattered debris and fuel in tall grass and underbrush. Most law enforcement agencies that operate helicopters have a forward-looking infrared television installation. If needed, an aircraft and a pilot can be rented for this purpose. Also, state and local law enforcement authorities may provide an aircraft. Do not try to fly yourself and take photographs at the same time.

Video or digital recordings of the accident site and wreckage documentation operations may also be valuable to the investigation. A continuous recording enhances the contextual understanding of the components viewed. Most modern video and digital cameras have considerable telephoto/macro abilities and can record images in very low light. Audio recordings are also valuable because the investigator can dictate a narrative of what is being viewed and its relationship to the whole. Investigators who use video and digital recording devices should consult the current NTSB orders concerning the use and retention of such recordings.

4.5 Wreckage and Site Diagrams

The format and complexity of wreckage distribution and accident site diagrams will depend on the type of aircraft and accident. The IIC will have to determine how detailed the wreckage diagram will be. However, the location of all of the aircraft's major structural surfaces, major components, and the significant ground scars should be documented. Aircraft in-flight contact points with obstacles or the ground before the main impact sequence should also be included.

Most wreckage and site diagram formats are based on a plan-view format, with variations on how the locations are recorded. One popular format is a drawn-to-scale pictorial representation on graph paper. Another method records distances along the center of a median wreckage distribution bearing, with offset side distances recorded for components. A polar projection method of recording the bearings and distances of wreckage components from some central point, usually the main wreckage mass location, can also be used. Some investigators log the global positioning system (GPS) coordinates of components and note them later on a topographical chart, while others dictate distance/bearing information to voice recorders to be added to a chart later. Regardless of the method used, the bearings of ground scars and the positional relationships and distances of the major components and any obstacle contacts must be documented. Investigators should not forget that the size and shape of ground impact scars could be important evidence. In complex accidents, consideration should be given to hiring a surveyor. Before hiring a surveyor, contact the Office of Research and Engineering (RE), via the RC, to find out if this can be accomplished using in-house resources.

In cases of in-flight breakups, midair collisions, or widely scattered debris, a conventional diagram may be impractical due to the distances involved and complexity of the debris patterns. The IIC should consider constructing a tabular listing of object identification and location. The location can be in the conventional bearing and distance from some central reference point grid coordinate location or the GPS latitude and longitude. The IIC should tag the parts or components with some identifying number that is keyed to the diagram so that the location and positional relationships of the components can be reconstructed and plotted on a chart later.

With numerous witnesses, it may be desirable to document their locations relative to the wreckage. This can be done using a separate witness diagram, either on an overlay, a street map, or the crash diagram.

The NTSB Basic Accident Investigation course contains a segment on accident site documentation, and the associated reference materials provided during the course may be useful in determining what type diagram(s) are the most suitable.

4.6 Cockpit Documentation

Cockpit switches, valves, and levers in the flail envelope of the front seat occupants can move during the impact sequence, and investigators must view with suspicion any inconsistent switch or control lever setting until it is corroborated with other evidence to establish preimpact position. During the procedure, look for settings and positions inconsistent with what would be normal for the flight regime associated with the accident sequence. Some light and cabin class twins (and even some older single-engine airplanes) have remote fuel selectors actuated by cables connected to the selector lever. Be suspicious of these fuel selectors until you actually look at the remote valves. If the aircraft is unfamiliar, obtain a copy of the flight manual for reference to determine normal system operational control settings. Inconsistent system control settings must be explained with corroborative evidence of preimpact position before being taken seriously.

4.7 Control Systems

The very nature of the structural collapse and the attendant trapping, severance, or binding of control cables or torque tubing makes determining control system(s) continuity problematic. If the "how it got there" determination is on the side of uncontrolled flight, examination and documentation of the control system is critical. However, most uncontrolled descents result in considerable structural collapse, which translates into trapped control cables or tubing. Cable runs in the crushed and collapsed fuselage will be difficult to document, and cockpit controls may be even more problematic because of instrument panel collapse.

Flight control cables can be connected backwards, or route cables can be run over keeper pins instead of between the keeper and pulley. Debris, trash, and even ice can trap cables in their runs. Electrical wire bundles behind the instrument panel can snag and trap the cockpit controls at the cable connections. Turnbuckle connections at intermediate points in the control cable runs can fracture or work loose and separate. Cables kinked during installation can fray and jam in the pulleys or lightening holes. Investigators should consider the potential for autopilot and electric trim runaways and, for larger aircraft and most helicopters, malfunctions in hydraulic power/boost units. With the continuing and rapid introduction of digital flight management computers and their interface with navigation components, advanced control systems may present significant challenges in determining software adequacy and interface with other systems.

In documenting the control system, investigators should not overlook the control surfaces themselves. Establish that the mass balance weights are present and/or accounted for in the wreckage or distribution area. The hinges, hangar bearings, and limit stops should be examined for evidence of operability and unusual operating signatures. Look for evidence of flutter or inflight hyperextension. In the case of the secondary high-lift flight control devices (flaps, leading edge devices, spoilers, and speed brakes), it is important to establish symmetry of position and logical consistency with the flight regime associated with the accident scenario. This will often involve looking for witness marks on actuators or adjacent structural elements to corroborate operating positions.

In most aircraft designs, the area of the control cable runs with the most complexity (in terms of pulleys and routing) is usually in the structure beneath the cabin/cockpit floor, which is also the area typically more severely crushed and folded. The critical aspects of the cockpit controls are usually behind the instrument panel or under the floor area, places that are most susceptible to severe impact deformation and damage.

Establishing full and complete control system continuity, in many cases, requires cutting into the floor or lower belly skins to expose the entire control cable run, which, in turn, requires the equipment to lift the structure and cut into the desired areas. Sometimes, preimpact control cable/torque tube continuity can be inferred through the cable or tube separation characteristics.

Tension overloads[16] of cables or the compressive distortion and separation of push/pull torque tubes imply physical continuity because the ends had to be connected to generate the force required to break the cable or compress the tubes. However, no information about proper routing or the potential for binding/trapping can be inferred with this method. To solve these questions, the investigator must examine the complete run from the cockpit to the control surface.

4.8 Engine

The initial accident site assessment will determine the probability of an engine problem and suggest the priority and depth of the power plant examination. Normal piston engine operability must often be inferred by the exclusion of evidence to the contrary. As noted previously, propeller deformation and damage can be an indicator of power output. However, the investigator must avoid reaching a premature conclusion based on this evidence. For example, a power output problem could have occurred, which precipitated the accident, but could have been resolved just before impact.

Engine problems are rarely caused by a catastrophic failure. Power loss events are often the result of failures in the accessories, i.e., fuel system feeds and returns, pumps, ignition, induction, or exhaust. High-impact energy states and crash angles, or other destructive forces, make identifying these failures difficult because structure often collapses onto the engine during the impact sequence. The accident site is, therefore, rarely the best place to look for subtle failures inside intricate components or systems.

Engine examinations, especially where power output ability may be suspect, require a holistic approach. In essence, the core engine is nothing more than an air pump. It is the accessory subsystems, and their integrated interaction with one another and the core, that turns this air pump into a machine capable of producing power. The examination must, therefore, include not only the core but also all related systems required for power production. This means the air path from where it enters the aircraft to the end of the exhaust pipe, fuel delivery, and metering from the firewall to the cylinders, ignition circuits (*including the cockpit switches and wiring to the engine*), and the power plant controls from the cockpit to the associated engine devices. For this discussion, the lubrication subsystem is included in the core.

If power problems are suspected, a decision needs to made about whether to bench test/run/flow the device to determine functionality, anomalies, or damage. The absolute proof of functional capability is turning the component on and seeing how well it works and if it meets specifications. However, once a device has been taken apart, it can never be put back together in exactly the same way, so the results of any follow-up functional testing could be meaningless. Where contamination is a possibility, test running or flowing the device will destroy any contamination evidence inside it. But if it is opened up to look inside for the contamination, it cannot be tested for functionality. The investigator should base these decisions on the suspected scenario. For example, if internal contamination, damage, or assembly/maintenance errors are

[16] Typically characterized by a broom straw appearance of the strands of separated cable ends and/or necking down of the individual strands at the point of separation. Other ways include looking for cables that have been pulled through metal structures (cable saw signatures) or actuator bell cranks that have been ripped from their mounting points or evidence of hyper extension of the control surfaces themselves.

likely, then disassembly is probably the best course of action. If the component history or circumstances do not favor contamination, damage, or maintenance issues, then test running the device may be the best decision.

There are numerous benefits obtained by conducting the engine teardown at a facility with proper tools and equipment. When there is specific interest in the engine and issues surrounding the engine (e.g., undetermined loss of power), the IIC should consider not conducting any engine teardown in the field but should bring the engine back to an appropriate facility or the factory for examination. Disassembling components in the field could eliminate the possibility to perform a valid functional testing.

Remember that any one particular appliance is just one part of an integrated system. Testing each component of a system separately does not necessarily mean that valid conclusions can be drawn about the functionality of the whole system. For example, removing a fuel pump from a fuel-injected engine and putting it on a test bench will tell you only that the pump works but not how it functions within the integrated fuel system as a whole. It is not unusual for the output of one system component to require adjustment, perhaps toward one extreme of its allowable envelope, for the entire system to operate correctly. A better test is to remove and test the entire fuel metering system from the pumps to the injector nozzles.

At the accident site, the engine was in the context with all of the airframe and power-related subsystems, including wiring harnesses, switches, fuel lines, fuel valves, vapor return lines, etc. The ideal and most meaningful test is to find a way to plumb a fuel supply to the airframe plumbing and run the engine in the context of the whole system. The more changes and replacements made to the original context, the less valid the test results. The opposite scenario would involve removing the engine from the airframe and replacing many accessories before installing it in a test stand. All this example would prove is that the core engine works, but no conclusion could be drawn about the functional capability of the power plant in the accident airframe, unless a great deal of work is done with all the related airframe systems to verify their functional capability.

Where does the IIC begin when standing in a field looking at the remains of an aircraft with ambiguous power signatures in the impact-sequence evidence and on the propeller? What items are important? Starting with the exterior cowl, look for unusual oil or fuel stains, localized areas of heat, or inside-to-outside impact signatures. Examine the start and end points of the air path, and make sure to examine the induction air filter and the exhaust stack for evidence of obstructions. Note that the internal baffling inside mufflers can separate and block the exhaust gas path. Remove the cowl(s) sections, again looking for unusual oil or fuel staining, evidence of heat or fire, exhaust stains in the vicinity of exhaust tubing fitting connections, and catastrophic internal failures. Check all fluid lines and fittings for security and proper torque. Verify that the balance of the induction and exhaust air paths is unobstructed. Also, check the carburetor heat box and/or alternate air doors. Check the quantity of oil and the security of the filler cap. Establish control and electrical continuity from the cockpit to the fuel metering unit/carburetor and magnetos. Check the magnetos for security in their mounting clamps, and examine the ignition leads for areas of potential grounding. Document the fuel system lines from the firewall to the cylinders, noting the presence of fuel[17] and the degree of contamination in each line or device. The flow divider, injector lines and nozzles, and the upper air deck reference lines should be checked for security, obstructions, or contamination.

For fuel-injected engines, one simple field method of determining the likely operability of the fuel injection system involves measuring the flow from each injector. This method requires a means of supplying electrical power to the boost pump. Remove the injector nozzles from each cylinder and place them in bottles or containers of equal size and shape.[18] With a source of fluid plumbed to the system, energize the pump and look for an equal fluid level in each container. This method only indicates that the distributor and injector nozzles are flowing evenly, not that the total amount of fuel is being correctly metered to the divider.

It is also important not to try to start engines that have electronic controls with digital memories installed (NVM) because the controls may be programmed to erase past information from memory components when the engine is started again or power to the control is turned on. To avoid the risk of losing valuable information about the accident, the IIC is encouraged to contact the manufacturer about the types of NVM that are on board an engine control before trying to restart the engine or power up the control.

A relatively quick method for ascertaining the relative health of an engine can be accomplished in the field, assuming that the engine can be unencumbered from the wreckage to the degree necessary to rotate the crankshaft. As items are removed from the engine, make sure to label or tag them so that their positions can later be reconstructed and the parts put back. Remove the rocker box covers, which will provide an indication of the lubrication inside the engine and will reveal any anomalies with the rocker arms, springs, or valve stems. Pull the lower spark plugs; check for excessive gaps or ovaling, look for fouling or evidence of oil soaking,[19] and compare the electrode coloration to expected normal combustion signatures.[20] If a borescope is available, the interior of the cylinders and piston crowns can be checked at this time. It is important not to rotate the propeller before all shear couplings have been verified and their state documented. With a thumb over each spark plug hole in order, rotate the crankshaft[21] and check for compression in each cylinder in the proper firing order. At the same time, look for proper valve action, including equal lift for like valves, and rotation of an accessory (vacuum pump sheer coupling is the easiest to see), which indicates mechanical continuity throughout the engine. With impulse coupling-equipped magneto(s), cutting the P-leads and holding the spark

[17] Possible fuel starvation can be established in this way. For carbureted engines, lack of fuel from the firewall to and including the bowl is a potential indicator. For injected engines, absence of fuel from the firewall to the fuel pump(s) is the indicator; it is not unusual to find fuel from the pump(s) to the flow divider and the injector nozzles in starvation/exhaustion events.

[18] Baby feeding bottles work well for this purpose. Usually they have calibrated ounce measurement lines along the side and are typically small and light.

[19] Oil will drain past the rings and flow to the down side of the engine, so oil fouling of the plugs from the low cylinders of an engine laying on its side would not be surprising.

[20] A light ash gray is consistent with normal combustion. Dark, sooty plugs indicate excessively rich mixtures. Excessively clean plugs may indicate very lean mixtures, detonation, or that a quantity of water was processed through the cylinder(s).

[21] This can be accomplished with a socket wrench and splined drive adapter through an accessory drive pad, such as the vacuum or fuel pump.

plug end of the ignition harness close to a cylinder or other grounding point is a way to see if the magnetos are capable of producing a spark. This process also serves to indicate if a particular ignition lead is shorted or leaking excessively. The relative timing of the magnetos to each other can also be checked in this manner by listening for the snap.

Several other important aspects of the engine should be checked during an on-site engine examination. Cutting open the oil filter can reveal the presence of metal contamination and the necessity for a complete teardown.[22] Removing the oil pan can reveal the same information and, on Continental engines, provide an easy look at the connecting rods and bearing saddles.

But be aware of the limitations of cursory field examinations. Engines can pass the benchmarks just noted and still have significant internal problems, which either were part of the accident sequence or are important safety issues to be addressed in proposal actions. One example involves spalling of the camshaft lobes. Spalling is a wearing away of the metal over time, usually resulting from rust or corrosion pits. This alters the shape of the cam lobes, which, in turn, alters the lift or amount of valve opening and duration of the associated valve cycle; this results in a 10 percent to 20 percent power loss in severe cases. Although the decision to do complete teardowns and/or component functional tests rests with the IIC, it is good practice to do so when power may be an issue in the accident scenario.

Compared to reciprocating engines, turbine engines usually present considerable information about whether and how they were operating at impact. Exceptions generally involve engines that do not see high vertical or lateral impact loadings or that are buried and protected inside structure, as in some ex-military fighter types. The key to the amount of information available is to understand the operating envelope. For typical engines, the core N2 is rotating at an rpm of 35,000 or higher when operating at 100 percent rated power, with corresponding flight idle speeds in the 35 percent to 40 percent range. As the case crushes and deforms in the impact sequence, these high-speed rotating compressor and turbine sections come into contact with the case and the stators, which results in rubbing between components. This rubbing or interference often will manifest itself in blades bent opposite of normal disk rotation, although an absence of such blade bending should not cause too much concern. It is not uncommon for blades to break off and damage or break other blades in a cascade of resulting damage aft through the engine. All of this rubbing and internal interference between parts produces lots of machined metal particles that are then processed through the combustion cans. If fuel was being burned in the cans, the metal particles will be melted or highly heated and will be deposited as metalized splatter on the turbine heat shields or first stage turbine nozzles or blades. Dirt and debris distribution through the engine and bleed air duct can also provide evidence of the power level.[23] Comparing the operating schedule of the bleed valves, and especially the surge bleed valves, to this distribution pattern suggests an inferred power level. For additional information, refer to the Powerplant Group Chairman Appendix in the Major Investigations Manual.

[22] Be cautious not to allow the presence of the metal filings that are created from cutting open the filter be interpreted as pre-impact metal contamination in the engine.

[23] If a turbine jet engine is running at the time of impact, the engine intake could ingest whatever dirt, rocks, vegetation, etc., is at the accident site.

However, be cautious about perceived turbine engine power signatures. Idle speeds for the N2/N3 rotating group(s) can be quite high (40 percent of 35,000 is still a lot of rpm) and the coast down time from a full power operating rpm may result in significant rotational speeds being developed for a considerable time after fuel cutoff or flame out. Just because rotational damage on the first stage compressor is observed (when looking in the front) does not necessarily mean the engine was running when it encountered impact forces. Evaluate evidence from the whole engine, including whether or not fire was present in the burner cans, to determine the power level output. If broken compressor or turbine blades are observed, the question of preimpact blade separation or separation resulting from impact needs to be resolved.

The complex fuel control units can also influence the power output of a turbine engine. Fuel control units, especially the pneumatic ones, are very sensitive to contamination or air leaks in the pneumatic lines. Rotor speed governors for helicopter applications can have subtle internal failures or irregularities, which will command the fuel control units to idle speed. Thus, checking the integrity of the pneumatic and fuel lines can be critical to an evaluation of turbine engine power output.

4.9 Fuel System

Documentation of the fuel system is critical in any accident where a power loss or power deficiency is suspected. All aspects of the fuel system should be examined, including all lines, valves, tanks, tank filler caps, pumps, vents, and vapor return lines. Just because fuel is found in a tank does not mean the fuel was capable of getting to the engine. Quantity and distribution of the fuel, although important in their own right, is as important as the system's ability to deliver fuel to the engine. As with the control system, the degree of airframe damage correlates to the difficulty in conducting a thorough fuel system examination.

Examination of the fuel system should start with the aircraft exterior. Check for staining around skin panel butt joints and filler caps, which may point to system leaks or siphoning from the fuel tank(s).

The condition and security of the filler caps and filler openings are important considerations. Deteriorated cap seals and rust or corrosion on the filler openings can be an indicator of water infiltration. Vented caps should be examined for the vents' condition and operability.

Check the interior of the tanks not only for quantity but also for contaminants. Lost objects, including shop rags, tools, and other debris have been found in fuel tanks and can be responsible for blockage of the fuel pickup ports. For bladder-equipped aircraft, the condition of the bladder envelope is important. Excessive wrinkles can point to the potential for water droplets to gather and eventually coalesce into a surprisingly large quantity of water. Mechanics have improperly installed bladder tanks by failing to adequately secure the tank peripheral envelope to the structure. While inside the tanks, the fuel level floats or capacitance probes should be checked.

One of the most overlooked aspects of fuel system documentation is the fuel tank vent system. The vents equalize the tank pressure with the outside ambient pressure as fuel is used from a tank. With the vents blocked, it is entirely possible for the engine(s) to run for an hour or more before the resulting vacuum in the tank overcomes the system pumps' ability to deliver fuel; note that various insects make fuel vent lines their homes so may cause some vent blockages. Some potential indicators of this condition include skin panels or internal bulkheads on wet wing aircraft that have a "sucked in" appearance or bladder tanks that are collapsed inside the wing bays.

The actual position of the fuel selector/firewall shutoff valve(s) should not be taken for granted. Structural deformation around the selector handle can result in the visual impression that the handle/pointer is in a different location from the actual valve operating position. Also, the valve selector handle or pointer may not have been indexed correctly to the valve stem the last time maintenance was performed on the valve. This is especially true in cases where the valves are remote and are actuated by cables or torque tube combinations. The valve positions can be determined by disassembly or, if a source of compressed air is available, by blowing through the engine side feed line and listening for airflow in a tank. If a cockpit valve control handle/switch is in an odd or inconsistent operating position, look around the area to determine if structural deformation or some other mechanism is responsible. For electrically actuated remote valves that are in positions inconsistent with the cockpit controls, consider the possibility that electrical shorts or ground faults may have triggered the valves to move during the impact sequence; note that some versions of electrically actuated remote valves have cycle times of less than a second.

Partial or complete fuel line blockages can occur anywhere in the system and may be the result of contamination or system component deterioration. The aromatic formulations of some automotive fuels can cause the deterioration and crumbling of O-ring seals and certain types of rubber hoses in common aircraft use. Air pressure can be useful in determining the presence of line blockages. However, a large amount of pressure or flow could dislodge the obstruction before the blockage becomes apparent. Directional flow of check valves can be tested with this airflow method.

Fuel system pumps can be harder to document. It is usually possible to provide a source of fluid and electrical power for a field functional test of electrically driven components. For engine-driven pumps, it is possible to use a reversible electric drill to drive them, again with a source of fluid to pump. Disassembly is another option where the internal condition can be documented as unremarkable and, therefore, likely functional. These field methods can only establish that the pumps can move fluid, not that they are functional to pressure and volume specification. For engine types or applications that may require specific pressures and flow rates for the system to operate properly, the best solution is a bench test at either the aircraft manufacturer's facility or a component overhaul shop.

Determination of fuel quantity can be a vexing problem, especially in high-angle and high-energy impacts. If the tanks have ruptured, look for evidence of the fuel spill. Fuel will soak into the ground and remain for some time; digging down can determine how deep the fuel-soaked ground is and provide some clue to quantity. On asphalt surfaces, remember that gasoline is an asphalt solvent. The tarmac will have an "acid-eaten" appearance. Dying vegetation or burn patterns in a spray pattern around the front of the wreckage is another indicator of fuel.

Hydraulic deformation (bulging) and rupture of a fuel tank is another indicator of relative quantity. On aircraft where the fuel tank bladder is in the leading edge of the wings and a quantity of fuel is in the tanks, it is not uncommon for the impact pulsed hydraulic surge to blow off the wing tip caps or blow the fuel filler caps out of the openings. Hydraulic signatures, although not as dramatic, can be observed in tanks located centrally in the wing structure, although the impact forces have to be correspondingly greater. A "ground fire meltdown" of the aircraft does not necessarily mean that there was a large quantity of fuel onboard. Once interior fabrics and plastics are ignited, they may burn furiously, even if the aircraft had little fuel on board when it crashed. In addition, a relatively small amount of fuel is necessary to create an intense, postcrash flash fire.

4.10 Electrical Generation and Lighting

It is critical to document electrical generation and lighting components and systems when investigating night or instrument meteorological condition (IMC) accidents, but the degree of impact damage, especially in cases of thermal destruction by fire, can make this difficult. There is no practical way to functionally test the generator/alternator, battery, current limiters, or the voltage regulator in the field. If suspect, these components will have to go to a manufacturer's facility or an overhaul shop for functional testing.

Some electrical system output and distribution can be observed through direct and indirect evidence. Communications and recorded radar data, such as a pilot/crew's strong clear signal in radio conversations with a controlling facility or a valid Mode C or secondary beacon target, will indirectly indicate power distribution to the avionics. Examining light bulb filaments for hot stretch[24] is another way to infer power distribution within the aircraft. The investigator should start with the likely sources, such as the navigation lights, rotating beacons, landing lights, instrument flood/post lighting, cabin lights, and light bulbs, that may be in other cabin accessories to develop a picture of the power distribution within the aircraft.

If electrical problems are suspected, the investigator should examine the electrical system from the origin through the end point of all critical systems for evidence of shorts or ground faults. Electrical shorts can be the result of worn wire insulation contacting the airframe ground or a contamination problem in a connector. Other sources of problems involve the inability of the bus to power a system due to a separated or intermittently loose connector. Multimeters can be used to determine dielectric continuity of circuits, assuming that the impact damage has not compromised the wires. In the absence of a dedicated multimeter, the investigator can use a flashlight bulb and battery and a length of wire as a makeshift circuit continuity tester. Evidence of arcing or high current loads[25] can also point to problem circuits.

[24] Hot filament stretch occurs when a light bulb filament, which operates at an incandescent temperature near its melting point, is subjected to a shock loading. The near molten filament then stretches out in the direction of the applied load. The wound spring-like filaments will have an "uncoiled" or stretched appearance, sometimes highly exaggerated. In some cases, broken glass fragments will be fused onto the filament. Cold (not lit) filaments will exhibit a fracture of the filament element without appreciable stretch.
[25] Arcing will leave small pit-like craters that will have a molten flow-like appearance to the crater lip. High current loads may manifest themselves in high heat signatures to nearby materials and melted or nearly so wire insulation.

Circuit breakers in common aircraft use are thermally activated circuit protectors, not current limiting devices. A current surge or flow in excess of the breakers' rating heats the elements until the breaker trips open, stopping current flow. The time it takes for the over-current condition to heat up the breaker depends on the amount of current and several other variable factors, so a prolonged over-current could exist that does considerable damage downstream before the breaker trips. Because the breakers are thermally activated, do not take at face value any "popped" or tripped breakers observed after a ground fire.

If high current or arcing conditions are suspected, carefully remove the suspect wires and components for forwarding to the NTSB materials laboratory. If the investigator is unsure of the observed signatures and desires a quick probability read on the evidence (and the site is near a large metropolitan area), consider contacting the municipal fire department and asking the arson unit or fire marshal to look at the material.

4.11 Instrumentation

Investigators should never take instrument readings at face value without evidence that the readings or settings are valid and that impact forces did not influence them. Instrument indications that may have validity include those where impact crushing has trapped the needle(s) between the glass and instrument face. In other cases, the instrument faces should be examined for evidence of "needle slap," where the needle or pointer has made a mark on the face dial or left a smear of paint. In older instruments where the needles are typically coated with a radium material, exposure of the instrument face to a black light will illuminate any radium material transference. Float-based fuel gages will always go to 0 when power is removed. The gage in capacitance type systems tends to remain where it was when power was removed. Drum-type number indicators can shift during impact, or the case can distort and show numbers above or below the indicators at the time of the accident.

Aircraft equipped with caution/warning/system annunciator light panels should be examined for individual light bulb filament stretch to determine what, if any, warnings were on at the time of impact. Aural warning systems should be functionally checked, and investigators should also determine if the warnings are sent to the headphones through the audio panel if the pilot was using them.

Investigators should check the pitot tube, the static ports and the associate plumbing. The tubes, ports, and plumbing should be checked for blockages and obstructions (again, insects love these openings). If the flight was in icing conditions or the potential for icing existed, examine the heating elements to ensure their functionality.

In accidents involving loss of control at night or in IMC conditions, the gyroscopically operated attitude, heading, and turn instruments should be examined for evidence of operability. For those panel-mounted instruments that incorporate an internal gyroscope, disassembly of the

---

High overload current flows can also leave a series of bead-like bubbles under the insulation along stranded wire runs, although high magnification is usually required to see the phenomena.

unit can reveal rotational scoring on the gyro rotor.[26] In the high-end flight director-type systems, the gyros are remotely mounted, usually in the empennage area. Do not forget the power source for these instruments. In the case of vacuum-driven gyros, the system plumbing must be traced from the vacuum pump to the instruments. Make sure to check the sheer coupling on the vacuum pump and disassemble the dry type to ensure an internal carbon block or vane failure has not disabled the pump. For electrically driven systems, look for the electrical power distribution signatures noted above.

Digital avionics, digital engine instrument displays, and electronic control /electronic flight information systems, including both panel mount and hand-held GPS navigation devices, are now common on many aircraft. Maintenance recording devices may also be located remotely from the cockpit. The typical application for the maintenance recorders is to record engine parameter exceedences, but several recorders in common use also record airspeed, altitude, time, and many other data bits useful to the investigation. As electrical/computer devices, they present special challenges for the investigation. All need electrical power to work and to read the information displayed. However, the aircraft electrical system is usually incapacitated in the impact sequence. Most of these devices use internal keeper batteries to retain at least the last displayed reading or setting. Many have memory modules or chips, which can store a surprising amount of historical data. Do not assume that the blank screen or display is useless. Also, do not power up the system if it is likely that there is non-volatile memory on-board because this would result in loss of information. Call the device's manufacturer to ascertain if the unit has memory, how to remove and package the unit, and where to take it for readout. Even if the circuit boards are broken or otherwise damaged, useful information might still be retrieved.

Do not hesitate to contact the NTSB vehicle recorder specialists concerning non-volatile memory. Additional information is available from the avionics manufacturers. Typically the aircraft original equipment manufacturer is the one contacted and their field personnel are the ones that get the first look at the avionics. The avionics manufacturer should at least be notified, and the on-scene team can be given any appropriate instructions necessary to preserve relevant information. Pictures of the instruments and associated switch positions at the scene can be very informative to the avionics manufacturer when they are trying to reconstruct events or cockpit information.

4.12 Doors, Seats, and Interior Furnishings

Aircraft doors, access panels, seats and seat tracks, and other interior furnishings should not be overlooked in the documentation process. The historical record is full of cases where pilots have reacted inappropriately to open doors and lost control of the aircraft. In other events, open cargo doors have been struck by propellers, or baggage/cargo has exited the aircraft and struck a vital structural or control element. In some aircraft types, crew seats have come loose on the tracks only to slide all the way to the rear at rotation, causing the pilot to lose control and

[26] The gyro rotors typically turn at very high rotational rates. If the impact shock load is on the correct vector, and the instrument case sees sufficient crush deformation, the gyro case can be squeezed onto the rotating rotor, thus producing the scoring. Absence of scoring in and of itself may not mean that the instrument was not working, only that the required damage did not occur in the impact.

crash. Other interior furnishings and appliances can also induce flight crew distractions, and these items need to be examined for telltale evidence.

Look for consistency and symmetry with the rest of the aircraft wreckage. If doors are missing or found in the open positions, look at the latch mechanisms for deformation to pins, bolts, and striker plates; lack of damage in a separated or open door must be explained. The door(s) should share the same crush fold patterns as the associated fuselage section if they were closed at impact. Damage to hinges and the surrounding aircraft skin should be consistent. If internal cabin/cargo compartment contents are found before the first significant ground contact point, this also has to be explained.

Finding seats loose on their tracks is not unusual at the accident site, particularly in the high-angle/energy events. A thorough examination of the seat tracks, locking devices, and the seat structure is necessary to resolve how this occurred. Most seat installations use a pin-type locking device, which engages holes in the seat tracks. If the locking pin was engaged, the impact loading will bend/break the pin and perhaps elongate the associated track hole. The tracks will sometimes exhibit gouges left by the seat leg feet as the seat moves along the track in the impact sequence. As the cockpit floor distorts in the impact sequence, it would not be unusual to find the seat leg feet separated from the tracks. If this is an impact-related phenomena, the feet and/or the tracks should exhibit distortion.

4.13 Midair Collisions

Midair collisions present special problems and challenges for investigators during the wreckage examination phases. The investigator must attempt to reconstruct the collision geometry of how the two aircraft came together. The foremost and obvious difficulty is the widespread wreckage debris field, which may have parts from both aircraft commingled. There are also problems inherent in the recognition and identification of the scratches, impact markings, and color transfers left on each aircraft as a result of the collision.

The speed and track vectors of the aircraft form two sides of a triangle, with the third side becoming the closure vector between the two. Two angles are critical in the solution of the midair collision problem. The collision angle is the angle between the flightpaths of the two aircraft. The other two angles in the triangle are the convergence angles, and they indicate the difference between the aircraft heading and the other approaching aircraft. The convergence angle is also the angle at which a pilot would have to look to see the other aircraft. If the speeds and headings of the two aircraft remain constant, both convergence angles will also remain constant. In this condition, the converging aircraft will appear motionless to the observer. Because the human eye will see relative motion sooner than a stationary object, this helps to explain why aircraft on a collision course are not as readily seen by pilots.

Convergence angles have to be based on heading rather than track to establish a valid visual perspective for each pilot. Once these angles are established and, using a reconstruction of the pilot eye level based on the pilot's seated height, the investigator can accurately replicate the visibility from an exemplar cockpit. Looking along the established convergence angle will provide a probable location of the converging aircraft. If there is windscreen surrounding this point, one can conclude that the pilot had the potential of seeing the other aircraft. If there is structure in this location, one can calculate when the size of the other aircraft would have been larger than the relative size of the structure and then calculate the time from that point until impact. If the relative location of the converging aircraft was in a position not normally scanned, it is not reasonable to expect the pilot to have seen the other aircraft. Spending the time to accurately document the necessary factual information will provide the investigator much better insight on the responsibilities for "see and avoid" of the pilots involved.

Using scratch marks to determine a collision angle yields the relative angle between the two aircraft headings rather than their compass headings. The scratch marks may also indicate the relative attitude of one aircraft compared to the other. However, it will not indicate the absolute attitude of either aircraft.

A valid scratch mark will always be straight and ideally will have a paint transfer from the other aircraft. The next criterion is to find the scratch mark on a horizontal surface (or a vertical surface if you are calculating climb or descent). Although it is possible to use scratch marks from a curved or non-horizontal surface and then convert them to an "equivalent" mark on a horizontal surface, the easiest marks to use come from a horizontal surface.

Although it is always desirable to obtain the scratch marks from the initial contact points of the two aircraft, this is not always necessary. The more direct the collision, the more important it is to use scratch marks from the initial contact. However, when the two aircraft do not significantly alter their flightpaths during the impact, scratch marks made later in the collision can be used if they are validated by damage patterns and are consistent. Viewed another way, changing the direction of a flying aircraft is a function of the force applied and the time over which that force is applied. The more direct the impact (force) or slower the impact (time), the more important it is to use scratch marks made early in the collision.

Once a scratch mark has been located, document the direction of the scratch and the angle it forms with the longitudinal axis of the aircraft. Angles between the scratch mark and the lateral axis can easily be converted to the longitudinal relationship. The angle between the scratch mark and the longitudinal axis is the angle of interest for the calculations needed to solve the collision geometry problem.

Several methods can be used to determine the collision and convergence angles in a midair collision when FDR information is not available. The most basic is to use graph paper to plot out the track and magnitude (speed) of each aircraft. Once this is done, the angles can be measured with a protractor. The advantage of this approach is that it does not involve mathematics and is easier to understand. However, there is a significant disadvantage to this method: The speeds and directions for both aircraft must be known, a condition that rarely occurs.

Another method of determining the collision and convergence angles is the trigonometric solution using the *Law of Sines* and/or the *Law of Cosines*. When three of four values are known, the fourth value can be mathematically derived (see Appendix 4). This approach also yields reasonable estimates when only two of the four values are known.

Another technique is the use of "relative damage direction" when the speeds between the two aircraft are significantly different, when the aircraft are almost head on, or when one aircraft is overtaken from about the 6 o'clock position. In this case, the general damage to the structure of one aircraft can be used to approximate the other aircraft's flightpath-.

The most common mistake that the new investigator makes when evaluating a midair collision is to assume that the scratch mark (or structure deformation) is synonymous with the track of the other aircraft. Investigators will sometimes find themselves sighting down the scratch mark as if that was where the other aircraft came from, and even experienced investigators can be seen placing one part of an aircraft into a matching damage area on the second aircraft, as if this replicates the convergence angles. In reality, a scratch mark is a combined product of two different bodies in motion. Only when one of the bodies is not moving, or when they are approaching from the 12 o'clock or 6 o'clock positions, will the scratch mark show the direction of the other object.

The techniques for determining the horizontal collision angle will work to establish the vertical angle of convergence by using scratch marks from vertical surfaces rather than the horizontal surfaces. The recommended technique is to do two separate sets of calculations, ending up with X degrees for the horizontal convergence angle and Y degrees for the vertical convergence angle. When doing the visibility study, both angles are used to determine the visibility of the other aircraft.

There are scenarios when the extent of the impact damage or fire makes it impossible to find reliable scratch marks on either aircraft. When this happens, it may be necessary to use an "equivalent" scratch mark, which equates to the direction of damage patterns created by the second aircraft. This can be used as a rough indication of an "equivalent" scratch mark. Although precision suffers in this approach, it may be the option of last resort.

The above methods can also be used to determine the collision angle when only a single propeller slash is available in the wreckage. Calculations or estimates for the speed of the two aircraft and the speed of the propeller tip need to be included. By using the diameter of the propeller, direction of rotation for the propeller, and the propeller rpm, a calculation for the prop tip speed can be established using standard trigonometric functions. Because the prop is always providing thrust at a 90° angle with the longitudinal axis of the aircraft, the square of the prop vector and the square of the aircraft vector can be used to get the square of the combined vector, which represents the prop tip moving through space. Combining this prop tip moving through space with the movement of the second aircraft yields the collision angle between the prop tip and the second aircraft. Then, using basic geometry, the collision angle between the two aircraft can be determined. (See Appendix 4 for the mathematical solution protocol to the collision geometry problem using scratch mark angles.)

A thorough and accurate charting of the debris field distribution pattern is one of the essential starting tools for the solution process. The patterns in the debris field will be a significant component to understanding what aspects of the two vehicles may have contacted one another, and the patterns are the starting point for the detailed examinations to follow. It is very important to tag or mark each piece and its location. Once charted, each piece in the debris field needs to be critically examined for propeller slashes, scratch marks, impact signatures inconsistent with ground impact, and any color or material transfers. The findings then have to be thoroughly documented and the angles measured in relation to the aircraft longitudinal axis.

Component location in the debris field is influenced by upper air wind direction and velocity, and component mass. Large or high mass objects tend to follow ballistic trajectories, affected primarily by initial inertia and gravity. Air mass movement influences small low mass objects, especially skin panels and light plastic or fabric materials. Intact airfoil sections can glide some distance once an equilibrium state is achieved.

Following the "as found in the field" documentation of the parts in the debris pattern, the next step is to recover the pieces to some central location. A two-dimensional layout of both aircraft side by side is essential to determine the damage patterns and to solve the collision geometry problem. If a ground fire extensively damaged one of the aircraft, the problems increase dramatically and the eventual solution to the collision geometry problem may have to be calculated with only one side of the physical equation.

Tools that will be very helpful in this process include three-view drawings of both aircraft at the same or approximate scale and models of the same scale of each vehicle. The drawings provide an excellent resource for documenting the damage patterns and any scratches, impacts, or color transfers. As the damage patterns are documented on both drawings, the attitudes of the aircraft as they contacted one another become clear. The drawings also provide a convenient means for including the factual documentation of the damage patterns and scratch-mark orientation in the case docket material. The models provide a three-dimensional representation of the drawings that can be posed in various attitudes to match the damage sequence and patterns. In addition, an exemplar aircraft of the same year, make, and model can help in identifying component locations and the shapes, sizes, and dimensions of various structural elements. The exemplar aircraft can also help the investigator assess the likely visibility of each aircraft to the other pilot once the approach angles and bearings have been defined.

Recorded radar data, if available, and witness observations can be helpful in identifying the general flight tracks and approach aspects of each aircraft, but this information is very inaccurate. Rarely do these sources provide clues to the last seconds of the collision geometry, where evasive actions may have been attempted by either or both of the flight crews. The clues to the attitudes and the convergence and collision angles of each aircraft at the time of the collision are contained in the witness marks on the wreckage. The preferred method, once scratch marks and/or propeller slashes have been identified, involves the trigonometric mathematical solution to the convergence geometry question.

The convergence angles and the relative speed difference of the two aircraft will dictate to some degree the amount of damage that will be seen on the aircraft. Two moderate-speed aircraft colliding with a head-on aspect will produce a tremendous amount of energy that will result in a high degree of damage to both. Two aircraft of similar speed capability on overtaking courses will have a low relative collision velocity and a correspondingly small amount of collision damage evident on the wreckages.

The distribution of aircraft components away from the final resting point of the main wreckage mass or localized heavy damage to one specific area of each aircraft will provide an initial point of focus. Carefully examine these focal points for unusual scratches, dents, impact signatures, or color/material transfer patterns. It is critical to isolate the initial damage, and care must be exercised to identify and exclude secondary and/or late-in-the-event damage. Once these patterns are identified, proceed to the other aircraft's focal points and attempt to match the dimensional geometry of the marks with components or structural elements of the right size and shape on the second vehicle.

4.14 In-flight Breakups

In-flight breakup investigations present many of the same challenges as midair collision cases. Both can present widely scattered debris fields. Each involves determining event sequences from an analysis of damage patterns and witness marks on components. As in the midair collision, a thorough charting and documentation of the debris field is essential, including unusual markings or deformation patterns on the components. Again, component location in the debris field is influenced by upper air wind direction and velocity and component mass. The lighter the object, the longer the float time, and consequently, the more wind drift effect that may be manifested in the wreckage distribution. Investigators should always obtain upper air wind information to understand the debris field distribution patterns.

After the debris pattern and component locations have been documented, the wreckage should be collected in a central location for a two-dimensional layout of the components. A key part of the investigation will involve reconstructing the sequence of failures as the structure broke up to locate the primary failure point. The damage and deformation patterns are important in understanding the loadings and forces involved in the event. Much of the evidence for failure sequence will come from witness marks, scratches, and paint/material transfer formed as the separating components contact and rub against one another during the breakup event. For example, in most cases when an outer wing panel separates, it will fold up and back. In this process, it will tend to "slap" the upper quadrant of the rear fuselage and continue aft, where it impacts and knocks off either or both of the vertical and horizontal stabilizers. In this case, everything after the main wing failure is a secondary event, and the investigator must work backward through the conflicting signatures to find the primary event.

Breakup events can be characterized by the pilot and/or outside atmospheric events exceeding the design limits of the structure or by an internal material deterioration or maintenance deficiency that degrades the structures capability to carry the loads imposed to the point where failure occurs sooner than the designed yield point. Typically, the first type of break-up results from an in-flight loss of control and a speed excursion beyond the never exceed (V_{ne}) or design diving speed (V_d) limit. Any control input at or beyond these speeds will usually result in overloading the main wing or empennage fixed and moveable control surface structures. The failure could also result from a combination of maneuvering and atmospheric gust loadings on the airfoils. At high speeds beyond V_d, control surface flutter and/or torsional divergence of one or more airfoils can induce an overload of the structure to the point of failure. Although less typical, severe atmospheric phenomena (i.e., thunderstorms, mountain wave rotors, and wake vortices) can induce gust loadings in excess of the design strength limits of the structure, especially if the aircraft is at a high cruise airspeed in excess of design maneuvering speed (V_a) when the phenomenon is encountered.

A breakup scenario involving material deficiency is often the hardest to determine without the assistance of metallurgical laboratory personnel. The typical mechanisms responsible include corrosion effects, fatigue, or manufacturing errors in the material itself. Also possible are errors or oversights by maintenance or airframe manufacturing personnel. Corrosion processes can include both external (environmentally or chemically induced) and internal metallurgical mechanisms. Fatigue may or may not be the result of a manufacturing process error or maintenance deficiency involving the introduction of tool marks or other stress riser initiators. Manufacturing errors in the production of the metal may involve improper heat treatments, inadequate stress relief, chemical composition of the metal, and the degree of interior inclusions within the metal matrix.

The degree of structural deformation not related to ground impact can give the investigator an indication about the primary scenario. Scenarios involving aircraft exceeding design limits involve relatively high degrees of deformation (torsion and bending) to the airfoil structural load-carrying members, and the deformation patterns may be widely distributed across the structure. Cases involving a material deficiency are characterized by little or no deformation. Composite structures tend to fail in both situations with little or no outwardly obvious deformation to the structural elements.

Except for highly brittle metals, ductile alloys such as aluminum have three behavioral modes. If loaded within their strength capability, they will deform under load and return to original shape when the load abates. At their yield points, they permanently deform under load, which may take the form of taffy-like necking down of the member or the assumption of a permanent bend set. At the point where the applied load exceeds the strength capability, fracture and separation occurs. Thus, fractures not accompanied by deformation of some type should be immediately considered suspicious until proven otherwise. Conversely, deformation in and of itself does not exclude metallurgical problems but only indicates a low probability.

In steady state flight, a conventional aircraft's main wing provides the lift to oppose gravity (lift vector upward), while the tail produces a balancing force to control aircraft pitch (lift vector downward) in the opposite direction.[27] Overloads occur when the amount of lift being generated is greater than the strength of the structure. In "positive" overloads, one or both of these members will deform and/or break in the direction of the generated lift, up in the case of the main wing and down in the case of the tail. "Negative" overloads are the reverse.

The main load-carrying member in a wing or tail is usually the main spar, supported to some extent by any additional spar structures. Spar members are constructed and carry loads just like I-beams in that the upper and lower caps carry the predominant bending loads and the center web serves as a spreader to keep the caps apart. In positive overloads, the lower cap is loaded in tension and the upper cap in compression; negative loadings impart the reverse. Therefore, in positive overloads, the lower spar caps will exhibit tension fracture face characteristics with the upper cap tending to show predominantly compression signatures. The upper caps may also have

[27] Canard designs differ in that both the main and secondary airfoils generate lift in the same direction.

torsion and tension elements as the wing or horizontal stabilizer twists during the final separation sequence. Localized crippling of the spar web in the area of failure is also demonstrated, and careful analysis of the load paths can help decipher the overall load seen by the structure. Negative overloads will tend to exhibit the reverse signatures. The investigator should not overlook the possibility that the structure saw both a positive and negative loading sufficient to induce material yield, with corresponding mixed signatures, just before structural failure.

Torsional forces exist normally in airfoils in response to aerodynamic forces. The torsional stiffness of a particular structure is taken, in part, by the skin, rivets/fasteners, and the fore and/or aft fuselage attach points. In high-speed excursions, the torsional forces generated may exceed the structure's resistance, and the resulting failure may initiate at the secondary airfoil attach points (fore or aft fuselage attach points), shearing of the rivet skin panel joints, or in tearing of the skin panels themselves.[28] In extreme cases, as the torsional strength of the wing or tail is approached or exceeded, the associated flight control surface may begin to act as a servo tab, in effect turning the whole outer wing into an aileron or the whole horizontal stabilizer into one large elevator that drives the ultimate main wing failure. Investigators should be alert to the above indicators of torsional divergence.

Recorded radar data can help determine whether the event is a typical loss of control and/or the resulting high-speed excursion versus the airplane breaking up within its normal speed and maneuvering envelope. Radar data can also be useful in plotting the probable location of missing structural elements. RE has several divisions that can be helpful in in-flight breakup investigations. For example, the Vehicle Performance Division can perform a radar study to reconstruct the vehicle's flightpath. Additionally, the data can be used to reconstruct the aerodynamic performance and loadings on the vehicle. The Materials Laboratory can also assist in the evaluation of suspicious fractures and the loadings on the airframe. The Aviation Engineering Division can provide technical assistance in the evaluation of the structure.

The following is a summary of in-flight breakup information points:

- Total load on the structure is the *sum* of the static loads, *plus* any additional maneuvering load additive, and any gust load imposed.
- Aircraft structures will break if the loads imposed exceed the design strength. The primary failure will typically occur at the weakest point in the structure. Overloads without material defect will exhibit structural distortion to the load-carrying members.
- Alternatively, structures will break if the material condition is defective or the strength margins have degraded below the design strength. These failures will typically not exhibit much structural deformation to the load-carrying members.
- For a main wing or tail to break as a primary failure, a mechanism has to be present to load the structure (positive or negative) to failure. This means that all aerodynamic surfaces had to be present to generate the load. Once the failure occurs, the structure unloads and the forces subside. Secondary failures of other parts of the structure can

[28] The rivet/fastener and skin panel tears will typically be on diagonals across the wing or tail surface.

occur during this period. The predominant in-flight breakup scenario involves the tail driving a positive main wing overload. Signatures would be positive load deformation (up on main wings, down on tail).

- In some cases where the tail fails first, the investigator may see a negative overload of one or both main wings. Prefailure positive deformation patterns would also likely be present in the structural members.
- High-speed events may exhibit evidence of control surface flutter, i.e., a wrinkle pattern to the surrounding skin surfaces and/or battering of the control limit stops, or over-travel of the control surface. Torsional divergence type loading evidence is also possible in the structure (diagonal skin panel tears, sheared rivets in a diagonal pattern), including the precipitating failure of the secondary fore or aft airfoil attach points.
- Flutter episodes will usually affect the control surface's mass balance. Alternatively, loss of the mass balance first will often induce a flutter episode and the resulting breakup of the structure.
- Lack of symmetry in the breakup pattern (failure confined to one side) indicates an asymmetric aerodynamic load, such as in a rolling maneuver during the failure.
- It is not unusual for the failure of an outboard wing panel to result in significant secondary damage to the aft fuselage and tail surfaces, including the in-flight separation of one or more empennage surfaces.
- Careful observation of the wreckage and a two-dimensional reconstruction of the wreckage are necessary to determine the failure sequence to identify the primary failure.

4.15 Wire Strikes

In the majority of cases, wire contact to aircraft is obvious. In cases where the wreckage has been consumed by a fire or no other apparent explanation exists for an accident (and if wires are present along the approach bearing of the aircraft), the possibility of a wire strike should be considered. Wire contacts usually result in separation of various aircraft appendages, and they will most likely be found under the wire struck by the aircraft.

High-voltage cross-country conductors are relatively large diameter steel-cored wires with a wrapping of aluminum strands. The high-tension towers usually carry "sky" wires strung above the conductors and between the towers. They are not conductors but serve as static structural elements of the towers. They are typically made of steel and will remain intact though damaged after a wire strike. These wires may also be severed in the collision sequence, depending on the type of aircraft and propeller involvement. Relatively low-voltage residential-type conductors or telephone wires are more fragile and are usually severed. However, depending on the type of aircraft and the part(s) of the aircraft contacting the wire, the wires may not be severed.

If a wire strike is possible but not readily apparent on the wreckage, the investigator should examine the wires and the area beneath them along the approach bearing of the aircraft's flight track. Wire strikes usually result in some aircraft debris falling beneath the wires in proximity to the impact point. In scenarios involving the steel-cored high-voltage wires, the most visible evidence will be the aluminum strand wrap, which may exhibit a frayed appearance and may be bunched into a ball at the impact point. Insulated low-voltage or telephone-type wires may or may not show disturbance to the insulation.

On the aircraft, look for striations and scrape marks that will have a pattern resembling wire strands. Semicircular gouges in propeller leading edges should be examined closely for strand-like patterns or arcing evidence. Material transfers matching the insulation will be evident on those parts of the aircraft that contacted the wire. Arcing evidence may or may not be evident, depending on whether the impact geometry favored a grounding of the conductor.

In most cases, the utility company that owns the wires will inspect the lines if a wire strike is suspected. Because power transmission lines are always monitored by distribution control centers, power companies can also provide the time that a ground fault (the airplane to wire contact) was recorded on a particular line.

4.16 Fire Investigations

Investigations involving fires, whether in-flight or postimpact, can be difficult because of the degree of damage and the resultant destruction of evidence. However, considerable evidence can be collected if the investigator knows where to look and how to interpret the evidence. Important safety improvement and crashworthiness survival factors information can be collected from a careful examination of postimpact fires. Important evidence pointing to airworthiness issues may also be hidden in the remains of a fire.

The following information on fire dynamics and traceable origin point signatures is useful in investigations involving fires:

- Fire needs fuel, heat, and air in the right proportions to sustain combustion. The more fuel and air available to a fire, the hotter the fire will burn. Combustion will continue with oxygen concentrations as low as 16 percent (normal ambient atmosphere contains 21 percent oxygen).

- For a fire to start, the right mixture of fuel vapor and air has to occur at the moment a source of ignition happens.

- Fires do not directly consume the fuel[29] they use; the fuel is heated to a gaseous vapor state, which then combines with air and is burned. This means that most anything, including metals, will burn if the temperature is hot enough to ignite the material.

[29] In this context, fuel is considered to be all of the combustible materials in the aircraft, such as paint, seats, and upholstery, carpets, paper, etc.

- This vaporization process, in concert with the heat buildup in a closed structure like an aircraft cabin, can result in the flashover effect, which can be intensely hot. Flashovers occur when a smaller fire heats the interior ceiling spaces (or whatever is oriented up) of a closed space to the ignition points of the various materials. The heat buildup near the ceiling from a relatively small fire in a closed fuselage can reach over 1,000° Fahrenheit (F) in short order.

- Just because an aircraft is burned into a pile of ash does not mean that a significant quantity of fuel was in the fuel tanks. As noted, once a postcrash fire gets to the combustible interior upholstery, the subsequent flash-over effect and resultant intensely hot fire in the cabin can consume the fuselage of an aircraft that may have had very little fuel in the tanks.

- Normal fires burn up and out, leaving a "V" or chevron-shaped pattern, the apex of which points toward the origin area of the fire. Accelerant-based fires leave an hourglass-shaped vertical burn pattern. Slow smoldering fires have a wide base burn pattern.

- Electrical arcs produce temperatures in the spark between 5,000° and 6000° F.

- Glass will melt in toward the fire area.

- The areas with the most destruction are typically the places where the fire burned the hottest and/or the longest and may very well constitute the origin area of the fire. Conversely, these may also have been the areas containing the largest, easily consumed fuel source or a source of oxygen.

- The heat effects, smoke, and soot from a fire will follow the airflow patterns, leaving a trail of heat-affected materials and soot deposits. Looking for the airflow patterns is a crucial first step in defining in-flight versus postimpact origin.

Investigators should evaluate the damage, heat, and smoke/soot patterns to identify candidate origin areas. Plot the temperature progression in the burned areas and work backward from the least to the most damaged areas of the wreckage. Because fires require three things to start and continue (fuel, air, and ignition), the investigative process carefully examines each area where these factors were present.

Fires consume the things they burn, leaving ash residue, which is considerably reduced in volume from the original mass and shape of the object consumed. As the object is consumed, the residue (ash and components not consumed) will be affected by gravity and will fall more or less straight down. This process produces layers of residue deposited in the same order as the material was consumed. Sometimes, material at the lowest level will be covered in ash before it is consumed and will be relatively protected. Logbooks or other important paper records may, in fact, be under that pile of ash. Other important physical system component evidence may be in the ashen remains. Investigators can borrow archeological dig techniques tools (paint brushes and trowels) to excavate fire residue one layer at a time. The evidence may be quite fragile, so care and patience is required for this excavation process. Investigators should have a clear picture in mind of the item(s) of importance and the imagination to picture what the object might look like when partially burned or melted.

From an airworthiness standpoint, in-flight fires are of the most concern and early determination of whether the fire was in-flight or postimpact is important to the investigation's scope and direction. Some characteristics to help the investigator make the initial in-flight versus postimpact determination are presented below:

- In-flight fires burn more intensely than ground fires due to the forced-draft effect of the slipstream airflow. Resultant temperatures range between 2,500° and 3,000° F and can reach higher levels.
- Postimpact ground fires typically burn in the 1,500 to 2,000° F range.
- In-flight fires create smoke, heat, and soot patterns that follow the air slipstream flow. Protuberances into the airflow have clean shadow areas on the aft/lee side. Smoke and soot will build up on the leading edges of rivet heads, skin panel joints, and plumbing fixtures, etc. The side aft of the protuberance will be clean.
- Postimpact ground fires create smoke, heat, and soot patterns that are principally vertical with prevailing wind-induced vectors.
- In-flight fires produce molten metal deposits that flow with the slipstream.
- Postimpact ground fires will produce molten metal deposits that pool.

If investigators are unsure of the signatures observed or find a confusing evidence set, local assistance may be available. Most large municipal or state level fire departments have arson investigation units. Arson investigators, although they may not necessarily be knowledgeable about aircraft, are experts in deciphering fire signatures, origin points, ignition sources, and the presence of accelerants (flammable fluids). Investigators who require expert help to understand and initially evaluate the fire evidence on-scene should check with the local fire authority. In many cases, the arson unit will be happy to provide an initial assessment. Additionally, the Office of Research and Engineering employs fire specialists that can assist you.

4.16.1 Electrical Fires

Most electrical fires result from overheated wires in contact with combustible materials and typically result in a single point of origin that will exhibit the classic V-shaped patterns. Overheated wires require excessive current, insulation to contain and focus the heat, a fuel source, and oxygen to develop into a fire. Wire circuits that cause fires typically do so at a junction or connection in the wiring. If a wire overheats due to excessive current, there will be uniform damage to the insulator and conductor along its entire length. More localized damage may be present where a wire passes through an insulated space. Shorts or ground faults in solid wires will exhibit beading on the wire tip, while intermittent faults will show a splattering effect. Shorts or ground faults in stranded wires will produce a stiff wire, due to the strands melting together.

If an electrical origin to a fire is suspected, the electrical system should be examined systematically for evidence of faults or source points. The following is a suggested protocol for the systematic examination:

- Begin at the electrical source (battery and alternator), and examine the wiring from the source to the buss bar, checking for ground faults, evidence of localized heating, arcing, or beading signatures in the wires.
- Examine the circuit breakers (protectors) and wiring coming off the buss bar, noting the sizes and conditions of the circuit breakers (CBs) or fuses. Note what circuits are served by any tripped, blown, damaged, or bypassed protectors. Examine the protectors for evidence of proper installation.
- Trace wiring from the bus bar to the area of the fire origin (using aircraft wiring schematics as needed), evaluating the circuit wiring for adequate size for the maximum rated circuit load (number of amps if all devices on the circuit are turned on). FAA Advisory Circular 43.13-1A contains a conductor size chart for this purpose. Check the wiring physical condition for evidence of carbon arcing, loose connections, foreign object contamination, worn switches, or non-insulated splices.
- Evaluate all electrical devices to ensure they were connected to the proper circuit and to the proper and correctly rated CB/protector.
- Evaluate broken wiring for evidence of overloads, shorts, arcing, or external fire influences.
- In cases of shorts or overloads, stranded wire will be stiff due to fusing of the strands together, with beading in the strands and on the insulation.

4.17 Crashworthiness and Survival Factors

Survival factors integrate impact and postimpact elements with occupant injury to determine why occupants survive or do not survive an accident. A great deal of survival factors data and information can be obtained from limited and C-form accidents, so the IIC is encouraged to work with the FAA and parties to actively collect survival factors data and information for all accidents.

The crashworthiness evaluation of general aviation aircraft requires the collection of data that address three areas; occupant injuries, impact severity, and the aircraft's occupant protection capabilities. The causes of injury can be related to both the severity of the impact and the ability of the structure (including seats and restraints) to protect the occupant from impact.

Precise measurements of crush damage, impact angles, estimated velocities, and distances can be used to estimate the forces experienced by the vehicle and the occupants. (The formula and examples for gathering the information required are listed in Appendix 6.) In addition, an excellent resource for detailed information on the formulas and methodologies for crashworthiness investigations can be also be found in NTSB reports on the *General Aviation Crashworthiness Project*, Phases 1, 2, and 3.[30]

In general, a survivable accident is an accident in which the forces transmitted to the occupant through the seat restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided for the occupants throughout the crash sequence.[31]

Other factors, including egress ability and time, fuel system crashworthiness, fire ignition and progression, and rescue/medical response, are also part of the survival equation. For air carrier accidents, the list is longer and more complex. (See Appendix 5 for a checklist for items typically examined in air carrier events with survival factors issues. Additional information on this topic can also be found in the Major Investigations Manual.)

In a crash sequence, structural crush, collapse of the seat supports and seat structure, and the nature of the objects impacted all absorb some of the deceleration forces generated in the accident. The occupant experiences the balance of the loadings not abated by the vehicle and seat structure. The human tolerance envelope for deceleration forces depends on the direction, magnitude, duration, and onset of the forces transmitted to the individual. Individual tolerance also depends on the occupant's age and physical condition.

Deceleration forces in an impact sequence are functions of velocity and the stopping distance. The higher the speed and the shorter the stopping distance in the impact sequences of a major deceleration event, the higher the g loading to the vehicle. One indicator on the amount of loading transmitted to the occupant involves examination of the seats and other points on the structure where definitive load limit values are known. Manufacturers can supply the seat design standard, and the results of any testing during certification. Manufacturers can also supply design data that can translate the degree of collapse of various structural elements, such as skids and skid cross tubes for helicopters, or landing gear attach points for fixed-wing aircraft.

"Livable volume" around the occupants indicates that there was no impingement to the occupied space by the aircraft structure or any other external or internal object. Examine and measure the structure for evidence of the amount of crush and collapse represented in the fuselage/cabin folds and wrinkles. A few measurements of the folded areas on the fuselages skin can approximate the maximum structural collapse around the occupied area of the seat(s).

A thorough examination of the seat tracks, locking devices, and the seat structure is needed to resolve the question of the seats remaining secured to the structure and the direction and degree of deformation. Most seat installations use a pin type-locking device, which engages holes in the seat tracks. If the locking pin was engaged, the impact loading would bend/break the

[30] The report and government accession numbers for these three reports are: Phase 1, NTSB/SR-83/01, PB83-917004; Phase 2, NTSB/SR-85/01, PB85-917002; Phase 3, NTSB/SR-85/02, PB85-917016. All are available through the National Technical Information Service.

[31] Does not take into account fire or explosive combustion events or other influences external to the vehicle that are not in the impact sequence.

pin and perhaps elongate the associated track hole. As noted previously in Section 4.9, the tracks will often contain gouges left by the seat leg feet as the seat moves along the track in the impact sequence. As the cockpit floor distorts in the impact sequence, the seat leg feet frequently separate from the tracks. The feet and/or the tracks can exhibit such distortion. Finding seats loose on their tracks is not unusual at the accident site, particularly in the high-angle/energy events. A few relatively simple measurements can document the deformation of the seat legs and seat pan/back. Again, the manufacturer can usually supply certification test data to translate this deformation into probable loading.

Restraint system components should be examined for evidence of use and adequacy. Look at the structural attach points, the buckle/latching mechanism, and the webbing for failures or unusual loading signatures. Evidence for significant loadings may be found on the deformation of the structural attach points, single point loadings on the buckle tangs and tongues, and localized stretching or stitch failure of the webbing. The aircraft or restraint system manufacturer can supply design and/or test data to translate this damage into loadings seen by the occupant. Look for the data tag on the restrain belts and buckles. These items are required to be manufactured to an FAA technical standard order (TSO) standard. There have been some instances in which worn aircraft restraints were replaced with automotive equivalents that were not manufactured to TSO standards, and the subsequent failures have been implicated in injury severity. The web material and the stitching deteriorates over time, especially when exposed to ultraviolet radiation. In cases of restraint web material failures, the material should be pull-tested to see if it meets the TSO specifications. Inertia reels should lock and release under appropriate loads.

Another area for examination includes the operability of all exits, especially in the case of fire fatalities where crash forces were likely survivable. Additional investigation points include the emergency locator transmitter (operation and mounting), the adequacy of the search-and-rescue efforts, and the crashworthy design of various systems and fittings—anything that is relevant to the survivability of the occupants.

4.18 Human Performance Aspects

Decisions or actions by flight crewmembers, servicing personnel, maintenance technicians, or dispatch staff of a commercial operator can contribute to and cause accidents. The human performance part of an accident investigation examines influences behind human failures.

Background influences on behavior include the training the individual had for the task, the ergonomics of the task or cockpit controls, and the personal interactions affecting the individual's life. They can also include medical conditions that influence an individual's capability and suitability for the task. (See appendix 7 for a detailed human performance investigation checklist.)

The human performance investigation begins with gathering the personal background information on the individuals of interest. A 72-hour history is generally sufficient, but longer historical periods can be documented, as necessary. The type of information includes sleep/rest/duty periods, eating habits, behavioral patterns, life stressors, family relationships, general and specific health problems, and medications used. The individual's training and job history should also be documented, along with the duties related to the accident and the individual's performance history. Examine the task profile related to the accident for difficulty, environmental influences, workload, diversions, and any time constraints. The cockpit design or work environment, including control/display/tool design adequacy and environmental distractions, should also be examined. In the case of companies, a look at the overall influence of management philosophy, oversight, and personnel practices should be included.

4.19 Investigations Involving Part 135 Operations

Part 135 operators range from small and large companies engaged in charters, to scheduled commuter operators operating many airplanes over a large route system. This diversity in operations makes general procedural guidance difficult. However, these operators, like their Part 121 air carrier[32] counterparts, have FAA-approved operating procedures that are contained in operations specifications (OpSpecs). Although the minimum standards that the operator must adhere to are contained in the regulations, 14 CFR Part 135 and 91, the FAA-approved operations specifications delineate the specific requirements that the operator must comply with during operations (and these may exceed the regulatory minimum). Included in the OpSpecs are approved maintenance programs for each aircraft; pilot and other critical employee experience and training minimums; and the specific operational mandates for dispatch, load planning, weather minimums, approach procedures, and flight following.

In accidents where errors are likely or suspected in the areas of operations, dispatch, personnel qualification/training, or maintenance, the first step is to obtain a copy of the OpSpecs to find out the procedural standards that the FAA requires of the operator. The investigative process then compares what occurred with the procedures and requirements that the carrier is required to follow.

In accidents where deficiencies exist, investigators should look at the operator's corporate culture and FAA oversight and surveillance. The FAA office in the geographic location of the operator's corporate offices is responsible for issuing the operations certificate and specifications to the operator and also has the principal surveillance responsibility. This FAA office is where the principal operations inspector (POI), principal maintenance inspector (PMI), and principal avionics inspector (PAI) are based. These respective inspectors have primary responsibility for certification oversight of the carrier's operation. It is possible for the main operations base of the operator to be located in another FAA office's jurisdiction, while the office with principal jurisdiction over the operator is located where the company headquarters is based. In this case, the principal FAA office arranges with the other FAA office for routine surveillance of the operator, usually through the second FAA office's geographic unit.

In cases where FAA oversight and surveillance patterns are potential issues, the investigator should first ask the FAA coordinator for a Safety Performance Analysis System database (SPAS)[33] printout on the operator. This report will detail any inspection, surveillance, or contact by any FAA office with the identified operator. Use this report to examine the

[32] Refer to the Major Investigators Manual for Part 121 air carrier incident and accident investigations.
[33] The SPAS system has taken the place of the Performance Tracking Reporting System, which was formerly used to identify FAA contacts with particular operators.

surveillance pattern with the operator. Other records to examine are the last base inspection conducted by the POI/PMI/PAI and the number of times a remote operations base was visited by other FAA offices. In some cases, the experience, training, and workload of the POI and PMI should also be examined.

The regional investigator should consult with specialists in the Operational Factors Division (AS-30), and the Major Investigations Manual, for additional guidance.

4.19.1 Fractionally Owned Aircraft

IICs should be aware that there are some specific differences between how a Part 135 operator and a 91 K (fractional) operator is structured and overseen by the FAA; e.g., OpsSpec versus Management Specification. Unique factors related to fractional aircraft ownership and an investigation that involves a fractionally or separately managed aircraft should be thoroughly understood when developing operations issues. Contact NTSB operations specialists (AS-30) to clarify information.

4.20 Maintenance, Operations, and Flight Crew Records

The scope of records and information review for maintenance, operations, and pilot issues can range from simple aircraft and pilot log books in a small general aviation aircraft investigation to considerable data in air carrier investigations.

Although falsification of records is relatively rare, the investigator should never take for granted that a record entry is true, especially in specific areas where issues or questions exist. In these cases, look for corroborative evidence that supports the record entry. For example, a straight maintenance logbook entry generally states only that a component was replaced or an inspection was completed. The detailed information is contained in the work orders, job cards, inspection checklists, scratch shop working notes and parts consumed/ordered lists, and perhaps even in the payroll records detailing specific billing projects on which a mechanic may have worked during a given day.

The operations, training, and pilot records areas are also places to look for evidence to support record entries. For example, if a Part 135 line check ride form says a particular pilot, and check airman flew a certain airplane for 1.3 hours on a given day, what do the other available maintenance and operations records show? Was the airplane in the shop for an engine change? Do the operations and pilot payroll records show that airplane was instead conducting revenue flights at another base during the time that it was supposed to be on a training or check ride flight? Ask yourself what other records are available to corroborate or disprove a particular record entry.

When looking at records, always try to get an overall picture of the activity while searching for specific detail. It may be more productive to scan the records first for broad patterns that might point to problem areas. For maintenance records, some of the broad patterns of interest include flight activity (Was it a hangar queen for 10 years before the accident, or was it operating regularly?), component and maintenance activity history (Does the engine go through particular cylinders in short time periods?). Do specific components wear out more rapidly than they should, or are particular systems more problematic than others? This method of looking at the overall pattern also works for operations and pilot record reviews.

Do not forget the FAA aircraft file containing the Form 337 modification history. Also, review the airworthiness directive (AD), service bulletin (SB), and service letter (SL) compliance history for the aircraft/engine/component, and compare them to the manufacturer and FAA lists of applicable directives, bulletins, and letters. For pilots and commercial operators, get copies of the airman and medical records files from the FAA to examine the pilot's history, including certification and violations, and sanctions charged or imposed. The FAA coordinator can help obtain certified copies of the FAA files on the aircraft, pilot, and pilot medical records. The history of a commercial operator can be obtained by requesting a SPAS readout for that particular operator.

Regional investigators should consult with specialists in the Operational Factors Division (AS-30) for pilot records, and the Aviation Engineering Division (AS-40) for maintenance records, and the Major Investigations Manual, for additional guidance in these areas.

4.20.1 Maintenance Records

Early in the notification and coordination phase, instruct the operator to collect and secure all maintenance records for the aircraft. In cases where the operator's base is far from the accident site, consider asking the local FAA FSDO to pick up the secured records from the operator. Many of the documents listed below are applicable to general aviation accidents.

Items to be Reviewed

- Company flight manual for aircraft involved
- Operational weight and balance regulations
- Aircraft flight log
- Manufacturers' flight and maintenance manuals
- Mechanical irregularity reports
- Complete overhaul and inspection reports for engine, propellers, and equipment
- Preflight inspection records
- Maintenance and repair records, including job cards, work orders, etc.
- Flight log prepared by the crew
- Flight operations bulletins and newsletters
- Applicable ADs and compliance
- Service difficulty reports (SDRs)
- Manufacturers' SBs and SLs
- Aircraft logs and records
- Maintenance practices of the operator
- Engineering changes and modifications

Maintenance Management

- Standards and procedures

- Quality assurance
- Equipment and facilities
- Personnel and training

4.20.2 Operations Records

The IIC should also contact the operator and ask that all records related to the dispatch or operation of the accident flight be secured. These secured records should be examined, or arrangements made for pickup, at the earliest convenient time. Obtain a signed statement for all persons involved, and remember that any interviewee has a right to legal representation. Following are typical records available for investigative review:

General Information

- Crew (flight deck and cabin) written statements. Conduct interviews, as necessary, of the appropriate crewmembers for the event at issue.
- Ground service or maintenance personnel written statements. Conduct interviews, as necessary, of the appropriate personnel for the event at issue.
- Captain's and/or lead cabin attendant's report of irregularity.
- Aircraft and/or cabin logbook, as appropriate
- Fligh plan
- Flightplan log
- Dispatch flight release
- Weight and balance
- Flight inspection report
- Charts used
- OpSpecs
- Aircraft flight manual
- Operator's operations manual
- Operator's training manual
- Operational contracts
- Airport diagrams and airport master log
- Cargo and weight manifest
- Fuel and oil record
- Company radio transmissions
- Airport certification

4.20.3 Flight Crew Records

As in the maintenance and operations areas, the following are typical records usually available in commercial operations.

Flight Crew Information

- Employment history

- Date upgraded to captain (accident aircraft)
- Prior and concurrent aircraft assignments
- Training records (initial and recurrent)
- Total pilot time
- Total pilot time: last 30, 60, 90 days
- Total pilot time, in type
- Total pilot time, in type: last 30, 60, 90 days
- Total instrument time
- Total instrument time, in type
- Total instrument time: last 30, 60, 90 days
- Total instrument time, in type: last 30, 60, 90 days
- Total night time
- Total night time: last 30, 60, 90 days
- Certificates and ratings held and dates acquired
- Proficiency checks
- Line checks
- En route inspections
- Letters of reprimand or commendations
- Domicile chief pilot's formal and informal (sometimes called the "bottom drawer" file) records on the crew in question

Flight Attendant Information

- History of employment
- Initial and recurrent training
- Training in accident aircraft
- Concurrent training or assignment to other aircraft types

4.21 Recording Devices

Flight Data Recorders (FDR) and Cockpit Voice Recorders (CVR) are required on board certain aircraft by regulations set forth in 14 CFR Parts 91, 121, 125, and 135 for accident investigation and prevention. They are required under 49 CFR Part 830 to be preserved by the aircraft operator for NTSB use to determine the facts, conditions, and circumstances relating to an accident or reportable incident. The regulations further state that information recorded from CVRs is to be used to assist in determining the cause of accidents or occurrences in connection with investigations under 49 CFR Part 830 and is not to be used by the FAA for enforcement action. Flight recorders found optionally installed on aircraft not requiring them are also required to be preserved for NTSB use.

FDRs and CVRs are most commonly painted bright orange or red, although a few are painted bright yellow. Reflective tape is applied, and the words "FLIGHT RECORDER——DO NOT OPEN" may appear on the outside surface in one or more languages. Both voice and data recorders are required to be mounted in airplanes as far aft as practical, but there is no similar requirement for helicopters. Under no conditions should any attempt be made to disassemble or download an FDR or CVR in the field. The recording could be erased or damaged.

Regional investigators must follow the specific guidance provided in the NTSB's Flight Data Recorder Handbook, and Cockpit Voice Recorder Handbook, when investigating accidents and incidents with recording devises available. In general, FDRs and the CVRs must be handled as follows:

- Protect the recorder from strong magnetic fields. Remember that an X-ray transmitter at an airport security station may damage the data. If a recorder, tape, or solid state memory unit is mailed, please mark the package "SENSITIVE FLIGHT RECORDING WITH CRITICAL DATA. DO NOT EXPOSE TO X-RAY RADIATION OR MAGNETIC FIELDS."

- Do not open the recorder. Do not allow anyone to remove the tapes or solid-state memory unit under any circumstances.

- If the recorder is dry and undamaged, use a shipping container obtained from the operator involved in the accident or incident, if possible. Otherwise, package it carefully for shipment, unless it is to be hand-carried; it is not necessary to package an undamaged recorder for hand-carriage.

- If the case is broken, do not remove the tape or solid-state memory unit from the device. Wrap the entire recorder and its contents in polyethylene or similar material or heavy paper before packaging for shipment. If you have any questions about what to look for, e.g., how many internal subassemblies exist, etc., please contact the NTSB Vehicle Recorder Division.

- If the tape reels or solid-state memory boards are separated from the unit, wrap them in polyethylene or paper before applying sealing tape. Never apply sealing tape directly to the recording medium. Do not remove the recording medium from the reels or enclosure.

- If the recording is a tape and it is found separated from the recorder, try not to wrinkle or crease it. Carefully wrap it on a spool or cardboard tube or something similar. Wrap this in polyethylene or paper, and pack it carefully. Enclose all fragments of tape, no matter how small. Never stuff the tape randomly into a box or container. Data are easily degraded; creases and wrinkles can cause electronic noise and permanent data loss.

- If the recorder is from a major accident, get it to the Vehicle Recorder Division lab by the fastest, most secure means possible. If an investigation team travels to the scene via the FAA airplane and the airplane is returning to Washington immediately, arrange to ship the recorder on it. Otherwise, the recorder must be hand-carried back to headquarters by an NTSB employee or a person designated and approved by the Director, Office of Aviation Safety. Circumstances may require that the recorder be transported back to Washington on a non-stop commercial flight in the custody of the flight crew. If transported this way, it is imperative that the transfer be coordinated by the IIC and the lab and that the recorder be picked up at the Washington, D.C., area airport by NTSB personnel. If the recorder is from a non-major accident or incident in which its quick return is not essential, it may be shipped (properly packaged) by registered mail overnight express, commercial shipping service, or hand-carried. Contact Vehicle Recorder staff for information about hand-carrying recorders.

- If the recorder is found in water, do not attempt to dry it. Rinse it in fresh water, preferably distilled, then arrange to ship the recorder immersed in water to the lab in a watertight container. Make sure the recorder stays immersed in water until it arrives at the laboratory. Pack it very securely. If the recording medium is tape, it must not be allowed to dry out under any circumstances.

The NTSB Vehicle Recorder Division is responsible for recovering data from recorders to support NTSB investigations. It is very important to secure recorders as soon as possible after an accident or incident and to deliver them intact to the Vehicle Recorder lab at Washington headquarters so that the laboratory may obtain the best possible recovery of the relevant data in a controlled atmosphere using an experienced staff. All requests for CVR and FDR readouts must be made to the Chief, Vehicle Recorder Division.

When accepting custody of a recorder from airline personnel or others at an accident site, complete an NTSB Form 6120.15, Receipt of Aircraft Wreckage, and enclose one copy of the form in the shipping container. This will provide the NTSB with information on how to return the recorder to the owner as well as provide documentation on the NTSB's receipt of the recorders from the owner. A copy of the ADMS/eADMS preliminary report should also be enclosed, and/or any other pertinent information regarding the accident. Address all shipments to:

National Transportation Safety Board
Office of Research and Engineering, RE-40
490 L'Enfant Plaza East, S.W.
Washington, DC 20594

4.21.1 Flight Data Recorders

The required parameters recorded by the FDRs for each aircraft type are detailed in the applicable federal aviation regulations (FARs), but many operators record additional information. Because of the large variation in recording parameters among aircraft operators, the FDR laboratory of the Vehicle Recorder Division maintains a computer system to catalog the decoding software.

There are two types of FDRs in existence. Most are magnetic tape recorders, referred to as DFDRs. The other is the solid-state digital flight data recorder (SSDFDR). The two are functionally equivalent and are visually similar. The SSDFDR has the advantage of having no moving parts and should, therefore, prove more reliable in extended use.

Regardless of the type of recording medium, magnetic tape or solid-state memory, the FDR is required to record a minimum of 25 hours of data. Most accident investigations will be satisfactorily served with 25 hours of recorded data available. However, in investigations of some incidents, the NTSB must take timely possession of the FDR, or pertinent flight information may be lost. Likewise, if FDRs from aircraft not involved in the accident or incident need to be examined and if the appropriate FDRs are not withdrawn from service within 25 hours, pertinent data will be lost. For those cases, expeditious notice to the operator to remove and hold recorders involved in an accident/incident is necessary to prevent the required data from being overwritten.

The Vehicle Recorder Division laboratory is prepared to give accident investigation FDR readouts high priority. Upon notification of an FDR readout request, lab staff will begin collecting the necessary documentation to decode the FDR. As soon as that information is collected, the IIC will be provided with the parameter list. This could occur almost immediately if the lab has the documentation on hand; provision of the list to the IIC could take 1 or 2 days if the lab does not have the documentation on hand.

Upon receipt of the FDR in the laboratory, it will be inspected, disassembled if necessary and its condition documented. The specialist assigned will then perform a preliminary readout. Any significant information developed will be immediately transmitted to the IIC. Work on the readout will progress whether or not an FDR group is expected to convene.

Not every investigation will require an FDR group to be convened. A major go-team type accident will usually involve an FDR group. However, regional investigations may also result in the formation of a group. With the growing complexity of aircraft systems being reflected in the increased complexity of the FDR-recorded data, formation of FDR groups for non-major investigations is occurring more often. The Vehicle Recorder Division staff specialist assigned will recommend to the IIC the advisability of forming an FDR group. The group, if convened, will be comprised of those parties who can provide specific technical assistance (generally one representative for each such party). The type of expertise required generally includes knowledge of the method of data recording and the relationships of the recorded variables to the aircraft systems.

The group will work until the group chairman is satisfied that the preliminary readout of the pertinent parameters is obtained. During the process of recovering data from the recorder, the data will be examined in sufficient detail to determine if the parameters appear reasonable and to provide for timely delivery of relevant information to the IIC. Dissemination of preliminary data to party representatives not actively participating in the group effort will be coordinated with the IIC and will be based on their ability to assist the NTSB in understanding the accident and for prevention purposes. The group chairman will not release any copies of the original FDR recording to any parties until the group has finalized the preliminary readout and is preparing to disband. As soon as the group has prepared a preliminary readout, the IIC and the group members will be provided a copy. Copies of the original FDR tape or disk or copies of the reduced data may then be made available to parties who need to know and with permission from the IIC. The FDR group will not be dismissed until the IIC is consulted and authorizes the FDR group chairman to do so.

The FDR factual report is a document that details the factual aspects of the recovery of the FDR data and presents the FDR data in a tabular listing or plots, or both. The FDR factual report will not interpret the data. Detailed interpretation of FDR data is necessary to produce an aircraft flightpath reconstruction. Likewise, the determination of how an aircraft's system performed often relies heavily on an interpretation of FDR data. If an IIC needs the FDR data interpreted, or placed into context with other factual data, this should be discussed with the Chief, Vehicle Recorder Division. The FDR specialist will not include such interpretations within the FDR factual report, although that specialist (or another specialist) may be assigned to prepare the related study.

4.21.2 Cockpit Voice Recorders

In all accident investigations, the contents of CVRs and transcripts of the recorded data are strictly regulated. IICs should adhere to the detailed procedures found in the Major Investigations Manual and NTSB's Cockpit Voice Recorder Handbook.

4.21.3 Other Types of Recording Devices

Many aircraft in service today have recording devices other than CVRs and FDRs. These recordings typically come from devices that are not required by regulation, nor are usually crashworthy. Nonetheless, valuable information can be recovered from them. They generally fall into two categories: maintenance recorders and non-volatile memories from digital avionics systems, engine fuel controls, and other components.

The operators use maintenance recorders to track the health of the aircraft and its various systems. They sometimes record information far in excess of what is required on the FDR. These recorders may be referred to as quick access recorders, airborne information data systems recorders, or airborne information management system recorders. The NTSB is capable of reading some of these recorders, but for those that it cannot read, the operators will provide an expeditious readout using their maintenance facilities, under NTSB direction or supervision.

Non-volatile memory units from digital avionics systems may also provide valuable information. Non-volatile memory may exist for autopilot systems, flight management systems, electronic engine controllers, and navigation systems. Hand-held GPS units also typically have non-volatile memory, some with substantial, useful data on historical track, waypoint and altitude. The NTSB can extract data from some of these devices, but sometimes the manufacturer's assistance is necessary. In addition, most high-performance competition gliders have devices that digitally record GPS-based altitude, speed, course, and ground track positional data for use in the substantiation of race competition claims. These data are sampled generally at intervals of under 1 minute. Some older systems record data using paper or foil-tape tracings.

The investigator should ask the appropriate operator or party if there is a quick access or maintenance recorder installed on the aircraft. Determining the existence of non-volatile memory in other potential units or devices may be more difficult because a representative of the supplier of the specific subsystem will not typically be on scene.

Investigators should not overlook the information that might be available in video cameras, tape recorders, and still cameras found in the wreckage. Tape recorders and the audio channels of video recordings can have important sound spectrum information, including engines rpms, propellers, rotor systems, transmissions, and cockpit aural warnings. The CVR lab can perform sound spectrum analysis of these recordings and provide useful information for the investigation. The laboratory will need the frequency of any cockpit warning tones and the number of blades associated with the propeller or rotor system. Other sounds of potential value include the harmonic frequency of helicopter gearboxes. Some of this information might also be recorded on ATC air-ground communications tapes. Video recordings and even still photographs (from within the aircraft and taken by witnesses) can be used by the Vehicle Performance Division to reconstruct angles of attack, acceleration profiles, and other critical aircraft performance information.

4.22 Materials Laboratory Examinations and Component Testing

If a material failure is suspected or if detailed examination of a part is desired, the IIC should seek the assistance of the NTSB materials laboratory. Even if an outside laboratory or manufacturer's facility is used for an examination, the materials maboratory should be consulted first. When the determination is made to have the part/component examined at the NTSB's laboratory, contact the lab before shipping the part. Accompanying the part should be a copy of the Preliminary Report of Aviation Accident/Incident, along with a Request for Materials Laboratory Examination Form. If the issues are complex, telephone or e-mail the materials laboratory specialists with detailed information about concerns or special circumstances. Arrange with the component's manufacturer to supply the laboratory with a contact name and phone number for follow-up questions that the metallurgist will have about part specifications and material processes. When an outside lab is used for metallurgical testing, a copy of its report should be sent directly to the NTSB lab. Generally, when possible, the RC should be consulted before the decision to have the suspect part sent to either the NTSB lab or an outside lab.

Testing, inspection, or teardown of a part or component is also frequently required. Depending on the part or component, the IIC will have to determine what can be accomplished at the accident site and what must be done elsewhere. Off-site testing should be performed at either the NTSB laboratory, a repair station, or at the manufacturer's facility. The IIC is responsible for informing the parties to the investigation when and where additional off-site testing will be performed. The parties should be offered the opportunity to be present at all component examinations. The IIC, group chairman, or an FAA employee designated by the IIC will oversee all off-site testing.

When parts/components are retained for testing, the NTSB is responsible for returning the items to the owner or owner's authorized agent, in accordance with the instructions and understanding reached at the time the parts were retained. All parts retained by the NTSB will be noted on a Release of Aircraft Wreckage form, NTSB Form 6120.15. When the NTSB has completed its examination/testing, parts will be shipped back to the owner in a manner that precludes damage or mishandling. When appropriate, use registered mail or airfreight systems, which provide tracking and proof of delivery. An updated Release of Aircraft Wreckage form should be included in the shipment to be signed by the recipient and returned to the IIC for inclusion in the factual report.

It is important for the IIC to obtain a cost estimate for part/component testing and teardowns before committing to having the work performed. Payment for services should follow the current administrative guidelines or NTSB orders.

Component tests and examinations should be approached with the same careful protocol considerations used during the on-scene wreckage investigation phase. Remember, you cannot functionally test and disassemble at the same time and have any meaningful information developed. Choose a basic initial fault tree branch course based on the accident scenario and the probability of contamination and/or maintenance/manufacturing process errors. Give careful consideration to the information needed and then determine a protocol that will best help answer the questions posed. Functional testing should be accomplished in as close to the original aircraft and system context as possible. Seek input from knowledgeable technical sources on how the component functions and how best to conduct the test or examination.

Careful documentation of the component test and/or examination is important. Take enough detailed notes and photographs to document the process steps, especially if the examination will destroy or alter the evidence. Large firms or manufacturers often photo document each step of the process and produce a detailed report of the examination. However, the investigator should take enough notes and photographs to have a basis for determining the accuracy of the manufacturer's submission.

4.23 FAA Aspects involved In the Investigation

Under the provisions of the Federal Aviation Act of 1958 and the Independent Safety Board Act of 1974, as amended, the FAA is the only entity with a statutory right of participation in NTSB aviation investigations.[34] As designated participants, the FAA representatives appointed to our investigations have the same privileges and responsibilities as any other party participant, including the burden of remaining responsive to the needs of the investigation and direction of NTSB personnel. However, the FAA representative participating in the investigation also must wear another hat by fulfilling the congressionally mandated responsibilities of the FAA.

4.23.1 Federal Aviation Administration Responsibilities

The congressionally mandated FAA responsibilities pertinent to aircraft accident/incident investigations are contained in 49 U.S.C. 40113 and 44702 and require that the FAA:

- Ensure that all facts, conditions, and circumstances leading to the accident/incident are recorded and evaluated, and appropriate action is taken to prevent similar accidents.
- Promulgate and enforce FARs for certificating civil aircraft airworthiness, for certificating airmen and air carriers for competency, and for certifying airports used by 14 CFR Part 121 and 129 air carriers for compliance with regulatory safety standards. This responsibility includes the continued surveillance of aircraft airworthiness, the

[34] This does not exclude the rights of designated foreign states to participate in selected aviation accident investigations under the provisions of the ICAO treaty.

safety of certificated airports, and the competency of airmen, air agencies, commercial operators, and air carriers. In the discharge of these responsibilities in investigations, the FAA representative is charged with ascertaining whether any of the following eight areas were factors in the accident/incident:

- Performance of FAA facilities or functions
- Performance of non-FAA-owned and -operated ATC facilities or navigational aids (NAVAIDs)
- Airworthiness of FAA-certificated aircraft
- Competency of FAA-certificated airmen, air agencies, commercial operators, or air carriers.
- Adequacy of FAA regulations
- Airport certification safety standards or operations
- Airport security standards or operations
- Violations of FARs

- Support the NTSB's investigation by verbally informing the IIC of all facts, conditions, and circumstances surrounding an accident/incident in which the NTSB does not perform an on-scene investigation. This includes supplying original or copies of photographs, statements, and other pertinent factual evidence.

- For NTSB on-scene regional or major investigations, participate in the investigation to discharge the FAA's congressionally mandated responsibilities.

- Participate with the NTSB in any foreign accident investigations in accordance with Annex 13 of the ICAO treaty.

- Conduct or authorize the conduct of autopsies and toxicological tests of the remains of persons onboard an aircraft involved in an accident.

FAA Order 8020.11, *Aircraft Accident and Incident Notification, Investigation and Reporting,* prescribes internal FAA procedures and responsibilities in accident/incident investigations. It provides direction and guidance to FSDO and other agency personnel and air traffic facilities on actions to be taken following the occurrence of an accident/incident and during the course of the subsequent investigation. The document is detailed and specific about the preservation, retention, and production of information related to accident or incident investigations, and the procedures for requesting and obtaining data. In addition, it specifies the duties and responsibilities of FAA personnel during the course of an investigation. All investigators should obtain and thoroughly read FAA Order 8020.11 to understand the FAA procedures and responsibilities.

During the course of an accident or incident investigation, the FAA as an agency assigns an "FAA coordinator,"[35] who is the principal agency representative to the investigation until

[35] The FAA uses the term "FAA investigator-in-charge (IIC)" for the coordinator. The Safety Board refers to the individual as the "coordinator" for the agencies participation in the investigation, as with other designated parties to our investigations.

completion of the inquiry. The designated agency coordinator has the authority to procure and utilize the services of all needed FAA personnel and facilities and to obtain FAA records or documents needed for the investigation. The designated coordinator is usually an operations or airworthiness inspector from the FSDO with jurisdiction over the accident site location. However, in certain high-visibility events or significant air carrier accidents, the coordinator may come from the FAA headquarters' Accident Investigation Division (AAI-100) in Washington, D.C. As the principal FAA representative to the investigation, the coordinator directs and controls all agency personnel involved in the inquiry. Although bound by the provisions of 49 CFR 831.11 which governs party participants to an NTSB investigation, the FAA coordinator does not have to sign the party to investigation statement form.

The FAA coordinator is the agency contact for information and facility access and all requests for information, documents, records, and facility access must be made through this individual. This is especially true for ATC records (including radar data) and access to facilities and personnel interviews. To avoid potential misunderstandings and consequent loss of information, or delays in obtaining needed documents, all requests to the coordinator should be made in writing. Under agreements between the NTSB and the FAA, the NTSB IIC informs the FAA coordinator of all aspects of the investigation and provides pertinent investigation records and reports in a timely and orderly manner.

Remember that the FAA as an agency wears two hats during an investigation. The first is to support the NTSB's investigation, with the ultimate goal of preventing future accidents/incidents and improving air transportation safety. The second hat is the agency's congressional mandate to enforce the FAA's own regulations. The two goals are sometimes at odds, and the specter of enforcement penalties or actions can have a chilling effect on the cooperation of pilots and operators. Ideally, the FAA coordinator should not also be the inspector who is performing the FAA's collateral investigation for enforcement purposes. The IIC should discourage this dual responsibility if he or she becomes aware that the coordinator is openly pursuing an enforcement action and instead suggest that the FSDO assign a separate inspector to conduct the enforcement investigation. In the event that the FAA coordinator decides that the agency needs additional information not required by the NTSB for the accident investigation, the letter of agreement between the NTSB and FAA provides that the FAA coordinator will seek that information in a manner that does not interfere with the NTSB's investigation. In pursuing any separate investigation, FAA personnel will clarify to those concerned that they are not acting under the NTSB's direction or jurisdiction.

4.23.2 Airman and Medical Records

The FAA maintains files on pilot[36] certificates and medical histories, which are on file in Oklahoma City, Oklahoma. The Airman Certification Branch, AFS-760, maintains complete historical files on all individuals certificated by the FAA. These files contain copies of all certification actions, including certificate applications, approvals, denials/rejections, written test results, enforcement actions, suspensions, and revocations. A certified copy of the pilot's file can be obtained through the FAA coordinator or by telephoning AFS-760 directly and identifying

[36] The term airman in this context means any FAA-issued certificate beyond those normally associated with flight crewmembers, i.e., maintenance technician, repairman, control tower operator, etc.

yourself as an NTSB investigator. The certified copy, also known as a "blue ribbon" copy, is supplied as a printout of the file. Some limited information from the files can also be obtained by telephone.

The Aeromedical Certification Branch, AAM-300, maintains the FAA medical history files on pilots. Similar to the Airman Certification records, a certified copy of a particular file may be obtained through the FAA coordinator or by direct telephone contact with AAM-300. Investigators should be sensitive to the confidential nature of the material contained in the medical files and certain parts of the certification. Most of the material is covered by the Privacy Act and should only be released in accordance with the provisions of NTSB Order 700A and the current Office of Aviation Safety policy directives on item inclusion in reports and the public docket.

4.23.3 Aircraft Records Maintained by the Federal Aviation Administration

The Aircraft Registration Branch, AFS-750 maintains aircraft historical records. As with the pilot and medical certification records, certified copies of an aircraft file can be requested through the assigned FAA coordinator or directly by telephone to AFS-750. The historical record on any aircraft consists of two files, the registration and the aircraft file. The registration file contains historical information on ownership and liens/encumbrances recorded. The aircraft file contains the airworthiness certificate actions and all FAA Form 337s of major repairs and alterations.

4.23.4 Service Difficulty Report/Malfunction Defect Report Records

Maintenance technicians, repair stations, and air carriers fill out SDRs and malfunction defect reports (MDRs) to report problems and failures with aircraft components or service procedures. The program tracks reports of serious defects in (or other recurring unairworthy conditions of) any airframe, power plant, propeller, or appliance. These reports are filed with and maintained by the FAA Aviation Maintenance Support Branch, AFS-640, in Oklahoma City. Important historical trend information on the reliability and failure history of aircraft systems or components can be obtained through an examination of these data. Data runs on any aircraft and component can be requested through the FAA coordinator or directly by telephone to AFS-640. Filters for the data runs can be as specific as a particular part number or as generic as "fuel system" components for a certain aircraft make and model. The generic filters are based on the Air Transport Association maintenance codes.

The aircraft certification directorates, their associated aircraft certification field offices, and the manufacturing inspection district offices are important sources of information for investigations involving potential design or manufacturing process-induced airworthiness concerns. A list of the offices and the manufacturers[37] that each office oversees can be found in Appendix 1 of FAA Order 8020.11. Each certification field office has teams of engineers assigned to oversee design approvals and engineering design change orders for each of the manufacturers. These engineers can be extremely helpful in understanding the history and

[37] The manufacturers overseen by these offices include the producers of major aircraft components and appliances, such as engines, propellers, magnetos, avionics, etc.

evolution of particular aircraft or appliance designs and should be consulted when concerns occur about design, airworthiness, or manufacturing process errors. The certification field offices will typically respond to assist in wreckage examinations where structural failures or design weaknesses are suspected.

4.23.5 Air Traffic Control Facility Access

Under the provisions of the Independent Safety Board Act, as amended, and the NTSB's regulations concerning accident investigations, investigators have a right to enter ATC facilities and examine any record or process which may have been involved in an accident or incident under the NTSB's jurisdiction. The accepted procedures used to gain access to ATC facilities involves the notification of the facility and regional air traffic management through the assigned FAA coordinator to the regional air traffic quality assurance staff. Investigators need to give serious thought and consideration to the documents and records that they want to examine and staff whom they want to interview during a visit to an ATC facility. Through the FAA coordinator, arrange a suitable date and time for the visit and provide a list of data to examine and facility staff the investigator wishes to interview.

4.23.6 Air Traffic Control Facility Communications Tapes

With a few exceptions, all air-ground communications and most landline communications between facilities and aircraft are recorded. The landline communications include pilot contacts with automated flight service stations (AARF) for weather briefings and flightplan filings and interfacility coordination conversations between all facilities and between the facilities and emergency response AARF units. The recordings are maintained at the facility for 45 days after recording. If no requests are made to hold the material, the data is erased. All transcripts are prepared from these recordings and are important information sources.

One reason to seek access to an ATC facility is to review the original recording of communications between AT and the flightcrew/pilot involved in the accident or incident. Pertinent FAA orders (principally contained in FAA Order 8020.11) specify that, unless otherwise requested, certified re-recordings will be made for the period from 5 minutes before the first contact to 5 minutes after the last contact with any facility. Transcripts of these communications usually contain conversations only between the facility and the flightcrew/pilot of the aircraft involved.

Because the preparation of a certified re-recording may take several days for the facility to complete, and official transcripts may take several months. Auditioning of the original tape enables the investigator to quickly determine if a detailed air traffic investigation is warranted.

The scope and contents of a "formal accident package" is defined in FAA Order 8020.11. The formal accident package is a legal document, containing many sections including the transcript, which is prepared when "Air traffic facilities may be or are involved in the accident." There is a somewhat subjective "level of service" determination by the FAA, but, in general, a formal package would qualify for any air carrier or air taxi accident, any instrument flight rules aircraft with fatalities or serious injuries, or a weather-related accident where a briefing was provided. "Informal accident files" may be prepared for other accidents or aircraft incidents, but a transcript may not necessarily be part of the file.

As noted previously, transcripts are normally "partial," i.e., only communications with or about the subject aircraft. Transcription begins at 5 minutes before initial contact to 5 minutes after last contact. For an air carrier accident, the transcript is "full," i.e., all communications regardless of source. ATC facilities providing normal service while handling the aircraft before the accident normally will not prepare a transcript.

The definition of "contact" is also somewhat subjective but generally is considered to be any communications with or about the subject aircraft or its flight crew. A controller attempting to locate a lost communications aircraft by calling other controllers would qualify. General guidance within the FAA calls for an end of the transcript when the aircraft wreckage is located and "airside" or "FAA business" returns to normal, such as when the airport reopens or stabilizes. Full transcripts are created by all handling facilities when they are informed that litigation is pending, but this is usually well beyond the time frame for the factual stage of the investigation.

Investigators are occasionally provided with transcriptions that go beyond the above guidelines. Draft or "working" transcripts are often created by ATC facilities to help brief FAA officials and are sometimes provided to NTSB investigators. They should be used with care and should always be compared to a final transcript or the voice tape.

Occasionally, FAA headquarters staff may request that a facility prepare a final transcript because of high interest or for FAA internal purposes. NTSB investigators are able to get these transcripts, but keep in mind that they are not prepared for the NTSB. In fact, it is rare for a transcript to be prepared based solely on an NTSB request. Investigators may convince their FSDO coordinator to request one, but it is ultimately the FSDO coordinator's decision, and they may or may not be convinced.

When requesting transcripts and packages, remember that the FAA Order 8020.11 treats the transcript as part of the entire formal accident package. Although the transcript may be finished, investigators may have to wait for the whole package to be approved by FAA legal and headquarters staff before it is released. Investigators may want ask for a draft or request the transcript separately in order to get the data before the accident package is released. FAA Order 8020.11 specifies that the FAA IIC must forward the completed FAA accident package to the NTSB within 60 calendar days from the accident.

If the FAA does not prepare a transcript, NTSB investigators may have to do this themselves. The FAA will always provide the recorded data, but if you have difficulty obtaining it, AS-30 specialists and the NTSB Research and Engineering audio laboratory can help with this process. When requesting recorded communications, request that the data be in DVRS/DAT format, which is much easier to work with. However, not all facilities have this capability.

4.23.7 Air Traffic Control Information Available

In cases where an aircraft or pilot received services from the FAA, either preflight weather briefings or in-flight ATC services, considerable information is available from the air traffic system. The following FAA reference handbooks and orders[38] are excellent resources to understand the information available and the minimum performance standards of the associated ATC personnel involved in the event.

- 7210.3 Facility Operation and Administration
- 7110.65 Air Traffic Control Handbook
- 7110.80 Data Communications Handbook
- 7110.10 Flight Services Handbook

During the course of an investigation, ATC information should be requested and obtained through the FAA accident coordinator.

- Coordinate through the FAA accident coordinator to have either the ATC facility chief or quality assurance specialist contacted regarding requested information.

- Request any facts known at that time. The facility will have listened to the tapes, debriefed the involved personnel, and reconstructed the event for internal FAA use shortly after the accident. At least a good capsule version of events should be available within a day of the event.

- Request a copy of all recorded voice communications as soon as possible. The transcripts may take some time to prepare and the re-recordings may be the only source of information in the interim. When the transcripts are eventually received, compare the transcript accuracy to the recording.

- Request copies of any pertinent transcripts of both air-ground and inter-facility land line communications as appropriate.

- Request radar data from the involved facility and from any nearby facility that may have been able to record the flight path of the aircraft.

The general categories of ATC information available include:

- Personnel statements
- Pertinent facility tape recordings
- Transcript of recorded voice transmissions
- Daily record of facility log, FAA Form 304
- Flight progress strip, FAA Form 7230.8
- Facility operations letter of agreement

[38] The number of the FAA order is part of the work's title. A letter suffix is attached to the number to denote the version of the order. As an example, FAA Order 7110.65J would be the 10th issue of the Air Traffic Control Handbook.

- Facility standard operating procedures
- Operational error reports
- Diagram of facility layout
- Copy of flight plan record, FAA Form 7233.3
- Airways facility sector certification reports, maintenance log(s), FAA Form 6030.1
- If pertinent, previous flight check reports of NAVAIDs
- Copy of instrument approach procedures
- Recorded radar data
- From terminal facilities, request the CDR data in RAPTOR format (which includes message types, TA, TU, TG). MicroEARTS files (Anchorage, Guam, Honolulu, San Juan) should include at a minimum types, TD,RB,BT,RT.
- From air route traffic control facilities, request that NTAP data contain at least LST3 data.

4.23.8 Controller/Air Traffic Control Personnel Interviews

Controller interviews should be arranged through the FAA accident coordinator, who will coordinate the event through the regional air traffic quality assurance staff and the facility manager. All persons interviewed have a right to representation by a person of their choice.[39] Review the questions to be asked in advance, and write the questions out in the anticipated order to be asked during the interview. Read the pertinent portions of the Air Traffic Control Handbook (FAA Order 7110.65) for a clear understanding of what the controller was supposed to do during the event in question, including the expected controller performance standards. Background information to obtain and review before the interview convenes should, at a minimum, include:

- Controller status in facility
- Certificate to operate (tower controllers)
- Health profile and medical certificate
- Weather observation certificate (tower controllers)
- Area rating records (center or terminal radar approach control [TRACON] facility)
- Training records, including off-the-shelf evaluation report and results of last tape talk
- Facility SOPs

4.24 Recorded Flight Track Data

4.24.1 Civil Radar

Recorded radar data and available sensory data records from other sources can be valuable investigative resources. Manipulation of the data can help reconstruct the ground track, altitude history, and flightpath performance of the aircraft. However, the recorded data are not continuous but are recorded based on the rotation rate of the system antenna. Most terminal

[39] If a controller selects a union official as their representative, that person cannot also be the party representative for the union to the investigation. This would also hold true for any case where a labor organization is a designated party to the investigation, i.e., the pilot, cabin crew, or mechanics union; the party representative cannot also be the personal representative for the person interviewed.

systems antennas rotate at 15 rpm, producing a record of the aircraft target in question at 4-second intervals. In en route systems, the antenna rotation rate is 5 rpm, yielding an interval of 12 seconds for each recorded target. The investigator is, therefore, looking at a series of snapshots of the aircraft, based on the system's recording interval. Care must be exercised to read only what is there in the data and not to leap to conclusions about aircraft motions between snapshots. A lot can happen to an aircraft in the 12 seconds between recording intervals in en route data.

Virtually all of the available data extractions come with a latitude or longitude location for each recorded target. In the case of terminal and military readouts, the data can be converted from the "as read" data set to a latitude and longitude format. Most FAA air traffic facilities can convert data sets into a graphical presentation. Several commercial software packages are also available that are specifically designed to graphically present recorded radar data from en route and terminal facility formats. It is also possible to use spreadsheet programs such as Microsoft Excel to make tabular and/or graphical plots of an aircraft's ground track and altitude versus time. The NTSB's Vehicle Performance Division and AS-30 air traffic specialists can be very helpful to investigators by assisting the ASI in understanding the presented data.

The NTSB's air traffic specialists can also help in identifying facilities, both civil and military, that may have had radar antennas looking in the vicinity of the accident site. Investigators should not overlook the obvious in asking for radar data important to the investigation. An aircraft that was being worked by one terminal facility may have been in clear view of an FAA or military radar antenna in a better position to see higher resolution data. It is always a good policy to look at the broader picture of what facilities may have had radar systems looking at an accident site and then to request all data from all sources.

Caution should be exercised when interpreting and analyzing any recorded radar data. The accuracy of the stored information on any specific target or series of target reports depends on many factors. The target motion and velocity relative to the antenna rotation direction and rate can introduce positional errors in the recorded location of any target report. The errors can result in recorded target positions that are as much as 0.2 nautical miles or more from the actual position. Although the terminal systems tend to be more accurate than the en route systems, potential errors are still likely.

Mode C altitude reports are in increments of 100 feet and aircraft encoders will round off an altitude to the nearest 100-foot value. The accuracy of the Mode C altitude report in any recorded radar data is dependant on the sensitivity and accuracy of the altitude encoder on the aircraft. Therefore, a recorded radar track on an aircraft that is displaying alternating altitude jumps of ±100 feet does not necessarily mean the vehicle was undulating in pitch. It may only mean that the airplane was at the pressure altitude between round-off values of the encoder.

In addition, preprogrammed software filters in ATC computer systems can also affect the accuracy of the presented radar data. The performance parameters of each aircraft type or classes of aircraft types are programmed into the radar system software. If the target's speed or altitude rate of change exceeds the programmed maximum value for that aircraft type, the computer system will drop or disregard that target in the processed radar data. The information will still be there in the system, but it will not be displayed in the processed data. Always ask for *all* data on a target track, including primary target skin paints.

In analyzing the data, do not forget that radar wave energy travels in straight, line-of-sight paths. The antenna has to see the target to record anything. Mountains or other obstructions can create shadow areas that the radar will not see. Secondary beacon code returns may be masked if the aircraft's transponder antenna is pointed away from the ground radar antenna. Slow moving primary targets (i.e., helicopters) may be filtered out of the system because the computer interprets them as stationary ground clutter. This is an excellent reason to always include in your request for data *all* primary returns as a filter parameter.

Because of all the potential inaccuracy inherent in the radar system data recording, there are a few key points to remember in interpreting and analyzing any recorded radar data:

- Even in the virtual world of recorded radar data, aircraft have to obey the laws of physics and motion. Just because the data print/plot out shows the recorded target turning 90° in 8 seconds, or nearly instantaneously doing roll reversals, or dropping in Mode-C altitude 500 feet in two sweeps, does not mean the aircraft did those things. Ask yourself if the aircraft is capable of that type of performance (roll, turn, climb, or descent rates) and, if not, suspect the data. Go back and look at the historical average of the plot track.

- If you are going to infer performance from the data, use multiple data point averaging (overall distance between five or seven points over the total time span). Five to seven or more point smoothing will result in reasonable representative trend averages of vehicle motion over the ground.

- Remember, the data show ground track distance and course. Account for wind aloft direction and velocity in the computations to arrive at headings and airspeeds.

Recorded radar data are available from three principal sources (the FAA's ATC system, military air traffic control facilities, and instrumented maneuvering ranges) and certain classified or restricted military and federal law enforcement sources. In most cases, the recorded data are maintained for 14 days. Unless data extraction is requested, the recording media are then reused, erasing the original recording.

Requests for ATC recorded radar data should be made, through the FAA coordinator assigned to your accident, to the FAA regional air traffic quality assurance staff. Military radar data should be requested through the FAA coordinator (in the case of facilities controlling civilian traffic) or to the military facility air traffic unit commander directly. All data requests should be made in writing to avoid potential misunderstandings and the consequent loss of valuable data. IICs have the authority, if necessary, to place a hold on the original recorded data so that the medium cannot be reused without the IIC's consent. If you place a hold on radar data recording mediums, make sure to release it back to the air traffic facility in a timely fashion after you are sure you have the data you need.

4.24.2 Military Radar Data

In some areas, a military approach control will handle the civilian traffic for nearby civilian airports. Other sources of non-classified military radar data are available on each coast and in selected locations in the Caribbean and Pacific areas. Operated by the U.S. Navy, fleet air control and surveillance facilities (such as FACSFAC) monitor naval flight activity in warning areas and other maneuvering ranges. AS-30 ATC specialists are able to request radar data from the US Air Force's 84th Radar Evaluation Squadron (RADES). Although RADES uses FAA radar antennas to record the data, NTSB staff is able to receive the data much faster than waiting for the data from FAA sources.

5 Post On-Scene Activities

The post on-scene phase is a time to finish necessary administrative tasks and prepare the case file for further development. All parts of the file should be examined to ensure that nothing has been overlooked. Accomplish the following upon return to the office:

- Ensure that, if required, the memorandum of initial notification has been completed and transmitted to NTSB headquarters by the morning of the second working day after the accident.

- Complete the preliminary report in ADMS/eADMS within 5 working days. ADMS/eADMS data block information comprises information from the pilot/operator, accident/incident report form (NTSB Form 6120.1). In cases that require an initial notification, the IIC should attempt to complete the preliminary report within 2 working days so that the preliminary and initial reports will be consistent and issued about the same time.

- Complete your travel voucher and overtime request sheet soon after returning to the office. Overtime usage must be in accordance with the current NTSB orders, AS policies, and the collective bargaining agreement.

- Compile a list of purchases for on-scene services, and ensure that invoices are correct and that your administrative staff assistant completes any required financial management system entries in accordance with current NTSB administrative guidelines.

- Complete your field notes, and write the sections of the factual report narrative that can be completed. If you keep the in-process factual narrative current with the results of pending investigative activities as they are completed, it will reduce time later when the report is finalized. Ideally, this writing can be done in the hotel after leaving the accident site so distractions are minimized, and information is fresh in your mind.

- Brief the RC concerning the status of the following:

  - A summary of accident

  - Investigative costs
  - Overtime costs
  - Travel costs
  - Status of investigation, including any required assistance from headquarters divisions or offices
  - Teardowns or component tests accomplished and/or pending
  - Safety recommendation potential
  - Parties to the investigation
  - Any issues or concerns with any part of the investigation

- Review all the wreckage release forms to ensure that the wreckage released and/or any components that are retained, is accurate.

- Arrange to complete necessary work, such as:

  - Lab analysis
  - CVR/FDR
  - Engine/component teardown
  - Instrument/radio testing or teardown
  - Toxicology
  - Autopsy
  - Requests submitted for FAA-supplied information, such as airman, medical, aircraft, service difficulty report (SDR)/malfunction defect report (MDR), and ATC data

- Contact the parties to the investigation and/or manufacturers to coordinate any expected follow-up examinations, reports, data submissions, etc. Reiterate the expected time line for completion of any pending projects.

- Compile the test results and complete the necessary supplement forms and portions of the factual narrative.

- Review all data to determine if a safety proposal or accomplishment is in order.

- As a gesture of cooperation, contact the local, state, or federal agencies that assisted you during the on-scene phase and thank them for their assistance during the particular portion of the investigation.

5.1 Report Preparation

After completion of the preliminary report in ADMS/eADMS, the IIC should be focused on completing the investigation, entering all pertinent data into the Accident Database Management System (ADMS/eADMS) and preparing the final report. The factual report narrative, brief of accident narrative, and probable cause narrative are to be completed in compliance with the most recent NTSB directives and policies on reports.[40] All reports will include a proposed probable cause statement for the NTSB to review, modify, and/or adopt.[41] During the report preparation process, the IIC will also begin to prepare materials for the public docket.

5.1.1 C-Form Preparation

If a C-Form[42] accident report is used, a preliminary report is not produced. However, the final report (factual and brief) must be completed within 30 days from the time the NTSB determines that the occurrence was an accident. In the event that NTSB Form 6120.1 Pilot/Operator Report is not received within 21 calendar days from the date that the NTSB makes the determination of the accident, a C-form should still be completed without Form 6120.1, if the following are obtained:

- A written statement from the pilot,
- An NTSB record of telephone conversations with the pilot, or
- An FAA statement/report that documents what the pilot stated regarding the accident.

The factual narrative of a C-Form will be a duplicate of the brief narrative. This will eliminate the need to write a separate factual narrative, while providing the public with an immediate narrative that provides an overall summary of the accident. This will also serve to reduce the time needed to draft and review two separate narratives. Because the brief is an NTSB-adopted product and may contain some analysis, the wording imported into the factual narrative should not contain any analysis or opinion. This can be done by either deleting or altering some of the analytical phrases in the brief narrative for use in the factual narrative. The probable cause and associated coding should be simple and appropriate to the limited factual information received. ASIs and RCs must ensure that there is no "overreaching" on conclusions, factors, and findings because this increases the potential for petitions for reconsideration.

---

[40] Most regional reports are completed within the ADMS/eADMS system. However, some regional reports with larger scope and complexity, may be produced in variants similar in format to a major accident investigation report. These report variants will be decided by AS management in consultation with the Chief of the Writing/Editing Division (AS-70) as deemed appropriate.

[41] There is once exception: "S" cases will not have a probable cause issued. These cases are for non-accidents and for incidents that are not formally investigated, but are kept for internal tracking purposes only. S-cases warrant only a prelimary report.

[42] Guidelines for C-Forms are contained in Regional Operations Policy Memorandum ASR2R-ROPM-008, "C-Form Criteria and Procedures."

5.1.2 Interim Factual Reports

NTSB Order 700A stipulates that "in a non-major investigation, the public docket is opened or first made available to the public when the factual report is entered." The reason for the non-major policy is that most docket items contained in a typical regional investigation do not have separate narratives from the group chairmen, as is the case with major investigations. In regional cases, the factual report in ADMS provides this necessary context.

However, for certain high-visibility cases, including reports that are slated for the notation process, it is necessary to open the docket before the completion of a regional investigation or final report. In these rare cases, a mechanism is needed to release the docket items with an "interim factual report" that provides the context.

First, complete the entry of data into all data fields of the ADMS factual report. Rewrite the ADMS long narrative so that it provides updated, factual information that replaces the preliminary report. The updated long narrative should briefly address the salient facts of the investigation and provide context to the docket contents. This narrative should not exceed three pages and may contain ICAO formatted headings. The following statement (including the dashed line) should be added to the very top of the updated long narrative:

"The following is an INTERIM FACTUAL SUMMARY of this accident investigation. A final report that includes all pertinent facts, conditions, and circumstances of the accident will be issued upon completion, along with the Safety Board's analysis and probable cause of the accident:
---"

The ADMS factual report should then be uploaded like any other completed case. Once the final report is completed, the interim factual summary narrative will be replaced with the final report narrative. This will require NTSB headquarters staff to "reset the flags" so that the RC can re-upload the final ADMS factual report. It is recommended that the ADMS final factual report be released simultaneously with the two-page brief of accident report. Direct coordination with the AS-2R analyst will be required to complete this task. Note that special procedures are necessary for handling aviation cases involving a CVR.

5.1.3 Documentation for Fractionally Owned Aircraft

All accident/incident reports involving aircraft that are fractionally owned and operated under the provisions of 14 CFR Part 91 subpart K must include the following phraseology:

- The first paragraph of the preliminary/factual report must document the operator/owner as "*fractionally owned by private individuals who delegated the management of the airplane to XXXX, Inc.,*"
- In the Accident Data Management System (ADMS) data block under "*Registered Aircraft Owner*," list the primary owner on the FAA registration, plus the number of co-owners.

- In the "Operator of Aircraft" data field, please enter "*XXXX*" (name of fractional ownership company) as the program manager.

5.2 Party Submissions

Any party to an NTSB accident investigation may submit written recommendations about the findings and conclusions to be drawn from the evidence produced during the investigation.[43] After the completion of the investigative activities and before the NTSB has made its determination of probable cause, each party to the investigation is responsible for informing the NTSB of its interpretation of the findings and conclusions to be drawn from the evidence relating to the accident. These written submissions should also be served on the other parties to the investigation.

Title 49 CFR 831.14 states the following:

> (a) General. Any person, government agency, company, or association whose employees, functions, activities, or products were involved in an accident or incident under investigation may submit to the Board written proposed findings to be drawn from the evidence produced during the course of the investigation, a proposed probable cause, and/or proposed safety recommendations designed to prevent future accidents.
>
> (b) Timing of submissions. To be considered, these submissions must be received before the matter is calendared for consideration at a Board meeting. All written submissions are expected to have been presented to staff in advance of the formal scheduling of the meeting. This procedure ensures orderly and thorough consideration of all views.

Regional IICs must ensure that all parties to all of their accident/incident investigations (including limited accidents) are given the opportunity to provide a submission in accordance with 49 CFR 831.14.

Submissions must be solicited, in writing, at the time that the IIC transmits his/her draft factual report for the parties' review. The transmittal message should state the following:

> *Attached is the NTSB's draft factual report of an investigation involving NXXXX that occurred on [date] in [location]. In accordance with 49 CFR Parts 830 and 831, and as a party to this investigation, you are granted the privilege to review this draft report and to provide comments and corrections.*
>
> *Additionally, and in accordance with 49 CFR 831.14, you may also submit written proposed findings to be drawn from the evidence produced during this investigation, a proposed probable cause, and/or proposed safety recommendations designed to prevent future accidents. You may utilize any*

[43] Details on party participation in NTSB investigations and party submissions can be found in 49 CFR 831.12.

format or means of transmission that you desire. Be advised that, under Section 831.14, your submission will be placed in our public docket.

You have 10 days from today to submit your comments and corrections on the draft factual and on your submission. Should you require additional time, please inform the IIC of this within 5 days.

Also, if you require any documents that were gathered during this investigation and used to support the draft factual report, please inform the IIC immediately.

Upon receiving the parties' comments and corrections to the draft factual, regional investigators must read and consider all of the submitted documents. The parties' draft factual comments/corrections do not have to be placed in the docket. However, their submissions must be placed in the public docket.

5.3 Freedom of Information Act Requests

Following notification of a FOIA request, the IIC should cease discarding any documentation related to the investigation, including paperwork, photographs, videotapes, audiotapes, electronic files, and electronic correspondence. Group chairmen, technicians, Board Members, and other appropriate staff should then be notified that they should also cease disposing of documentation. The IIC and NTSB employees should not attempt to determine which items in their possession are subject to the FOIA request. If NTSB FOIA personnel request material before an investigation is completed, investigative staff should photocopy all items that may be needed in the future to complete the investigation. The IIC should then deliver the originals of all investigation material to FOIA personnel, except that material that has been placed in the public docket. Be aware that it will be extremely difficult to retrieve items once they have been surrendered, so it is important that investigative staff make copies of whatever they will need. Following the initial delivery of material to FOIA personnel, the IIC should make copies, as necessary, of all material that he or she receives for use during the remainder of the investigation and provide the originals to FOIA personnel immediately thereafter.

The NTSB general council office and FOIA office can assist with any questions regarding FOIA requests and procedures.

5.4 Petitions for Reconsideration

After the Board Members have adopted an accident report and probable cause, a party or any other interested persons with a direct interest in the accident investigation can formally petition the NTSB to reconsider all or part of the analysis, findings, conclusions, or probable cause under the provisions of 49 CFR 845.41. When petitions are received, they are formally acknowledged and assigned to staff for research and evaluation of the issues raised. The staff of AS-2R handle most petitions involving regional accident investigations. Regional Operations staff or regional staff who were not involved in the investigation write the petition response. However, they consult IICs and other investigators involved. Petitions must meet the threshold requirements for reconsideration by the NTSB, i.e., whether the petitioner has presented new factual material or has demonstrated that the NTSB's analysis was faulty. The NTSB's response to a petition consists of three basic elements: a discussion of the NTSB's original reasoning, a summary of the arguments and/or evidence provided by the petitioner, and the proposed response to the petition. Staff specialists at NTSB headquarters and from the regional offices are involved in the response depending on its emphasis and content and the specialty involved.

6 Other Investigations

6.1 International General Aviation Accidents/Incidents

6.1.1 Incoming Notifications of Events that Occur Outside of the U.S.

The NTSB, as the independent accident investigation authority of the United States, is charged with fulfilling the obligations of the United States under the provisions outlined in Annex 13 of the International Civil Aviation Organization's (ICAO) treaty. Annex 13 contains specific requirements for the notification, investigation, and reporting of certain incidents and accidents involving international civil aviation. The NTSB performs its responsibilities as a member state of ICAO, consistent with Department of State requirements. Regional offices are responsible for the timely processing of all international general aviation accident/incident notifications. Detailed procedures for processing these notifications are listed in Appendix 11.

The Deputy Director of Regional Operations has assigned each region worldwide areas of responsibility, which include specific foreign countries and geographic territories. The NTSB Communications Center receives almost all notifications from foreign countries via fax, email, etc. The Communications Center will do their best to triage the notifications by country, type/category of aircraft, or level of response required.[44] Once a notification is received, the Communication Center will forward each notification, via email, to the NTSB recipient/responder list. The list includes each Regional Chief, one backup for each region, pertinent headquarters management, and the AS-10 duty officer. Typically, if the notification involves a transport category aircraft, the AS-10 duty officer has responsibility to process the notification.

For all notifications involving general aviation aircraft, the responsible Regional Chief/Office without exception or delay will:

- Acknowledge receipt of the notification by email reply to the recipient list **and** assign a regional investigator to process the notification. These initial actions **must be** timely and are critical to track response/actions, define who has responsibility for the response, eliminate duplication of efforts, and provide a method to inform AS management of actions.

- Determine the level of response/action based on all available information.

[44] Due to the various formats in which notifications are received from foreign countries, basic information may not be readily apparent when the communications center forwards the notification to the recipient list. Some notifications may be in foreign language. For these reasons, due diligence is required to open and read the attachment to determine the proper respondent and level of response (i.e. whether a regional or AS-10 response is required, assignment of an accredited representative is needed, additional notifications are required, etc.).

- The assigned investigator shall send a basic response to the country from which the notification was received by the quickest and most practical means (email, fax letter, phone, etc.). Regardless of the reported complexity or level of response each notification shall be positively acknowledged and the notifying country, at a minimum, will be given the name, contact numbers, and email address of the NTSB investigator handling the initial response.

- Care shall be taken to clearly acknowledge the notification from the foreign country and the acknowledgment shall be documented in an appropriate file system. There may be instances whereby a foreign country may ask for assistance after they receive acknowledgment from the NTSB. To ensure adequate allocation of resources, each request for assistance will be brought to the attention of the Regional Chief before the investigator responds to the request.

- Forward the notification to the appropriate U.S. airframe and engine manufacturers, foreign certificate holder safety organization (i.e., TSB Canada, for light Bell helicopters), and any NTSB technical division chief that may have an interest in the event. When forwarding the notification to an NTSB division chief, always "cc" AS-2I and AS-2R.

- Any report of public use general aviation accidents/incidents in a foreign state will require special handling to include the U.S. government agency concerned to coordinate response.

- If applicable and in compliance with current report policies and directives, enter a keys number and produce a "WA" or "RA" report. The report shall include only information provided by the foreign country, with no implication of cause or analysis. Once the report is complete and transmitted via ADMS/eADMS, the responsible investigator will remain vigilant to further communications from the foreign country whereby additional or corrected information could be added to the report. It is important to note that the "WA" or "RA" report is simply a vehicle to document the occurrence in the NTSB database, and the information contained therein is only that which is provided to the NTSB by the foreign country.

When assigned as the NTSB U.S Accredited Representative, the following general guidelines shall be observed:

- Always keep your immediate supervisor informed of all correspondence and/or requests from foreign countries in accordance with standard NTSB practices. Pertinent developments should be forwarded through the appropriate chain of management.

- When designated as an Accredited Representative, notification to the foreign country (State of Occurrence) shall include a statement that identifies you as the NTSB Accredited Representative, and your intention to "travel," "not travel," or "travel to be determined."

- The NTSB Accredited Representative will appoint advisors from the FAA and other appropriate organizations as necessary to provide a U.S. response to the investigation.

- As data are provided to or received from a foreign IIC, the NTSB Accredited Representative should make clear to foreign state authorities, the U.S.-filed Differences with ICAO Annex 13, to include the provisions in the NTSB Act, Paragraph 1114, pertaining to the two-year FOIA exemption.

- The accredited representative should, as the investigation proceeds, advise the chain of management of significant issues within the investigation that may be appropriate to bring to the attention of the staff or the NTSB. Information critical to flight safety, and appropriate for an NTSB Safety Recommendation, should be forwarded with urgency.

6.1.2 Notification to Foreign Countries of Events that Occur in the U.S.

If the airframe or engine is of foreign manufacture, the aircraft is of foreign registry, or the operator is based in a foreign country, make sure that the appropriate foreign government accident investigation authority has been notified, in accordance with the provisions of International Civil Aviation Organization (ICAO) Annex 13, as soon as possible.[45] The recognized states that have rights to participate and that may require notification are: State of Design, State of Manufacture, State of Registry, State of the Operator, and the State with the predominate citizens on board. If the aircraft is multi-engine and over 2,250 kg (~4,950 pounds) gross weight, an additional notification must be made to ICAO (inbox@icao.int).

6.2 Investigations of Public Use Aircraft Accidents

Upon notification of an accident involving a government agency aircraft, whether it is a launch or a limited investigation, IICs must immediately communicate with the agency to ensure that it assigns a representative to act as the agency's point of contact (POC) in the investigation. The government agency will be made a party to any and all aircraft accident investigations involving the agency, in accordance with 49 *United States Code* (U.S.C.) 1131(a)(2)(A), which states "The NTSB shall provide for appropriate participation by other departments, agencies, or instrumentalities in the investigation." Regional investigators also must:

- Ensure that the POC is fully aware of the NTSB's authority. As stipulated in Section 1131(a)(2)(A), the NTSB "has priority over any investigation by another department, agency, or instrumentality of the United States."

- Provide the agency's POC, or his/her designee investigator, a reasonable amount of time to respond to the accident site before wreckage removal. However, should removal be warranted, the regional investigator must make every effort to coordinate this effort before doing so by contacting the agency POC.

- Allow the government agency to conduct its own independent investigation of the accident, in accordance with Section 1131 (a)(3), which states that the NTSB's authority ". . . does not affect the authority of another department, agency, or

[45] It is recommended that someone other than the IIC, such as the RC or the duty officer, perform this task, so that the notification is not delayed.

instrumentality of the Government to investigate an accident under applicable law or to obtain information directly from the parties involved in, and witnesses to, the accident."

- Share all documentation with the government agency, including notes, transcripts, interviews, or drawings and pictures to ensure accuracy and thoroughness, in accordance with Section 1131 (a)(3), which states: "The Board and other departments, agencies, and instrumentalities shall ensure that appropriate information developed about the accident is exchanged in a timely manner."

Regional investigators should remind the POC of 49 CFR 831.13(b), which states: "All information concerning the accident or incident obtained by any person or organization participating in the investigation shall be passed to the IIC through appropriate channels before being provided to any individual outside the investigation. Parties to the investigation may relay to their respective organizations information necessary for purposes of prevention or remedial action. However, no information concerning the accident or incident may be released to any person not a party representative to the investigation (including non-party representative employees of the party organization) before initial release by the Safety Board without prior consultation and approval of the IIC."

IICs must ensure that the government agency be granted 10 days to review the final draft of the NTSB's accident report. If the agency provides comments, the IIC must consider them for inclusion into the final and communicate with the agency's POC to verify that the comments have been reviewed and considered.

If the NTSB does not send an investigator to the accident site, then the agency must be authorized to collect factual information on NTSB's behalf and forward its completed report to the assigned regional investigator. Additionally, if an FAA representative arrives at the accident in accordance with FAA accident investigation protocol, the IIC must ensure that an "on-scene commander" is chosen to lead the on-scene portion of the investigation. To determine who should be the on-scene commander, the IIC should consider the specific circumstances surrounding the accident, the FAA's specific role and authority in regard to the operator, the qualifications of the agency and FAA investigators, and the logistics involved in documenting the accident. In some cases, the FAA may not have jurisdiction over a particular public use operator or may not send an inspector. Conversely, to further preserve the neutrality of the investigation, the IIC may not want the agency POC to lead the on-scene investigation if an experienced FAA inspector is on scene. ***In any case, the IIC must maintain frequent communications with the FAA, the affected government agency, and the on-scene commander to ensure that the on-scene documentation is conducted in an efficient and cooperative manner.***

IICs are prohibited from including in the docket and/or factual report any information that the affected government agency deems sensitive or proprietary, unless absolutely necessary in supporting key facts or safety issues. Additionally, IICs must attempt to independently verify information obtained from the agency's investigative efforts, rather than relying solely on the agency's information for the NTSB investigation and report.

Appendix 1. List of Recommended Tools and Equipment

This appendix contains a list of recommended tools and equipment useful for on-scene investigation activities. The list is not meant to be all inclusive, nor mandatory equipment to be carried to each and every accident. It is a menu of useful tools and equipment that each investigator should draw from as the needs of each particular accident dictate.

The diversity of aircraft and accident types makes it difficult to list all the necessary equipment available or useful for every accident. All of the items on this list would take up certainly more than one backpack and weigh a considerable amount. Remember that the investigator's kit made up of the tools and equipment for an accident has to be carried. Do not overload it with unnecessary or duplicate items that take up valuable space and weight. Evaluate your kit every 6 months or so, if you haven't used an item in that time, you probably never will, and think about moving it to the standby selection box.

Be weight and size conscious, and look for ways to combine several tools into one utensil or find replacement items of smaller size and weight. Spend some time in hardware stores or the tool sections of large home center stores. Many of the tools and equipment listed in this appendix have inexpensive plastic counterparts that can save weight, with an added advantage that they can be easily replaced if lost. An example is the Abney Level used for exact angle measurements of objects with respect to the horizon. The typical Abney Level weighs a pound or more and is an expensive piece of equipment. Most hardware stores sell plastic angle finding gauges used by carpenters; they cost just a few dollars and weigh just a few ounces. Another example is 50-foot measuring tape, which weighs a couple of pounds and takes up a large space. Plastic optical range finders are available in outdoor stores and from catalogues. One more alternative to the 50-foot tape is to know your own pace measurement and save space, weight, and dollars.

Certain items commonly used in every investigation should be kept in readiness for dispatch at all times. Based on the projected needs of each specific accident, the investigator should add the tools and equipment needed for that accident investigation.

Accidents in remote areas require special consideration of the provision for shelter, food, and water. Think about the needs of the investigation *before* you launch, and make wise decisions on what to take and what to leave behind.

Personal and Safety Specific Items

- Proper clothing should be the first consideration. Selection of good serviceable clothing capable of withstanding rough usage is recommended. Selection should be appropriate to climate and environment. Multiple layers may be the best choice for colder climatic conditions where exertion is anticipated.
- Footwear appropriate to the accident site terrain/conditions (steel-toed shoes or boots, rubber over-boots, or waterproof boots, as necessary for conditions).
- Coveralls and/or hooded sweatshirt and coat or jacket.
- Rain gear.
- Headgear (hardhat, stocking cap, and/or NTSB baseball hat).

- Back pack for tools and equipment. Should have sturdy frame and be ergonomic.
- Canteen and/or thermos. Take enough water and/or sports drinks for expected climate conditions and length of investigative activities (in hot arid climates, need 1-gallon of fluid per person per day minimum).
- Sunglasses and safety goggles. (If you wear prescription lenses, an extra pair should be available).
- Multi-tool survival pocket knife.
- Small supply of prescription medications, especially any allergy or asthma-relief agents. Also, pain relief medication.
- Portable oxygen (if hiking above 8,000 feet in mountainous terrain).
- Candy bars, gum, cookies, or other quick-energy foods.
- Communications devices to remain in contact with individuals not on site. *(If contemplating use of a cell phone, make sure of coverage area capability. Small hand-held two-way radios can be purchased in local electronics stores, if necessary.)*
- Large, heavy-duty plastic trash bags (used for carrying parts, log books, etc.). *These can also be used as makeshift ponchos and/or survival shelters.*
- Water-purification tablets.
- Fire-starter or waterproof matches.
- Space blanket.
- Whistle.

Protective Equipment

- Biohazard personal protective equipment specified in Operations Bulletins OSH-GEN 001 through 014.
- Plastic bags (various sizes for small parts).
- Leather work gloves, two-pair.
- Disposable rubber or latex gloves, dozen pair.
- Germicidal wipes (for cleaning tools and equipment).
- Small container of chlorine bleach.
- Hand cleaner and antiseptic wipes.
- First-aid kit, snakebite kit, and first-aid instructions.
- Insect repellant, lip protectant and sunscreen lotion.

General Equipment/Tool Items

- Magnetic compass.
- Global positioning system (preferably with waypoint designation and memory for logging locations of parts).
- Small protractor to measure control surface deflections.
- Angle-finding device (carpenters angle gauge or Abney Level) to measure angles between objects.
- Measuring device for distances over 25 feet.

- 8- to 12-foot measuring tape with high contrast numbers/divisions suitable for photos.
- 6-inch narrow steel pocket ruler to measure trim tab actuator extensions.
- Magnifying glass or loupes (10X or stronger).
- Marking pens, paint pens, grease pencils, and/or chalk sticks.
- Clip-on tags for Left, Right, Top, and Bottom (for photo identification).
- Small tags (or high-contrast gaming dice) numbered 1 to 6 (photography of engine cylinders, spark plugs, pistons, etc.).
- Screwdrivers, general-purpose slotted and #2 Phillips (or combination multibit handle).
- Pliers, water pump type.
- Adjustable wrench.
- Tin snips.
- Vice grip (Needlenose offers the best versatility.).
- Small crowbar.
- Hacksaw (with spare blades).
- Diagonal cutters, 6-inch.
- Cable cutters, 6- to 8-inch for cutting control cables.
- Small crash-axe or hatchet (for cutting into aircraft skin). *An alternate possibility is a small roofing hammer, which has cutting axe blade on one end.*
- Small pocket flashlight, spare batteries, and spare bulb.
- Multimeter or other form of electrical-circuit testing device.
- Camera with flash attachment and spare batteries or charger (with a combination lens with close-up capability or macro lens attachment).
- Pocket audio recorder, extra blank tapes if not digital, and spare batteries or charger.
- Steno pad, clipboard, ruled paper, graph paper, pencils, and pens.
- NTSB accident report forms.
- Parts tags with string or wire (NTSB Forms 6120.15 and 6120.18 and/or FAA Form 8020-2).
- Passenger and Witness Statements (NTSB Forms 6120.9 and 6120.11) for interviews.
- Independent Safety Board Act, 49 *United States Code*, and 14 *Code of Federal Regulations* 830 and 831.
- Grid, county or state highway maps and sectional (navigational) map for area of accident.
- Investigator's checklists.
- Clean containers for fuel and oil samples. (Baby feeding bottles work well.)
- Small amount of wire, tape, string, or nylon cord to tie and/or secure things.
- Small, handheld inspection mirror to look in small, inaccessible locations.
- Small wire or stiff-bristled brush.
- Small trowel or large artist putty knife.

Engine Specific Tools

The following list of tools is the minimum necessary for a comprehensive field examination of piston engines.

- Combination wrenches, 5/16 through 7/8.
- Crescent wrenches, 6 and 8 inch.
- Diagonal cutters, 6 inch.
- Needlenose pliers, 6 inch.
- Channel lock pliers.
- ½-inch drive ⅞-inch deep socket (for spark plug removal).
- 3/8-inch female to ½-inch male drive adapter (to drive spark plug socket with 3/8-inch drive ratchet).
- 3/8-inch drive ratchet, swivel head, long handle.
- 3/8-inch drive ½-inch deep socket (for fuel injection nozzles).
- 3/8-inch drive 3-inch extension.
- 3/8-inch drive 5/16-inch Allen head socket.
- 3/8-inch drive spline tool (used to rotate crankshaft through vacuum pump drive). *This can be locally fabricated from a 3/8-drive 5/8-inch deep-impact socket welded to a propeller-governor drive spline.*
- 5/16-inch Allen wrench (fuel pump bolts).
- ¼-inch drive mini breaker bar.
- ¼-inch drive 6-inch extension.
- ¼-inch drive 7/16-inch swivel socket (intake pipes, accessory gearbox cover screws).
- ¼-inch drive ½-inch swivel socket (magneto hold-down clamps, exhaust pipes).
- Large blade long shank screwdriver.
- Small crowbar.
- Combination screwdriver (either reversible flat to Phillips or multibit type).
- Magneto synchrophaser (timing box).
- Permanent ink markers or paint pens (white paint).

Other Items

Toxicology mailing kit (tox box with proper mailing label).

Appendix 2. Wreckage Investigation Checklist

Structures (Walk Around)

- Absence of airframe sections
- Impact attitude
  - Heading
  - Bank
  - Pitch
  - Yaw
- Terrain
- Specific irregularities in airframe components (Failures)
  - Impact
  - Preimpact
- General wreckage distribution
- Evidence of fire
  - In-flight
  - Postimpact

Photographs

- General – eight compass points
- Ground scars and surrounding terrain
- Position of controls
- Flight control surfaces
- Fracture points

Wreckage Distribution and Diagram

- Identify centerline of wreckage path
- Identify parts – Tag or mark with grease/paint pencil
  - Identify part and its location along the wreckage path. Mark parts in succession or number their positions along opposite sides of the wreckage path centerline (i.e., 1L, 2L, 1R, 2R, etc.)

Ground Scars

- Length
- Depth
- Headings
- Correlation with airframe components

Detailed Examination (Detailed Notes and/or Sketches and Photographs)

General Airframe (Fuselage, Wings, Empennage)

- Note position of part as it came to rest

- Note where on the airframe failure(s) occurred
- Identify the type of failure(s)
- Fatigue
- Overload
- Flutter
- Identify evidence of fire (Take soot samples.)
- In-flight
- On ground
- Identify evidence of material transfers (i.e., paint, metal, rubber, fluid, etc.)

Flight Controls

- Document position of flight control surface(s)
- Use both surface and actuator positions
- Examine movable mechanisms (attach points) for integrity
- Establish control cable continuity from cockpit control to the control surface
- Measure travel of control surfaces
- Examine integrity of balance tabs and weights
- Examine control limit stops for unusual markings

Systems (Cockpit Documentation)

- Allow no one to enter the cockpit until system documentation is completed.
- Do not move or change position of controls, levers, and switches until documentation is completed.
- Use diagrams from appropriate manuals to identify controls, levers, and switches.
- Describe the actual conditions in specific terms.
- Document following positions, settings, and readings:
  - All switches
  - Engine controls
  - Flight control levers and trim settings
  - All instruments
  - All avionics
  - Circuit breakers

System Documentation: *The priority and degree to which system documentation should be done will vary with each accident. If a particular system and/or component is suspect, a more detailed examination may be required. This may include either a bench test and/or teardown. In such cases, caution must be used in removing the components from the aircraft to protect their integrity as found.*

- Use schematic diagrams to trace systems and their components.
- Do not move or change the position of system components until they are documented.
- Describe, in specific terms, the actual location and condition in which the component is found.

- Be specific in describing points of measurements of actuator-extended lengths.
- Record the following information for each component when necessary:
  - Name of component
  - Manufacturer
  - Part number (P/N)
  - Serial number (S/N)
  - Position and description

Hydraulic System(s)

- Reservoirs
  - Amount of fluid
  - Sample of fluid
  - Condition of filter(s)
  - Auxiliary reservoirs
- Hydraulic pumps engine-driven, auxiliary, electric
- Make, model, P/N, S/N
- Fluid sample(s)
- Condition of pump(s)
- External
- Internal
- Accumulators (Condition)
  - External
  - Internal
- Fluid sample(s)
- Air preload
- Pressure regulator, pressure-relief valve(s), bypass valve(s), flow control valve(s), and actuators
- Condition
- Position
- Settings and operation
- Filters, fittings, lines, and hoses (Condition)

Electrical System

- Engine-driven generator(s), alternator(s), inverter(s) (Condition)
  - External
  - Internal
- Evidence of operation
- Bearing condition
- Test for shorts and grounds
- Functional test
- Voltage and frequency regulators
- Test for operation
- Constant speed drives

- Condition
- Functional test
- Circuit protectors, buses, wiring, switches, terminals, relays and solenoids, transformer-rectifier units, and battery(ies)
- Light bulbs
  - Operation
  - Filament analysis

Instruments

- Visual inspection of indications
- Internal inspection for evidence of operation at impact
- Bench test, if needed

Pitot Static System

- Pitot Hebe blockage
- Static source heat operation
- Static source blockage
- Integrity at operation
- Pitot Tu of tubes, hoses, and fittings
- Cockpit selector

Flight Instruments

- Internal examination for evidence of operation
- Bench test, if needed

Integrated Flight Instruments (Flight Director, Horizontal Situation Indicator, Attitude Direction Indicator Angle of Attack, etc.)

- Electrical continuity
- Internal examination for continuity
- Bench test, if needed

Communication Equipment and Navigation Instruments (Very High Frequency Omni directional Range, Distance Measuring Equipment, Automatic Direction Finder, RMI, Data Communication Interface, Marker Beacon)

- Electrical continuity, servos
- Frequency selection
- Internal examination for continuity
- Bench test, if needed

Engine Instruments [Engine-Pressure-Ratio Indicator (EPR), Exhaust Gas Temperature, Tachometer, Fuel Gauges, Pressure Gauges]

- Mechanical continuity
- Electrical continuity
- Calibration

Electrical Instruments

- Readings
- Bench test, if needed

Autopilot

- Document cockpit selector
- Components that can be bench-tested
    - Amplifier
    - Servo motors
    - Servo rate controls
    - Mach trim system
    - Yaw damper

Pneumatic System

- Ducting
- Flow control valves

Ice and Rain Protection

- Cockpit controls
- Ducting
- Flow control valves
- Combustion heaters
- Windshield wipers
- Windshield chemicals
- De-ice boots

Environmental Systems

- Turbo-compressors
- Cabin superchargers
- Outflow valves
- Emergency depressurization valves
- Emergency depressurization handle
- Ducting
- Temperature control valves

- Air conditioning packs
  - Primary and secondary heat exchangers
  - Expansion turbines or air cycle machines
  - Freon compressor and motor
  - Freon condenser and evaporator
  - Cabin mixing valves
  - Flow control valves
  - Cooling fans
- Combustion heater
- Cockpit controls

Oxygen System

- Crew and passenger bottle(s)
- Condition
- Bottle pressure
- Line(s) integrity
- Regulators/valves
- Portable bottles
- Condition
- Pressure
- Valves

Fire Detection and Protection

- Fire detection system
  - Detector units, type and condition
  - Detector relays
  - Wiring
- Fire extinguisher system
- Bottles
- Pressure
- Lines to engines
- Type of agent
- Discharge indicators
- Cockpit controls
- Portable extinguishers
  - Condition
  - Pressure
  - Type of Agent
  - Operability

Power plants

- Reciprocating

- Cowls
  - Impact or in-flight separation
  - Evidence of an uncontained failure
  - Evidence of in-flight fire
  - Integrity and security of cowl latching mechanisms
  - Measure actuator shaft extension for cowl flap position

Fuel System

- Integrity from fuel tank(s) through engine fuel lines
- Position of main engine, fuel, crossfeed, and firewall shutoff valves
- Fuel sample(s) from engine (line, carburetor, fuel flow divider, strainer)
- Integrity of fuel tanks
- Presence of fuel in lines, carburetor, flow divider
- Condition and operability of boost pump(s)
- Carburetor make/model, P/N, S/N
- Security, rigging, and position of carburetor linkages
- Integrity of fuel selector valve
- Condition of fuel filters and intake air screens
- Operation of fuel injection master control, vapor vents boost, and venturi suction
- Condition of flow divider(s)
- Fuel leaks and security of fuel-line fittings
- Operation and security of fuel discharge nozzles

Lubricating System

- Condition of oil filters
- Oil pressure relief valve
- Oil sample
- Integrity of oil lines
- Magnetic sump drains
- Condition of oil pump
- Condition of oil sump and cooler, installation, and condition of vents
- Position of oil dilution system control solenoids

Electrical System

- Condition of spark plugs
- Condition of electrical harness
- Condition and operability of magnetos

Propellers

- Determine blade angles

- Blade damage, i.e., leading/trailing edge, chordwise scratching, gouges, bending, torsional twisting
- Inspect propeller governors for rotational scoring

Induction Section

- Condition of air filter
- Linkages and operability of alternate air source
- Condition of impellers on turbocharged engines
- Evidence of impeller rotational scoring
- Indications of oil leakage at impeller seals and inside intake pipes

Combustion Section

- Cylinder damage
- Crankshaft rotation
- Cylinder compression
- Remove rocker box covers and rotate engine to observe valve action
- Valve and rocker arm conditions
- (if necessary) Remove cylinders
- Condition of pistons and piston rings
- Cylinder wall damage

Exhaust Section

- Condition of exhaust manifold
- Condition of muffler
- Condition of exhaust stacks

Accessory Section

- Gear action with crankshaft rotation
- Condition of drive gears

Jet Engines

Inlet and Compressor Section

- Degree and direction of blade bending, leading and trailing edge breakage, rub marks on blade edges
- Debris and its distribution within the inlet area
- Inlet guide vane damage if engine had variable guide vanes (Check inlet case for impact markings to determine stator position at impact.)
- Anti-ice valve positions and plumbing
- Nose cone damage and condition of PT2 probe
- Oil leakage at front bearing

- Compressor rotation

Engine Bleed System

- Examine bleed systems for evidence of debris to provide an indication as to the minimum speed, EPR, and thrust by relating individual operating schedules to the bleed locations where the ingested material is found
- Boroscope compressor section for integrity
- Surge bleed valve position

Turbine Section

- Condition of visible blades and stators
- Evidence of overheat in first-stage nozzle guide vanes
- Damage to pressure and temperature exhaust probes, cones, and struts
- Oil leakage in area of rear turbine bearing
- Debris in fan discharge ducts
- Boroscope compressor exit guide vanes, combustion area, and visible turbine area
- Degree of turbine rotation
- Twisting or bending of shaft

Accessory Section

- Integrity of attached components
- Integrity of accessory gear box and tower shaft (Rotate N_2 rotor by means of the stator drive pad.)
- Condition of fuel and oil filters
- Oil sample
- Condition of fuel control leakage
- Damage to plumbing, electrical wiring, and pneumatic ducts
- Condition of engine mounts

Survival Factors Investigation, as appropriate (See Appendix 5 for detailed guidance.)

Human Performance Factors Investigation, as appropriate. (See Appendix 7 for detailed guidance.)

Appendix 3. Glossary of Descriptive Terms for Wreckage Damage

Accordioned: Crushed into pleated layers. Usually associated with crushed sheet metal or other material with a high capacity for plastic deformation.

Battered: Damaged by repeated blows or impacts.

Bent: A deviation from the original line or plane usually caused by lateral force; associated term "bowed."

Binding: Restricted movement, such as a tightened or sticking condition, resulting from high or low temperature, foreign object jammed in mechanism, etc.

Brinnelled: Small indentations pressed into a surface by contact with other objects.

Buckled: Bent, warped, or crumpled. Usually used to denote deformation by heat or column buckling.

Bulged: Localized convex or concave distortion usually caused by excessive local heating and/or differential pressure.

Burnished: Frictional polishing of a smooth metallic surface by contact with another smooth metallic surface.

Catenary: The curve assumed by a chain, heavy cord, or the like hanging between two points of support.

Charred: Frictional wear damage usually caused by two parts rubbing together with limited motion.

Chipped: A breaking away of the edge, corner, or surface usually caused by heavy impact (not flaking).

Compression Fracture: Occurs in two general forms block compression and buckling. Block compression is generally found in heavy, short sections; buckling is found in long, lighter sections. When buckling occurs in such a way that a whole piece buckles, it is referred to as column buckling.

Cracked: A narrow fissure or rupture caused by fracture of the material; partial separation of material that may progress into a complete break.

Crimped: Bent or pressed into ridges or folds.

Crippled: Normally used to denote a local deformation in a thin wall structure that has been overloaded but not fractured. The local buckling typical of short column failures as contrasted to the general bowing failure of a long column.

Dented: A surface indentation with a rounded bottom usually caused by impact of a foreign object; parent material is displaced but seldom separated.

Deposit: A buildup of material on a part either from foreign material or from another part not in direct contact.

Disintegrated: Separated or decomposed into fragments. Excessive degree of fracturing as with disintegrated bearings. Complete loss of original form.

Distorted: Extensive deformation of the original contour of a part usually due to impact of a foreign object, structural stresses, excessive localized heat, or any combination thereof.

Exfoliated: A type of corrosion that progresses approximately parallel to the outer surface of a metal, causing layers of the metal to be elevated by the formation of corrosion products.

Failed: Distortion, break, or deterioration that results in the affected part failing to satisfactorily perform the function for which it was designed.

Fatigued: The progressive fracture of a metal by means of a crack that develops and spreads under repeated cycles of stress.

Flaking: To form into flakes, to chip or peel off in flakes, or to become spotted with flakes.

Fracture: The creation of new surfaces by a rupture that produces a crack or results in complete separation into two or more parts.

Frayed: Worn into shreds by rubbing actions.

Fretting or Fretting Corrosion: Action that results in surface damage, especially in a mildly corrosive environment when there is repeated or vibratory relative motion between solid surfaces in contact under pressure.

Fused: Parts or materials joined by solidification after they have been subjected to melting.

Gouged: Scooping out of material usually caused by a foreign object.

Grooved: Smooth, rounded furrow or furrows of wear, usually wider than scoring, with rounded corners and a smooth bottom.

Melted: Changed by heat from a solid to a liquid or semi-liquid state.

Necking: Localized reduction in cross-sectional area during deformation under tensile loading.

Nicked: A sharp surface indention caused by impact of a foreign object. Parent material is displaced but seldom separated.

Peened: Deformed or dented by numerous hammer-like blows.

Pitted: Small irregular-shaped cavities in the surface of a material usually caused by corrosion, chipping, or heavy electrical discharge.

Ruptured: Breaking apart of material usually caused by high stresses, differential pressure, locally applied force, or any combination of these.

Scored: Deep scratches in an object made by contact with sharp edges of foreign particles.

Shredded: Dividing a body by cutting action, i.e., division of a body so as to cause its parts to slide relative to each other in a direction parallel to their plane of contact.

Spalled: Sharply roughened area characterized by progressive chipping away of surface material. Usual causes are surface cracks, inclusions, or any similar surface injury causing a progressive breaking away of the surface under load.

Stripped: A condition usually associated with threads or insulation. Involves removal of material by force.

Tearing (Shear): Occurs when the applied forces are acting out of the plane of the surface. The failures are characterized by a lipping of material on the edges of the sheet and by scoring lines on the fractured surface. The concavity of the scoring can be used to tell the direction of tearing. The direction of tearing is from convex to concave. Sometimes, if there is a heavy paint film, the saw-toothed breaking of the paint film can be used to tell the direction of tearing.

Tearing (Tensile): Occurs when the material tears under tensile forces. Except in thin materials, examination of the fracture will disclose "herringbone" marks with the head of the herringbone pointing back to the origin of the tear.

Tensile Fracture: Part of all the fractured surface is usually made up of a series of planes inclined approximately 45-60° to the direction of loading. Considerable local deformation or "necking" with a reduction of cross-sectional area is also generally evident in ductile materials. If the fracture is pure tension alone, the two halves of the fractures will part cleanly, and there will be no evidence of rubbing.

Torsional Fracture: Similar to the shear failure. Evidence of the direction of torque can be seen on the fractured surface by observing the scoring marks. Most parts retain a permanent twist.

Appendix 4. Midair Collision Geometry

A midair collision involves two vehicles on intersecting ground tracks at speeds that cause the two to meet at one point in space and time. If we think about ground tracks (you can substitute headings or bearings) and target speed, we are using the term "vectors." Vectors have magnitude (speed) and direction (ground track, heading or bearing) and can be represented in a graphic plot as a line of definitive length in a common scale representing the vector magnitude and oriented in a specific way on the page in relationship to the vector direction. These two intersecting vectors form two sides of a triangle, with the third side the convergence (closure) rate. As a triangle, the geometry of a midair collision can then be solved either graphically with a plotter or mathematically using the mathematical functions of geometry and trigonometry.

Graphic Solutions of Mid-Air Collision Geometry (Triangles)

In cases where the sides of triangles represent vector quantities (having both magnitude and direction), such as force, acceleration, and velocity, graphical solutions for unknown portions of the triangles are possible when the known quantities include enough information to allow the drawing of a complete triangle. This geometric or graphical solution of triangles is not restricted to right triangles but may be used for any triangle created by the vector quantities of a midair collision.

Normally it is necessary to know either the lengths of two sides of the triangle and the magnitude of the angle between the sides, or the magnitudes of two angles and the length of any side of the triangle in order to use the graphic solution method. This method of solution is to physically plot the known information on paper using a plotter with a convenient scale to represent the magnitude of the numbers involved, then complete the triangle and measure the unknown quantities that are desired, using the same scale that was used to plot the known quantities. In this process, the magnitude units of the plotted vectors must be the same (feet, knots, miles per hour, etc.)

This method is convenient and, if care is used in the plotting and scaling of the known information, the solution accuracy is well within the requirements of the typical investigation. The tools needed for this method are a scale, a straight edge, and a protractor or aeronautical chart plotter.

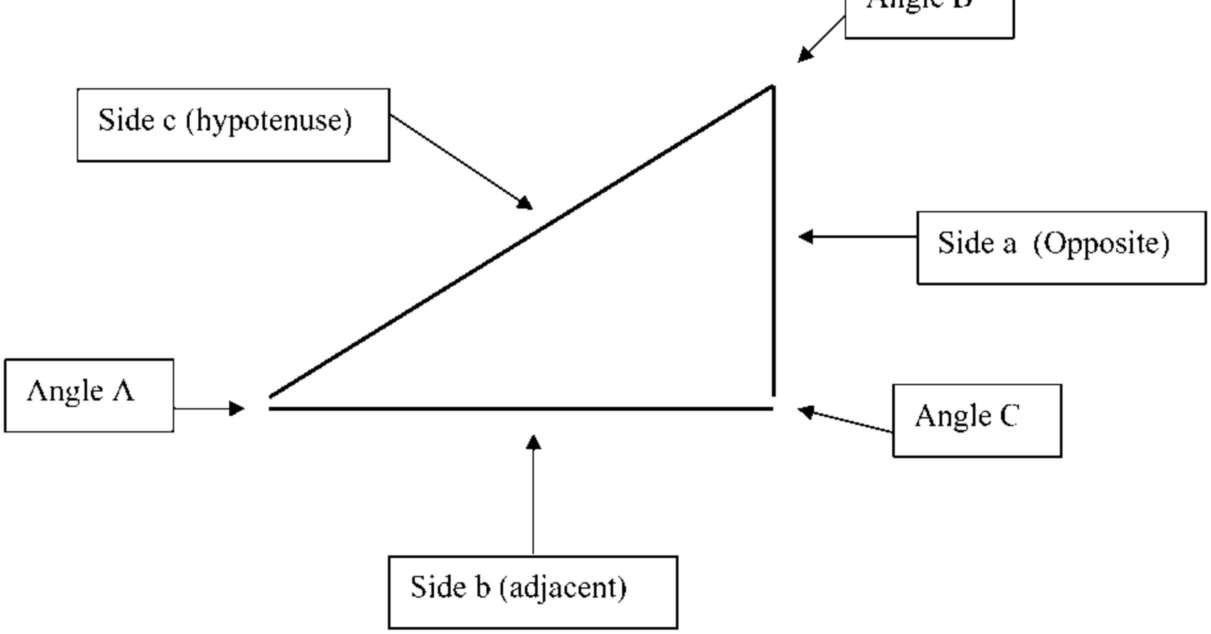
Trigonometric Solutions of the Midair Vector Triangle

To understand the mathematical solution for determining the collision geometry of a midair vector triangle, it is helpful to review the relationships of triangles and a few mathematical laws from geometry and trigonometry.

- The sum of the interior angles of any triangle is 180°.
- A right triangle is a triangle with one of the inside angles at a 90° angle.
    - The sum of the other two angles must then equal 90°s.

- The square of the length of the hypotenuse (long side) of a right triangle is equal to the sum of the squares of the lengths of the other two sides. For the following triangle, this may be stated:

$$a^2 + b^2 = c^2$$



Basic numerical trigonometry provides a method for obtaining the solutions of triangles arithmetically. Most solutions can be completed using the sine, cosine, and tangent functions, which are ratios of certain sides defined as follows:

$$\text{sine} = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \text{cosine} = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \text{tangent} = \frac{\text{opposite}}{\text{adjacent}}$$

where,

adjacent = side adjacent to an acute angle of a right triangle

opposite = side opposite an acute angle of a right triangle

hypotenuse = side opposite the 90° angle of a right triangle, or the long side.

For the triangle shown, these functions may be illustrated as:

For angle A

$$\text{sine A} = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{a}{c}$$

$$\text{cosine A} = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{b}{c}$$

$$\text{tangent A} = \frac{\text{opposite}}{\text{adjacent}} = \frac{a}{b}$$

For angle B

$$\text{sine B} = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{b}{c}$$

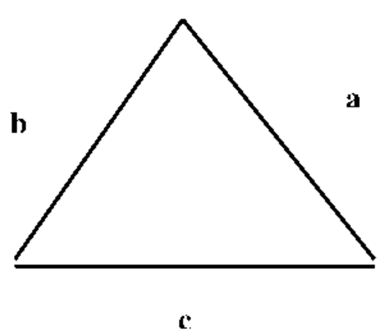
$$\text{cosine B} = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{a}{c}$$

$$\text{tangent B} = \frac{\text{opposite}}{\text{adjacent}} = \frac{b}{a}$$

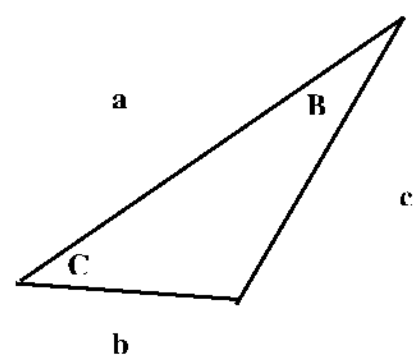
The numerical values of these trigonometric functions for each possible angle have been determined and are available in tabular form or from many hand-held calculators. Using the trigonometric tables, it is possible to determine the numeric value of the trigonometric functions when an angle is known or to determine the angle when the numeric value of a function is known.

Oblique Triangles

An oblique triangle is one that does not contain a right angle. Such a triangle contains either three acute angles or two acute angles and one obtuse angle. Using the same lettering conventions as previously noted for the right triangle, the two oblique triangle configurations are:



ACUTE
All interior angles less than 90°



OBTUSE
Two angles less than 90°, one larger than 90°

When any three values are known involving at least one side or more and one or more angles, we can completely solve the triangle using the *Law of Sines*, which states:

In any triangle, the three ratios obtained by dividing a side by the sine of the opposite angle are equal.

This can be illustrated by:

$$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$$

The second important mathematical law for solving oblique triangles is the *Law of Cosines*, which states:

> *The square of any side of a triangle is equal to the sum of the squares of the other two sides minus twice the product of these sides and the cosine of the angle between them.*

This can be illustrated by:

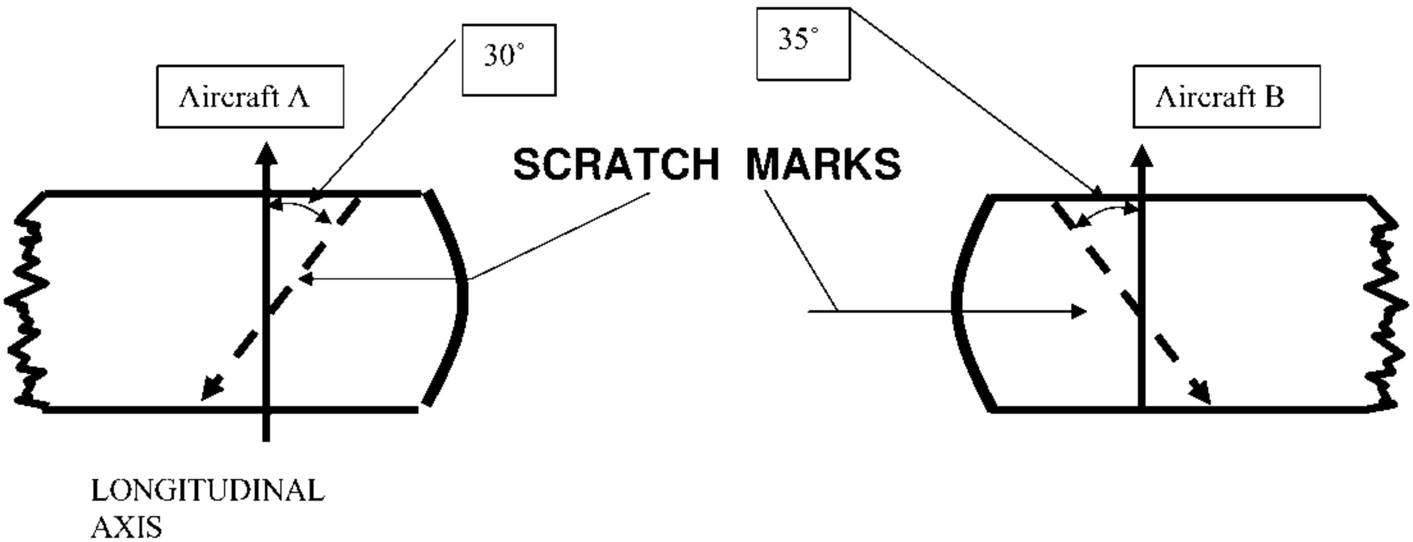
$$\text{Cos C} = \frac{a^2 + b^2 - c^2}{2ab}$$

A second form of this law is:

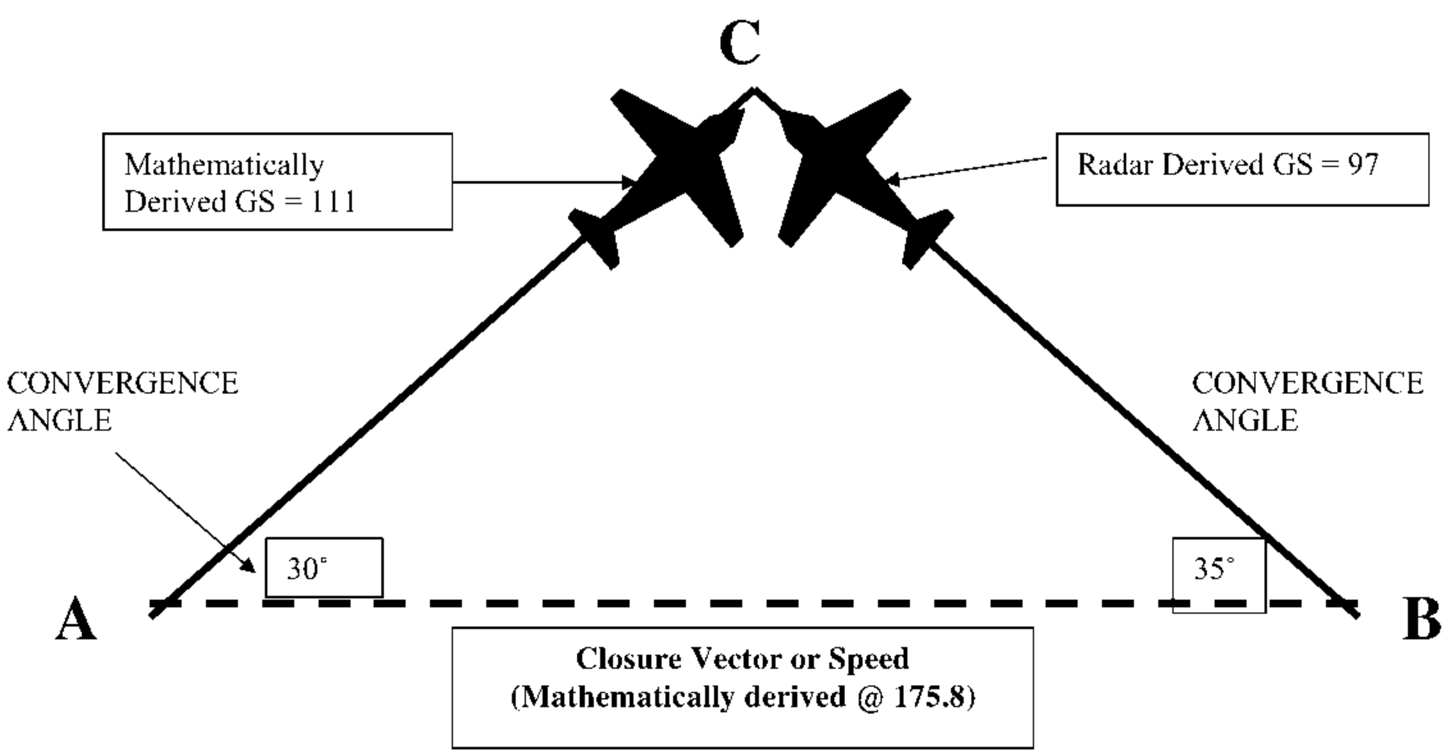
> *The cosine of any angle of a triangle is equal to a fraction whose numerator is the sum of the squares of the adjacent sides minus the square of the third side and whose denominator is twice the product of the adjacent sides.*

Many other angular relationships can prove useful in specific situations. However, the angular relationships just discussed will provide the investigator with the basic tools to complete an investigation of most mid-air collisions. The relationships will also prove useful in other accident investigations when determining impact angles, heights of impact points on trees or other structures, etc.

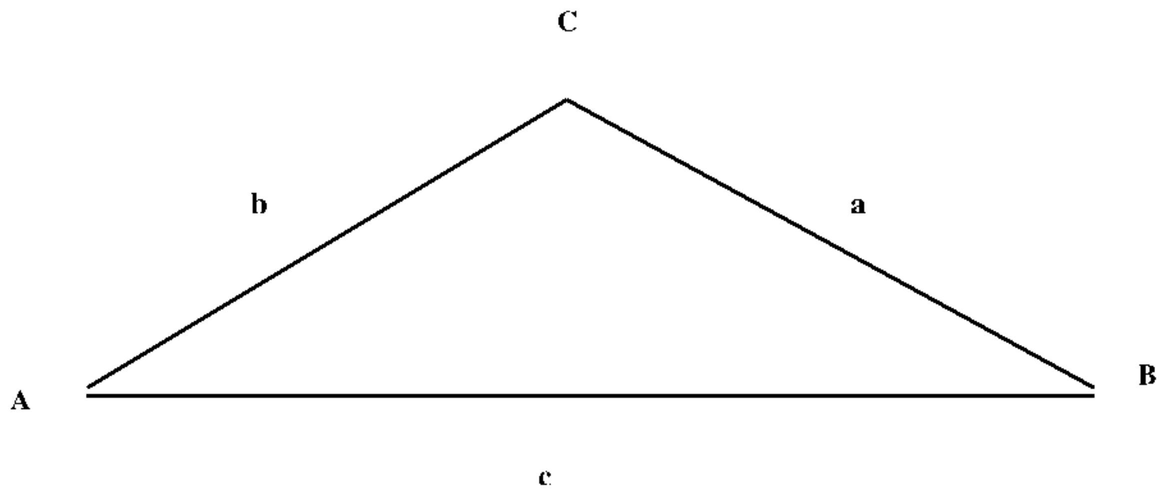
Sample midair collision problems with a graphing of the geometric problem and the mathematical solutions are presented in the next several pages of this appendix.



COLLISION ANGLE 'C' = 180° - (30° + 35°) = 115°



If we reduce the preceding diagram to a graphic triangle, we have:



Angle C is the collision angle between Aircraft A and Aircraft B: 115°
Angle B is the scratch mark measured on aircraft B and also the convergence angle of aircraft B: 35°
Angle A is the scratch mark measured on aircraft A and also the convergence angle of aircraft A: 30°

Side 'a' is the speed of aircraft B:	97 (Derived from radar ground speed)
Side 'b' is the speed of aircraft A:	Unknown
Side 'c' is the convergence or closure vector:	Unknown

Using the *Law of Sines*, we can solve for the two unknowns:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$\frac{a}{\text{Sin } A} = \frac{97}{\text{Sin } 30^\circ} = \frac{97}{.50} = 194$$

$$\frac{b}{\text{Sin } B} = \frac{b}{\text{Sin } 35^\circ} = \frac{b}{.573} = 194$$

$$\frac{c}{\text{Sin } C} = \frac{c}{\text{Sin } 115^\circ} = \frac{c}{.906} = 194$$

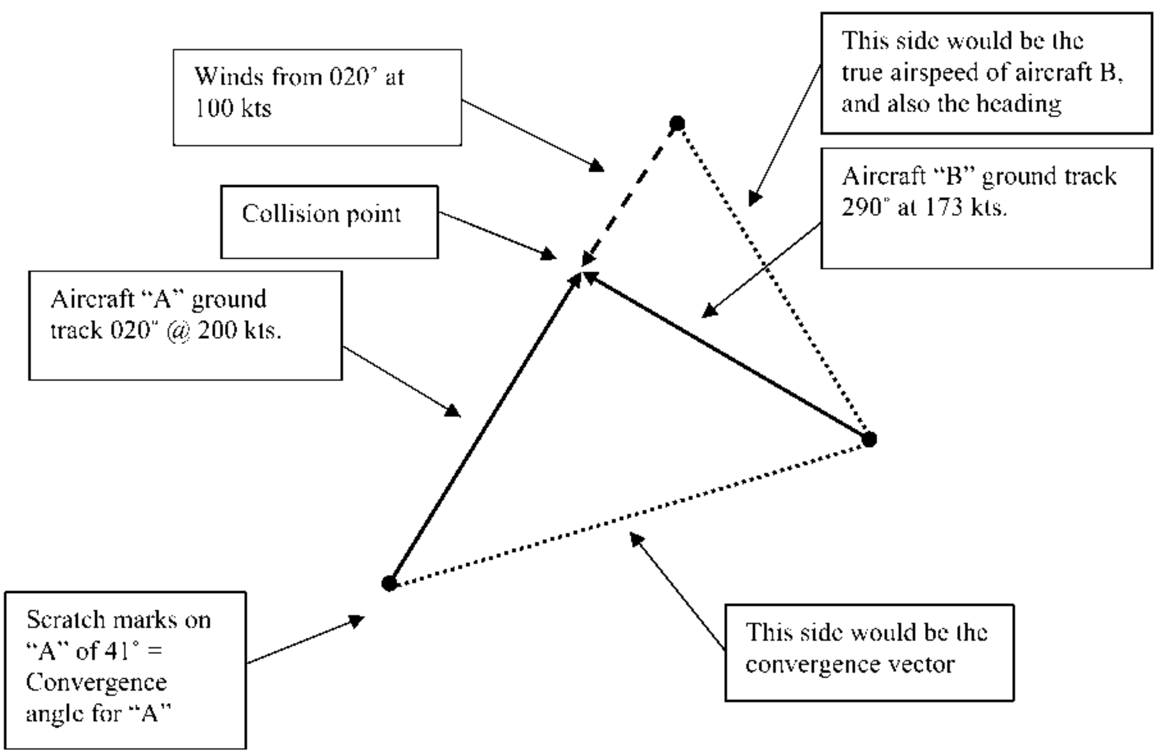
Side "b": the velocity vector of aircraft A is 111; and side "c": the closure or convergence vector between the two is 175.8.

Effect of Wind on Scratch Marks

Let's look at the effect of winds aloft on the midair collision triangle solution problem and the scratch mark patterns deposited on each aircraft. For this problem, we find from recorded radar data that aircraft "A" was on a ground track of 020° at a ground speed of 200 knots. Aircraft "B" was on a ground track of 290° at a ground speed of 173 knots. The winds aloft at the altitude of the collision were from 020° at 100 knots. Paint transfer and scratch marks were observed on aircraft "A" oriented 041°. The only identifiable scratches on aircraft "B" are at 079°, but an initial graphing of the radar tracks shows the scratch marks should be more like 049° and the collision angle close to 90°. Because these data are inconsistent, the triangle solution method can be used to confirm what the scratch marks should be on aircraft "B." Using the solution methods discussed, we can obtain answers to find:

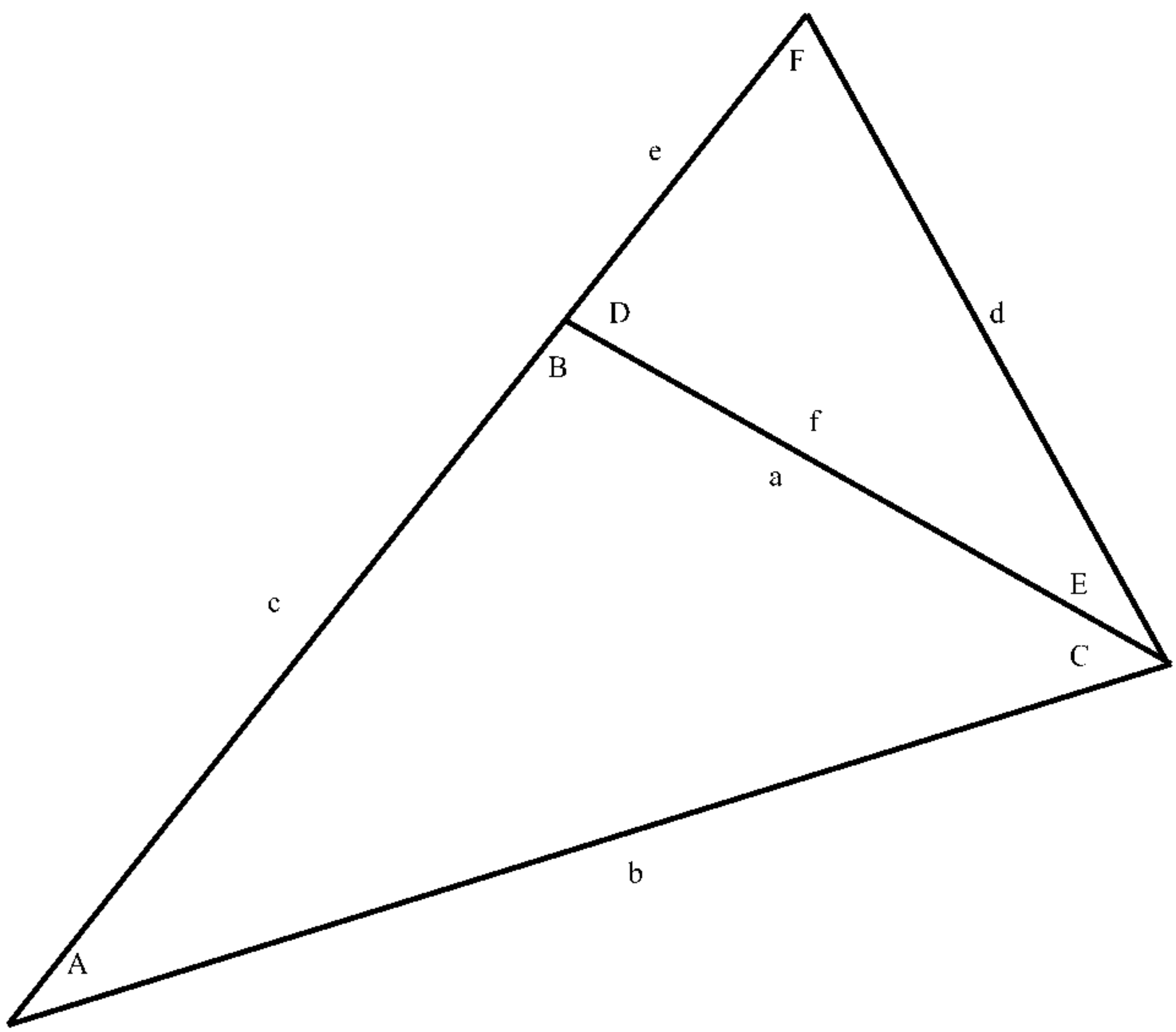
- The convergence angle on aircraft "B" and, thus, the scratch mark orientation. Also, determine the convergence rate between the aircraft.
- The headings of both aircraft "A" and "B."
- The true air speeds of each aircraft.

A plot of the information available from the radar data, the winds aloft, and the markings on aircraft "A" yields the following diagram:



As we can see, the resulting plot is really two triangles, and, because the difference between the ground tracks of the airplanes is 90°, the triangles are right triangles. Using the triangle solution methods discussed, the answers to the midair collision geometry problem are easy.

Refining the plot to triangles with classic mathematical nomenclature yields:



We know that angles "B" and "D" are 90° from the difference between the ground tracks (020° - 290°).

Angle "A" (the scratch mark and convergence angle) was measured on Aircraft A at 41°, therefore, angle "C" should be 49°. We know this because (41° + 90°) 180 = 49°.

Angle "E" is the wind correction angle for aircraft B and, therefore, angle "C" plus angle "E" would be the convergence angle that we should find on aircraft B.

Side "c" (200 kts) is aircraft A's ground speed, and side "e" is the wind speed (100 kts). Side "c" plus "e" would equal the true airspeed for aircraft A (300 kts).

Side "f" is aircraft B's ground speed (173 kts). Side "d" (unknown) would be aircraft B's true airspeed.

Side "b" is the convergence vector or rate between both aircraft.

In first solving the wind correction angle ("E") and TAS (side "d") portions of the problem, we know the sides "e" (wind speed of 100) and "f" (aircraft B ground speed of 173), and because we have the opposite and adjacent sides of a right triangle, the solution for angle "E" would be:

$$\tan E = \frac{100}{173} \qquad \tan E = .578 \qquad E = 30^\circ$$

With the wind correction angle thus identified for aircraft B, we now know that the convergence angle (C + E) is 79°, which matches the scratch marks originally measured on that aircraft. Angle E plus the radar ground track of aircraft B would also equal the heading of aircraft B, which, in this case, is 290° + 30° = 320°.

To solve for aircraft B's true airspeed (side "d"), we can use either of two methods: the side squared or a trigonometric function of either angle "F" or "E."

For the side squared method,

$$d^2 = e^2 + f^2 \qquad d^2 = 100^2 + 173^2 \qquad d^2 = 39929 \qquad d = 199.8$$

For the trigonometric method,

$$\text{Sin } E = \frac{d}{c} \qquad \sin 30^\circ = \frac{d}{100} \qquad .5 = \frac{d}{100} \qquad d = 200$$

We now know that aircraft B's true air speed was 200 kts on a magnetic heading of 320° at the time of the collision.

The only question left to answer is the convergence vector or rate between the aircraft. This is side "b" of our triangle.

For the side squared method: $b^2 = c^2 + a^2 \qquad b^2 = 200^2 + 173^2 \qquad b = 264.4$

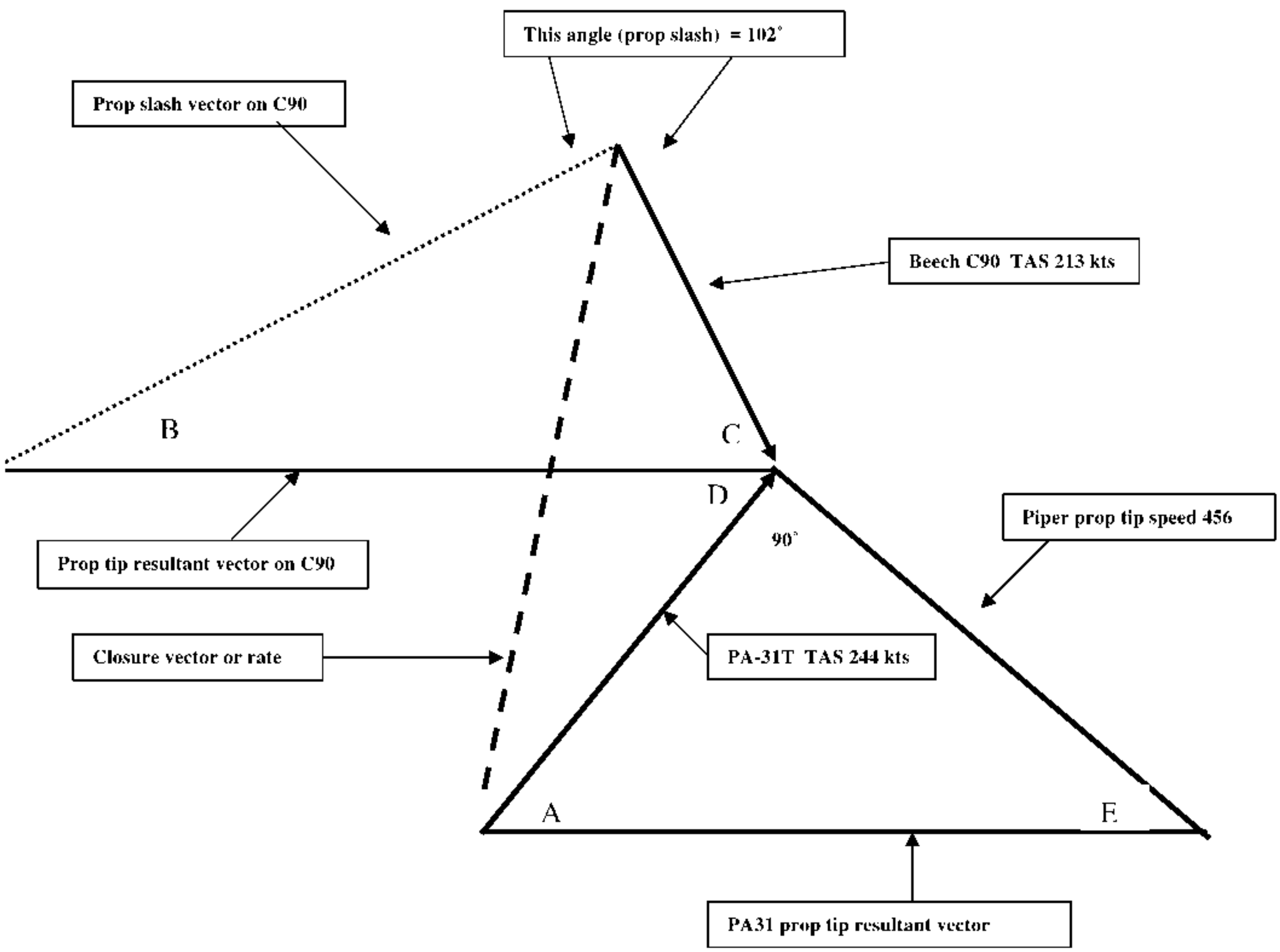
For the trigonometric method:

$$\cos A = \frac{c}{b} \qquad \cos A = \frac{200}{b} \qquad \cos 41^\circ = \frac{200}{b} \qquad .7547 = \frac{200}{b} \qquad b = 265$$

The convergence vector (closure rate) between aircraft A and B is 265 kts.

Using mathematical triangle solution methods can assist in solving the collision geometry problem in a midair collision. A final illustration follows, which shows the solution of a midair collision with one propeller slash mark and the true airspeeds of the involved aircraft as the only known quantities.

Collision Angle Solution with only one prop slash and TAS known



A Beech C90 and a Piper PA-31T have collided in flight and the resulting on-ground fires have destroyed much of the collision evidence. In this problem, the only identifiable mark is found on the Beech C90. The mark is a single prop slash on the bottom of the fuselage, which is measured at 102° from the C90's longitudinal axis. The estimated true airspeeds reconstructed from previous flights are 213 kts for the C90 and 244 kts for the Piper PA-31T. The manufacturer supplied the Piper propeller tip speed, which is 456 kts. As the investigator-in-charge, you must find the collision angle and the closure rate of the two airplanes.

We first solve for the PA-31 prop resultant (AE), because this is the same as the prop resultant on the C90 (BC). Using the sum of the squares method for a right triangle, we have $244^2 + 456^2 = 517^2$.

Because angles A and D are equal, we now solve for A using the tangent function of the side ratios 456/244 = Tan A. Therefore, angles A and D = 62°.

Next we find angle C, because the sum of D + C will give us the collision angle, and, with angle C, we can also solve for the closure vector side. Because both problems involve acute triangles, we use the *Law of Sines* to solve both questions.

To arrive at angle C, we need to solve for angle B. Sin 102/517 = Sin B/213 = 24°. Recall that A + B + C = 180°. 180° - (102° + 24°) = C. Therefore, C = 54°.

The collision angle = C + D = 116°.

Graphically plotting the triangle with a protractor and scale rule, we find that the closure vector is 380, and that angle G = 34° and angle F = 30° degrees. Using the *Law of Sines,* we can confirm the graphic plot solution.

X/Sin 116° = 244/Sin 34° = 213/Sin 30°

[The ratios 244/Sin 34° and 213/Sin 30° while not exact, are very close to each other and usable in this case to verify the relative accuracy of our plot measurement.]

X/.8987 = 244/.5591 = 213/.5

X = 382 versus the scale rule measured 380.

If we use the *Law of Cosines,* we can further refine the closure vector:

$$\text{Cos } C = \frac{a^2 + b^2 - c^2}{2ab}$$

$$c^2 = 244^2 + 213^2 - 2(244)(213) \cos 116^\circ$$

$$c = 387.9$$

Appendix 5. Survival Factors Checklist

Survival Factors Investigation Topics

The following investigation topics and areas of inquiry are presented for investigators to use in cases where survival factors issues may exist. The checklist is oriented toward air carrier events; however, many are applicable to general aviation and air taxi operations that experience on-airport accidents.

Crash Kinematics

- Horizontal velocity (ground speed) fps
- Vertical velocity (descent rate) fps
- Terrain angle
- Flightpath angle
- Impact angle
- Attitude at impact
- Magnitude of velocity component
- Stopping distance
- Measure fuselage/airframe deformation
- Measure ground scars

Aircraft: The condition and operability of the following items should be noted:

- Exterior
  - Cockpit and fuselage/cabin damage
  - Direction, degree, and location of deformation
  - Thermal damage
  - Blocked exits

- Interior
  - Instrument panel
  - Flight controls
  - Windshield, window(s), escape hatches
  - Crew life support systems
  - Condition of seats and restraints
  - Floor deformation and relationship to seat failures
  - The condition of galleys and other interior furnishings of mass. Relate any failures to injuries sustained by occupants.
  - Assess how cabin class dividers and other layout features affect evacuation difficulty and occupant survival.
  - Any design features (inadequately padded seat backs, food storage trays, bulkhead reinforcing members, etc.) that may have contributed to injuries.
  - Loss objects in the cabin (luggage, flight bags, cargo, etc.)
  - Document any overhead storage bin failures.
  - Emergency exit operability and adequacy of exit markings and operating placards.

  - Did any obstructions restrict the use of any doors.
  - Identify exits used and the numbers of persons who used each exit.
  - Document any fatalities found near exits and the reasons for not succeeding in egressing the aircraft.

- Emergency Systems
  - Public address system
  - Equipment (flashlights, first-aid kits, O_2, etc.)
  - Emergency lighting
  - Evacuation alarm system
  - Emergency escape slides
  - Life rafts

Injuries and Injury Mechanisms

- Interview passengers and crew to determine what injuries were sustained during the accident.
- Identify occupant seat positions, and relate them to injury patterns and airframe damage.
- Obtain autopsy and toxicological reports from coroner to determine what caused fatal injuries.
- Relate the injuries to the parts of the aircraft or cabin interior that may have caused the injuries.

Police Response

- Interview department personnel, as needed.
- Count the number of units responding, pertinent times, and number of persons.
- Obtain police report.

Medical Response

- Were local hospitals placed on alert? If so, when?
- Was the alert in accordance with disaster plan? Was the plan adequate?
- Did medical personnel respond to the scene?
- What services were provided, i.e., ambulance, helicopter, medical triage team?
- How many were admitted to hospital(s), released, dead on arrival?

Crash/Fire/Rescue

- Search and Rescue
  - Interview personnel involved.
  - Count the number and the types of units and the number of persons involved with the search-and-rescue phase.
  - Determine how and by whom department(s) were notified.

  - Notify and respond in accordance with disaster plan.
  - Perform the last disaster response drill.
  - Determine the time to complete the firefighting/rescue operation.
  - Collect the on-scene commander and command post information.
  - List the type(s) of communications network(s) used.
  - Describe the difficulties encountered.
  - Provide the number of persons rescued alive.
  - Obtain reports on ground and air searches from participating organizations.

- Fire Response

  - Type and amount of firefighting agents used
  - Origin and the intensity of fire

Cockpit and Cabin Crew

- Duties and responsibilities during evacuation
- Efforts made to assist passengers
- How and when crew egressed from aircraft
- Preparation of passengers for impact and evacuation
- Cockpit and cabin communications adequacy, cockpit resource management issues

Passengers

- How passengers egressed from aircraft
- Difficulties in egress
- Observations of CFR response
- How passengers were injured

Disaster Preparedness

- Airport disaster plan
- Local community disaster plans, mutual aid agreements
- Recency of disaster drill
- Obtain copies of response reports

Appendix 6. Crashworthiness Investigation Information

G-LOAD CALCULATION FORMULAS

To determine the G-loads generated in the impact sequence, it is first necessary to establish the impact attitude and measure the total crush of the structure. Once the crush line and impact attitude are established, a drawing is made with the airplane in that attitude. Lines can be added to the drawing parallel to the impact surface, which will act as distance marks and will help to display the progressive crushing of the structure up to the crush line or stopping point. (See Figure 1.)

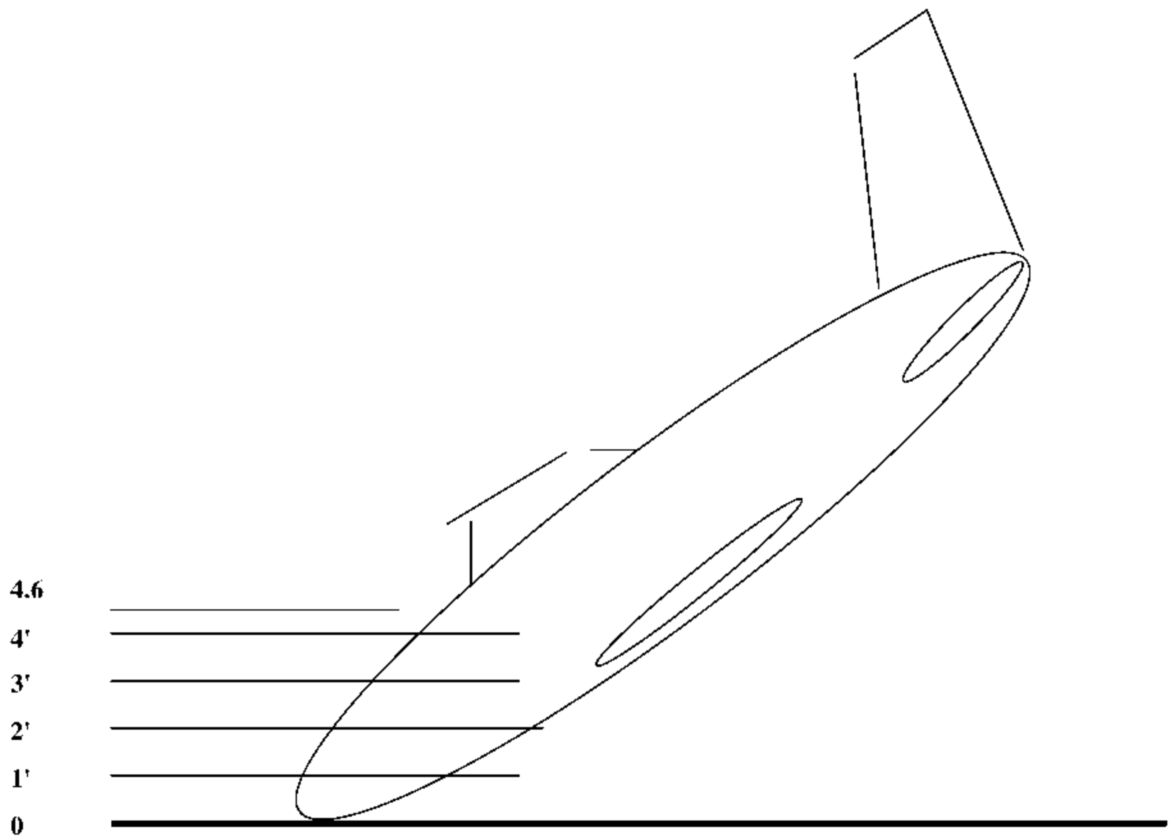


Figure 1. Measuring crush distance and impact attitude.

The pitch attitude of that airplane at impact also can be calculated by algebraically adding the values for the flightpath angle and the angle of attack. The flightpath angle is determined by aligning sequentially tree or object strikes and the ground impact point. The angle of attack can be estimated based on the airplane's speed and maneuvers just before impact. Although not as precise as using several ground scars, the value for pitch attitude derived by this method is sufficiently accurate for purposes of analysis when no other information is available.

Change in Velocity. Once the stopping distance has been established, the change in velocity[46] during the principal impact must be determined. The initial velocity is estimated based on knowledge of the airplane's maneuvers just before impact, the airplane's performance parameters, the pilot's statement, or a witness statement. For example, an airplane may have been seen flying level in a nose high attitude and pitching over just before hitting the ground. From this information, it can be assumed that the airplane was at or near stall speed when the impact occurred. Another example is a twin-engine airplane that crashes out of control after power is lost in one engine. In this case, it is reasonable to estimate that the initial velocity was near the airplane's single-engine minimum control speed (V_{mca}). Witness statements, radar data, and airspeed readouts from flight data recorders, if available, also are helpful in estimating the initial velocity.

The total velocity component of the principal impact acts along the flightpath. The flightpath angle is used to break down the total velocity component into its vertical and horizontal components, relative to the horizon. In the vertical direction, the final velocity is used to determine the velocity change. The final velocity usually is 0 because the maximum vertical crush is achieved when the ground stops the downward movement during the principal impact. As the vertical velocity becomes 0, the maximum vertical crush is achieved. In the horizontal direction, most airplanes tend to slide along the ground for some distance after principal impact, and the difference between the initial velocity and the final velocity (a value greater than 0) must be established for the principal impact.

In crashworthiness analysis, the velocity change is the most critical item and is the most difficult parameter to estimate. In the formulas for the calculation of the G-loads, the velocity appears as a squared factor, thus magnifying small errors in the estimate. Last second maneuvers of the airplane (controlled or uncontrolled) also can change the velocity by a small but important amount. Accounting for these changes is a difficult task and care must be taken to utilize all available information.

After establishing values for distance and velocity changes during the principal impact, the final step is to estimate the horizontal and vertical crash pulses, or a combined pulse, which represents the change in velocity over the measured stopping distance.

Pulse Shape Development

Quick Look Analysis. Because National Aeronautics and Space Administration general aviation crash test data show that a triangular crash pulse shape accurately describes the principal impact in the test crashes, a triangular pulse shape (T) can be used to calculate the most reasonable peak decelerative force in crash analyses. The following formula will be used for calculating the triangular crash pulse shape:

[46] The change in velocity is the difference between the initial velocity (the velocity just before the principal impact) and the final velocity (the velocity just after principal impact).

$$G_T = V^2/gS$$

where V = impact velocity (ft/sec)
G = earth gravitational constant (32.2 ft/sec^2)
S = stopping distance (ft)

The minimum peak decelerative force, based on the same change in velocity and distance, is calculated using the formula for the constant (rectangular shaped) pulse (C). The constant crash pulse shape is calculated using the following equation:

$$G_C = V^2/2gS$$

Where V = impact velocity (ft/sec)
G = earth gravitational constant (32.2 ft/sec^2)
S = stopping distance (ft)

The total time of the pulse is calculated as:

$$t = V/gG_C$$

For example, figure 1 depicts an airplane that crashed in a 30° nose down attitude. The 4.6-foot line represents the total depth of crush. Impact velocity was 90 miles per hour, or 131.94 ft/sec. For the vertical crash pulse, the impact velocity would be V_v = 131.94 Sin 30° = 66 ft/sec. The minimum peak pulse in the vertical direction is then calculated as:

$$G_{vC} = V_v^2/2gS = 66^2/2(32.2)\ 4.6 = 14.7\ {}^{G}vC$$

The triangular (maximum) peak $G_{vT} = V_v^2/gS = 66^2/32.2\ (4.6)$ or 29.4 G's, which, for this shape, is twice the minimum peak value. This results in a range (bracket) of 14.7 to 29.4 G's. Both pulses require a time of

$$T = V_v/gG_{vC} = 66/32.2\ (14.7) = 0.139 \text{ second}$$

This method results in a fast and reasonably accurate "quick look" evaluation of an accident and only requires that the values for velocity change and total stopping distance be known. However, a more detailed approach will yield a more accurate crash pulse, and, with the use of shaping techniques, the range of accelerations between the calculated minimum and maximum peak G-loads can be better defined, as shown below.

Detailed Analysis Based on Shaping Techniques. The following example illustrates how a detailed vertical pulse shape is developed. First, as in the "quick look" method, a visualization of the crash is developed, including the parallel lines showing the increasing amount of structure involved as the airplane crushes. Figure 1 shows that the nose area, which is comprised of lightweight material, is involved in the first 1 foot of crush. At the 1-foot mark, the components involved include some lightweight skin, the nose gear structure, and small frame structure. Starting at the 3.6-foot line, the structure being crushed includes the cockpit bulkhead, engine, engine mounts, cockpit floor, and side walls.

As the crush progresses to the areas of increasingly massive structure, higher decelerations, or G-loads, are expected to occur. Allowances are made in the analysis for the differences in the type and mass of the crushed structure. The least massive structure, referred to as nonproductive structure, is unable to support major loads and, thus, collapses easily. This structure has a crushing distance, but it does not produce a significant deceleration. In this example, the distance from 0 to 1 foot is comprised of lightweight material and imparts no crash loads to the occupants while it is crushing; hence, it is nonproductive.

Nonproductive crushing is not considered when estimating acceleration levels in a pulse. However, an increase in the mass of structure involved will cause the crash pulse to be modified (shaped), based on the assumption that the magnitude of the crash pulse generally is proportional to the mass of structure being crushed. Correcting for nonproductive crushing and the increase in the mass of the structure involved is not precise, but these corrections make the results more accurate by eliminating large errors and by skewing the curves in a logical manner.

Also, as in the "quick look" procedure, the minimum and triangular peak G's are calculated for the purpose of establishing a reasonable range of values. Because the first foot of crushing involves nonproductive structures, the stopping distance of 4.6 1.0 or 3.6 feet is used in calculations. The minimum peak G then is $V^2/2gS = 66^2/2(32.2)\ 3.6$, or 18.79 G's, and the triangular peak load is $V^2/gS = 66^2/32.2\ (3.6)$, or 37.58 G's. These values become the minimum (19 G's) and maximum (38 G's) limits for the force values in the crash analysis. It should be noted that this step is quite easy and can be included in many quick look analyses.

The next step in the detailed analysis is the modification or shaping of the constant (rectangular) pulse. This modification is performed to create a pulse magnitude and shape between the calculated minimum and triangular peak G-loads, which is more representative of the actual impact.

Target values for changes in distance (crush) and velocity, determined from the visualization and the physical evidence, are used to facilitate shaping of the crash pulse. The distance targets are fixed in magnitude, and the velocity targets also are fixed in magnitude at the end points. The distance targets are set at 0, 1, 2, 3, and 4.6 feet, respectively. The velocity targets are set at 66 ft/sec (0 feet crush and 0 time) and 0 ft/sec (maximum crush and total time).

A four-tiered pulse is assumed, based on the previously set crush distance targets. Each tier of the pulse represents the average G-load over a given distance of crush. For this case, an initial estimated value of 27 G's was assumed as the highest value for the modified constant pulse. Any of the values between the established maximum and minimum values may be chosen for the estimate. However, analytical experience has shown that the midpoint, 27 G's in this case, is a reasonable value for the initial estimate. This value can be revised and the analytical procedure can be repeated for the number of iterations needed to satisfy the distance and velocity target criteria.

The 27 G value and the distance targets are used to establish values for the relative magnitudes of the deceleration tiers. Judgment again is used in estimating how much of the total deceleration has occurred during each interval of crush. The results of these estimates are presented in the following table:

Crush Level (feet)	% of Total Deceleration	G's
0 – 1	0% of 27 G's	0
1 – 2	33% of 27 G's	9
2 3	66% of 27 G's	18
3 4.6	100% of 27 G's	27

Although many methods can be used to establish target times, it is advantageous to make the estimate as accurate as possible. This reduces the number of iterations necessary to meet the fixed target values when shaping the pulse. A method for calculating the target time is presented below.

After an average velocity is calculated for each segment, the average time for each segment is calculated, and the distance targets are set at those times. For segment 1 (0-1 ft), it is assumed that there is no change in velocity; therefore, the average velocity is 66 ft/sec. The average time for this segment is calculated as:

$$T_{ave1} = S/V_{ave1} = 1/66 \text{ or } 0.015 \text{ second.}$$

Because there was no appreciable change in velocity in the first segment, the starting velocity for the second segment (1-2 ft) also is 66 ft/sec. For S_2 = 1 ft, t_2 = 1/66 or 0.015 ft/sec. g_{s2} = average G estimate for the second segment, from the above table. The change in velocity for this segment is:

$$\triangle V_2 = gG_{s2}t,$$

$$\triangle V_2 = 32.2(9)(0.015) = 4.35 \text{ ft/sec},$$

giving an ending velocity of 66 - 4.35 or 61.65 ft/sec for this segment. The average velocity for the second segment is V_{ave2} = 66 - 2.18 or 63.82 ft/sec. The average time for the segment is t_{ave2} = 1/63.82, or 0.06 second, for a cumulative time of 0.031 second.

Segment 3 (2-3 ft) is treated similarly, resulting in a velocity change of 9.27 ft/sec, an ending velocity of 52.38 ft/sec, and an average velocity of 57.01 ft/sec. The average time for the segment is 0.018 second, for a cumulative time of 0.049 second.

The velocity change in segment 4 (3-4.6 ft) is from 52.38 ft/sec to 0 ft/sec, the final velocity. The average velocity is 26.19 ft/sec. The average time for this segment is t_{ave4} = 1.6/26.19, or 0.061 second, for a total pulse time of 0.110 second.

With the derived time versus velocity change over distance refinements, a rework of the calculations produces a narrowing of the range of likely forces from the original 19 G's (18.79 to 37.58 G's) to 9 G's (27 G's to 36 G's).

Appendix 7. Human Performance Factors Checklist

The following human performance factors checklist presents investigative topics and areas of inquiry to use, as appropriate, in cases where gross deficiencies existed in the performance of flight crew and operations or maintenance personnel.

Personal Information

- 72-hour history
- Work performance
- Behavioral attitude
- Behavior on the day of the accident
- Activity pattern (eating, drinking, social activities)
- Family information
- Education
- Future plans
- General health
- Nutrition
- Vision problems
- Hearing problems
- Medication being taken
- Smoking habits
- Sleeping habits

Operational Information

- General training (amount, type)
- Specific training (amount, type)
- Experience

Job History

- Types of jobs held
- Frequency of job changes

Operating Procedures

- Duties
- History of performance

Operator History

- Operator history
- Recent changes in operator-established policies
- Size of operation
- Personnel procedures
- Payment of salaries

- Personnel selection
- Promotions
- Rewards or penalties
- Company morale
- Labor strife or job actions

Task Profile

- Duties performed
- Responsibilities
- Attention diversions
- Workload
- Difficulty of tasks performed
- Time constraints on performance of tasks

Equipment Design

- General layout of cockpit
- Restrictions within cockpit
- Communication restrictions within cockpit
- Illumination within cockpit
- Noise levels within cockpit
- Instruments and equipment
  - Size
  - Shape
  - Color
  - Illumination
  - Direction(s) of movement
- Control design and characteristics
- Seat and restraint design and characteristics

INVESTIGATING OPERATOR FATIGUE IN A TRANSPORTATION ACCIDENT

Initial Screening Questions

If any of the following is true, proceed with the detailed methodology:

• Does the operator's 72-hour history suggest little sleep, or less sleep than usual?
• Did the accident occur during times of reduced alertness (such as 0300 to 0500)?
• Had the operator been awake for a long time at the time of the accident?
• Does the evidence suggest that the accident was a result of inaction or inattention on the part of the operator?

Detailed Methodology

It is important to establish two factors before concluding that operator fatigue contributed to an accident. First, determine whether the operator was susceptible based on sleep lengths, sleep disturbances, circadian factors, time awake, and/or medical issues. Second, if it is determined that the operator was likely experiencing excessive fatigue, evaluate information concerning the operator's performance, behaviors, and appearance at the time of the accident to determine whether they were consistent with the effects of fatigue.

A finding that the operator was susceptible to the development of a fatigued state in the absence of performance or behaviors consistent with fatigue should not be used to support operator fatigue as a probable cause or contributing factor in the accident, but may still be an important safety issue to be addressed in the accident report.

Part 1: Determine whether the operator was susceptible to fatigue.

Sleep Length

Determine whether the operator had acute or chronic sleep loss by documenting sleep/wake patterns for at least 72 hours before accident and learning about the operator's "normal" sleep habits.

• Ask operator:

  o Describe your typical sleep pattern of when you go to bed, awaken, and how much sleep you get during days off.
  o What time did you fall sleep the night before the accident? What time did you wake up? What was the quality of your sleep? (Repeat for two nights before, three nights before, etc.)
  o Did you take any naps? When, where, for how long, and why?

• Interview family members, hotel staff or other witnesses who can help complete the operator's sleep/activity schedule before the accident.

• Use receipts, cell phone records, work schedules, log books, alarm clock setting, or other records to help complete the operator's sleep/activity schedule before the accident.

Fragmented/Disturbed Sleep

Determine if the operator's sleep was fragmented (e.g., multiple sleep episodes per 24-hour period) and/or disturbed (e.g., awakenings during sleep due to internal or environmental factors) in days leading to accident.

• Use sleep/wake information collected in "Sleep Length" to examine the lengths and patterns of sleep episodes for split sleeps or daytime sleep.

• Ask operator (or determine through interviews with family members):
  - o Are there factors in your environment (e.g., noise, light, phone calls, etc.) that interfere with your sleep?
  - o Was your sleep pattern different or disrupted in the days leading to the accident?

Circadian Factors

Determine if accident happened during a circadian low point. The primary circadian trough is approximately midnight to 0600, especially 0300 to 0500, while a secondary "afternoon lull" occurs at approximately 1500 to 1700. Also, determine if the operator suffered from circadian issues due to recently crossing multiple time zones or to rotating, inverted or variable work/sleep schedules.

Sleep Disorders, Health, and Drug Issues

Determine if sleep disorders or other medical factors (e.g., disease or drug use) were present in the operator's history.

• Ask operator:

  - o Do you have difficulty falling asleep or staying asleep?
  - o Have you ever told a doctor about how you sleep? If so, why, when, and what was the result?
  - o What drugs/medications do you use regularly, and did you take any in days prior to the accident?
  - o Do you have any medical concerns that affect sleep (e.g., chronic pain, GERD, etc.)?

• Review operator's toxicological results for substances that may affect sleep or alertness.

• If applicable, have the operator evaluated by a physician who specializes in sleep medicine.

• Other evidence sources include the operator's medical or pharmacy records, or any drugs or medicine found within the wreckage.

Time Awake

Determine how long the operator had been awake at the time of the accident, using interviews or records to estimate wake up time from most recent significant sleep before the accident.

Additional Suggestions

• Check work records and records of previous accidents/incidents (including DMV and/or insurance records) for evidence of prior falling asleep during vehicle operation.

• Determine what kind of training the operator had received regarding fatigue management.

• Review operator's environment and tasks for unusual conditions on the accident day that would depress arousability, like low lighting, operational delays, or boredom.

• Determine whether representatives of management of labor union parties have indicated complaints of operator fatigue in the recent past?

Part 2: Determine whether the operator's performance, behaviors, or appearance were consistent with the effects of excessive fatigue, and whether their performance or behaviors contributed to the accident.

Operator Performance

Determine whether the operator's performance was consistent with the effects of fatigue.

• Use available evidence to determine whether the operator's performance was deteriorating prior to the accident. For example:

o Did the operator overlook or skip tasks or parts of tasks?
o Was there steering or speed variability?
o Did operator focus on one task to the exclusion of more important information?
o Was there evidence of delayed responses to stimuli or unresponsiveness?
o Was there evidence of impaired decision-making or an inability to adapt behavior to accommodate new information?

Operator Behaviors and Appearance

• Determine whether the person's appearance or behaviors before the accident were suggestive of sleepiness/fatigue, as based on witness interviews, operator report of being tired, audio or video records of the operator's behavior.