DESIGNING AN NHTSA CRASH INJURY RESEARCH ANALOG PROGRAM FOR GENERAL AVIATION / ADVANCED AIR MOBILITY

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16. Abstract
The MITRE Corporation was tasked by the Federal Aviation Administration's (FAA's) Office of Aerospace Medicine (FAA-AAM) to benchmark the National Highway Traffic Safety Administration's Crash Injury Research and Engineering Network (CIREN) and develop an analogous program focused on general aviation (GA) crashes with potential extensibility to Advanced Air Mobility (AAM). The resulting program model proposed in this document is referred to as GA/AAM CIREN. After benchmarking the current CIREN program, experts responsible for collecting and processing fatal GA accident and injury data were consulted. While CIREN is operationally very different from FAA crash investigation processes, the program has elements that the FAA can replicate to collect similar data for injury causation research. The FAA gathers GA crash scene, aircraft, and autopsy data for its own needs and to support National Transportation Safety Board investigations. However, the data collected are not typically sufficiently detailed for assigning occupant injury causation. The FAA can use the program model and implementation plan presented here as a framework for collecting and conducting CIREN-like data and research with existing FAA resources and expertise. If the proposed pilot study proves feasible, a longer-term program to research fatal GA crashes and those from emerging aircraft could be established.

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Contents

Introduction

The MITRE Corporation was tasked by the Federal Aviation Administration's (FAA's) Office of Aerospace Medicine (FAA-AAM) to benchmark the National Highway Traffic Safety Administration's (NHTSA's) Crash Injury Research and Engineering Network (CIREN) and develop an analogous program focused on general aviation (GA) crashes with potential extensibility to Advanced Air Mobility (AAM). The resulting program model proposed in this document, is referred to as GA/AAM CIREN.

In 2020, over 2.2 million occupants were injured in vehicle crashes on U.S. roads [1]. The population of fatal GA crashes available for study is orders of magnitude smaller than the fatal highway crash population, which was 38,824 in 2020 [1]. In 2021, the National Transportation Safety Board (NTSB) estimated that 1,157 GA accidents[1] occurred, resulting in 344 fatalities and 241 seriously injured persons [2]. Unfortunately, the GA fatality rate from 2012 to 2021 ranged from 1.53 to 2.15 per 100,000 flight hours [2], far exceeding the U.S. air carrier operations fatality rate, which was statistically zero during many of those years [3].

CIREN is a network of physicians, engineering professionals, automotive crash investigators, and data experts contracted to collect medical data from highway victims who enter certain level 1 trauma centers [4]. Retrospective crash scene and vehicle data are gathered to determine the specific biomechanical causes of injury in each CIREN case. Experts collaborate on an analysis and use findings to improve medical treatment, guide NHTSA research priorities, advise regulatory decisions, and inform engineering design changes. Despite the millions of serious injuries on highways annually, NHTSA studies only a few hundred cases per year at the level of detail CIREN necessitates [4].

While CIREN is operationally very different from FAA crash investigation processes, the program has elements that the FAA can replicate to collect similar data for injury causation research. The FAA gathers GA crash scene, aircraft, and autopsy data, both for its own needs and to support NTSB investigations [5] [6]. However, the data collected are not typically sufficiently detailed for assigning causation to occupant injuries. Processes are not focused on gathering information to support specific research initiatives, and data publicly released via the NTSB are often too sparse for analysis. Crash investigation and autopsy data are maintained in separate databases and file-sharing locations. There is no regular process conducted for fusing and analyzing data holistically to develop or better understand research priorities.

CIREN relies heavily on photographs to conduct its analyses, stating that "extensive, high-quality photographic documentation is a critical responsibility of the CIREN field investigators [7]." As the most common responders to a fatal GA crash scene, FAA's Flight Standards Services field office investigators can collect more photographic evidence in support of research activities, especially with direction from the highly experienced aviation accident investigators in the Office of Accident Investigation and Prevention. Media from the accident scene can be stored to complete the GA/AAM CIREN injury causation analyses once autopsy and toxicology data are received.

The FAA's May 2023 *Forecast Highlights (2023–2043)* suggests 3.5% growth in the GA sector over the next 20 years [8]. The FAA expects AAM services to begin in 2025-2026 [8]. The introduction of passenger carrying AAM vehicles and some of their staggering volume projections allows the FAA to improve its ability to capture and analyze more detailed data to inform research priorities, safety management systems, and other oversight activities [9]. Collecting higher fidelity GA data to perform more holistic accident and injury analyses can serve as a blueprint for similar future activities in AAM.

The FAA can use this program model and implementation plan as a framework for collecting and conducting CIREN-like data and research. By convening experts and increasing the exchange of information like photographs across related lines of business, FAA-AAM-600 can develop a GA/AAM CIREN program with existing FAA resources.

[1] Defined as involving "a U.S. registered civil aircraft not operated under 14 CFR 121 or 14 CFR 135."

It encourages more coordination amongst parties in the current data collection processes and establishes a collaborative case review process with a wide cross-section of experts.

Method

To develop a GA/AAM CIREN program model and implementation plan, MITRE first thoroughly reviewed CIREN. MITRE then documented the FAA fatal accident and pilot medical, autopsy, and toxicology data handling processes. FAA and other subject matter experts (SMEs) involved in these activities were interviewed (see Appendix C) to understand the current investigation workflows and data exchanges. MITRE then designed a program to improve the collection and distribution of information from typical[2] fatal GA accident investigations to facilitate injury causation analyses and research. If the pilot program indicates a broader, longer-term GA/AAM CIREN program is feasible, actions to further improve the model efficiencies and data flows are indicated.

Purpose

This document outlines an implementation plan that FAA-AAM can use to develop a GA/AAM CIREN research program. It contains several diagrams to represent the data process flows for the NHTSA CIREN program, the current FAA data collection process, the proposed FAA GA/AAM CIREN pilot program model, and the future ideal FAA GA/AAM CIREN program model. Expected program roles and responsibilities for GA/AAM CIREN and its future state are described.

The implementation plan is presented in four phases evocative of the project management lifecycle actions (initiate, plan, execute, close) [10]. These phases establish a course of action for the FAA to leverage existing expertise and data to conduct injury causation analyses and research. It suggests that FAA-AAM-600 begin (1) convening experts, (2) defining a pilot study sample, (3) conducting a pilot study, and ultimately, (4) assessing the pilot study results. A final "future" phase includes methods for further improving data collection, dissemination, and storage processes in an ideal state GA/AAM CIREN program.

[2] Most fatal GA accidents do not launch an NTSB Major Investigation and are primarily supported by FAA-AFS field investigators geographically convenient to the crash. The GA/AAM CIREN model assumes those personnel are the primary collectors of on-scene data, but nothing precludes more parties to the investigation from contributing data to the program.

CIREN DATA COLLECTION PROCESS AND PROGRAM ROLES

After a 1985 National Academy of Sciences recommendation [11], NHTSA developed CIREN as a multidisciplinary program where medical, engineering, and crash investigation experts collaborate to determine motor vehicle injury causation [4]. Teams develop purposive, highly detailed injury causation case records based on a seriously injured highway victim and evidence from the related vehicles(s) and crash scene. Fatal occupant data are accepted but are not a focus of the program.

NHTSA does not populate the CIREN database itself, it relies on data generated by a network of experienced medical centers located at level 1 trauma hospitals and engineering centers located at universities with histories of biomechanical research [4]. Medical Centers, through expert physicians, coders, and crash investigators, are primarily responsible for gathering the injury, crash scene, and vehicle data [12]. Engineering Centers, through biomechanics and coding experts, are primarily responsible for determining occupant injury causation using those data [12]. Experts involved in collecting and analyzing CIREN data work together to finalize and publish appropriate cases with NHTSA's Program Manager [12]. The high-level process for developing a CIREN case is shown in Figure 1[3], followed by a clarification of process roles and responsibilities in Table 1.

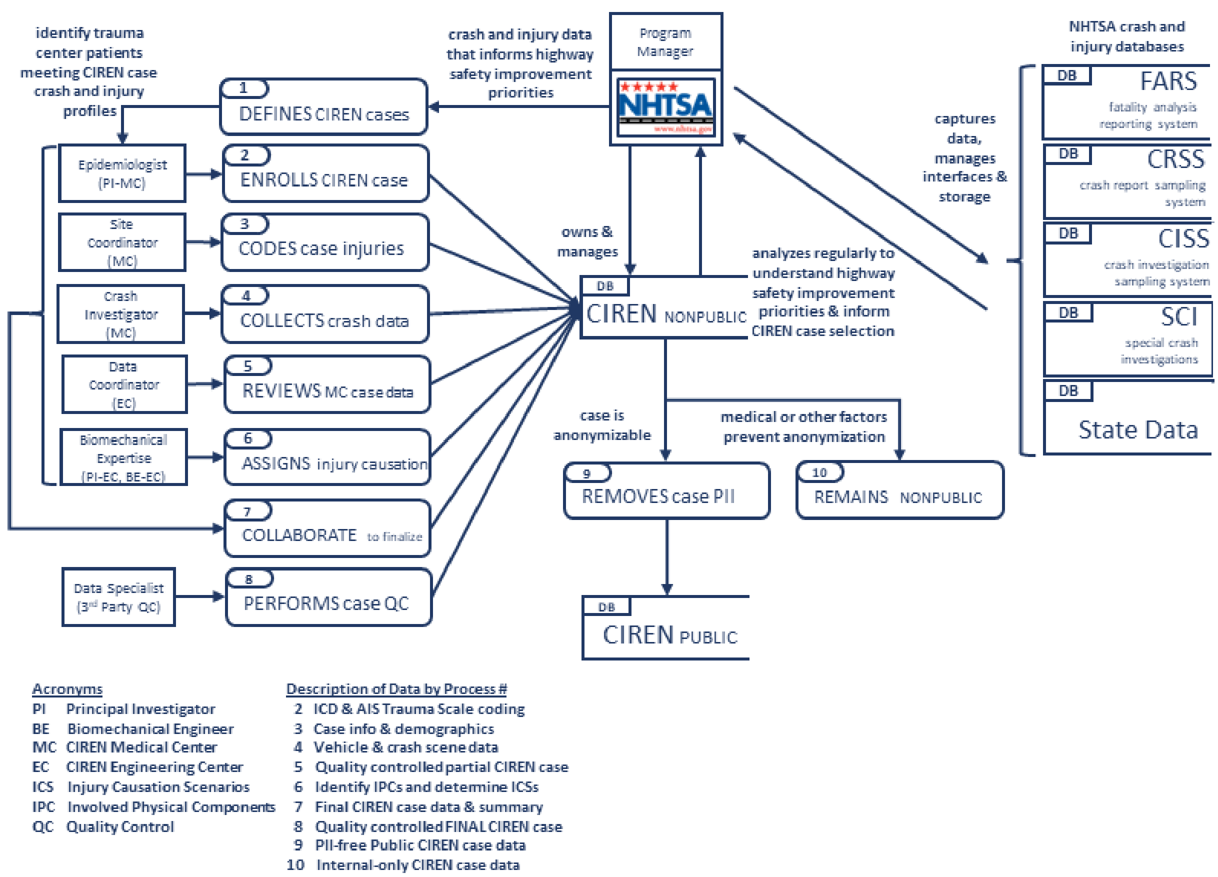

Figure 1: CIREN Data Process Flow Diagram

[3] See Appendix B for a data process flow diagram key.

Table 1: CIREN process roles and responsibilities

STEP #	Process Description	Role	Responsibility
1	DEFINES CIREN cases	Program Manager	NHTSA
2	ENROLLS CIREN case	Medical Expert, Principal Investigator	Medical Center
3	CODES case injuries	Site Coordinator	Medical Center
4	COLLECTS crash data	Crash Investigator	Medical Center
5	REVIEWS MC case data	Data Coordinator	Engineering Center
6	ASSIGNS injury causation	Biomechanical Experts: Principal Investigator & Engineer	Engineering Center
7	COLLABORATE to finalize	All contributors to steps 1-6	NHTSA, Medical Center, Engineering Center
8	PERFORMS case QC	Data Specialist	Third-Party QC Contractor
9	REMOVES case PII (if anonymizable)	Program Manager	NHTSA
10	REMAINS NONPUBLIC (if not anonymizable)	Program Manager	NHTSA

Note: MC = CIREN medical center; NHTSA = National Highway Traffic Safety Administration; QC = quality control.

AVIATION ACCIDENT AND INJURY DATA COLLECTION

The NTSB is granted the authority under 49 CFR § 831 to investigate civil aircraft accidents in the United States [13], but the FAA (along with other experts such as aircraft and powerplant manufacturers) has extended party status to participate [14]. To maximize resources at both agencies, FAA Flight Standards Services (AFS) field office personnel closest to the event are commonly used to gather on-scene data to assist the NTSB investigation and evaluate whether any of the Nine Areas of Responsibility were violated [5]. FAA-AFS investigators in charge (IICs) propagate crash particulars and an event narrative to FAA Form 8020-23, *FAA Accident/Incident Report* [5]. If collected, photographs, scene diagrams, and other supporting information are provided directly to the NTSB and the FAA Accident Investigation Division (FAA-AVP-100) for their business purposes and data storage systems.FAA-AAM-600 collects and analyzes autopsy and toxicology data for most certified airmen involved in fatal aviation accidents. Some high-level NTSB investigation details are fused with injury data in the office's MANTRA database, but detailed crash aspects are not captured to determine injury causation [15].

Operationally, there are few parallels the FAA can draw from NHTSA's administration of the standalone injury-causation-focused CIREN program. While CIREN primarily focuses on injured occupant data, the FAA-AAM-600 has the most direct access to fatal occupant data. This likely means a greater emphasis on excessively severe injuries that are more difficult to mitigate. However, the FAA can begin research in this area by mirroring CIREN's retrospective crash and autopsy data approach to develop and study occupant injury outcomes. The high-level GA crash, autopsy, and toxicology data collection processes that can be used to develop a GA/AAM CIREN program are shown in Figure 2. While data dependencies exist—for example, an autopsy must be conducted prior to the receipt and analysis of the report—there is no regular process that coordinates data of the type and fidelity required to perform injury causation analyses with research experts.

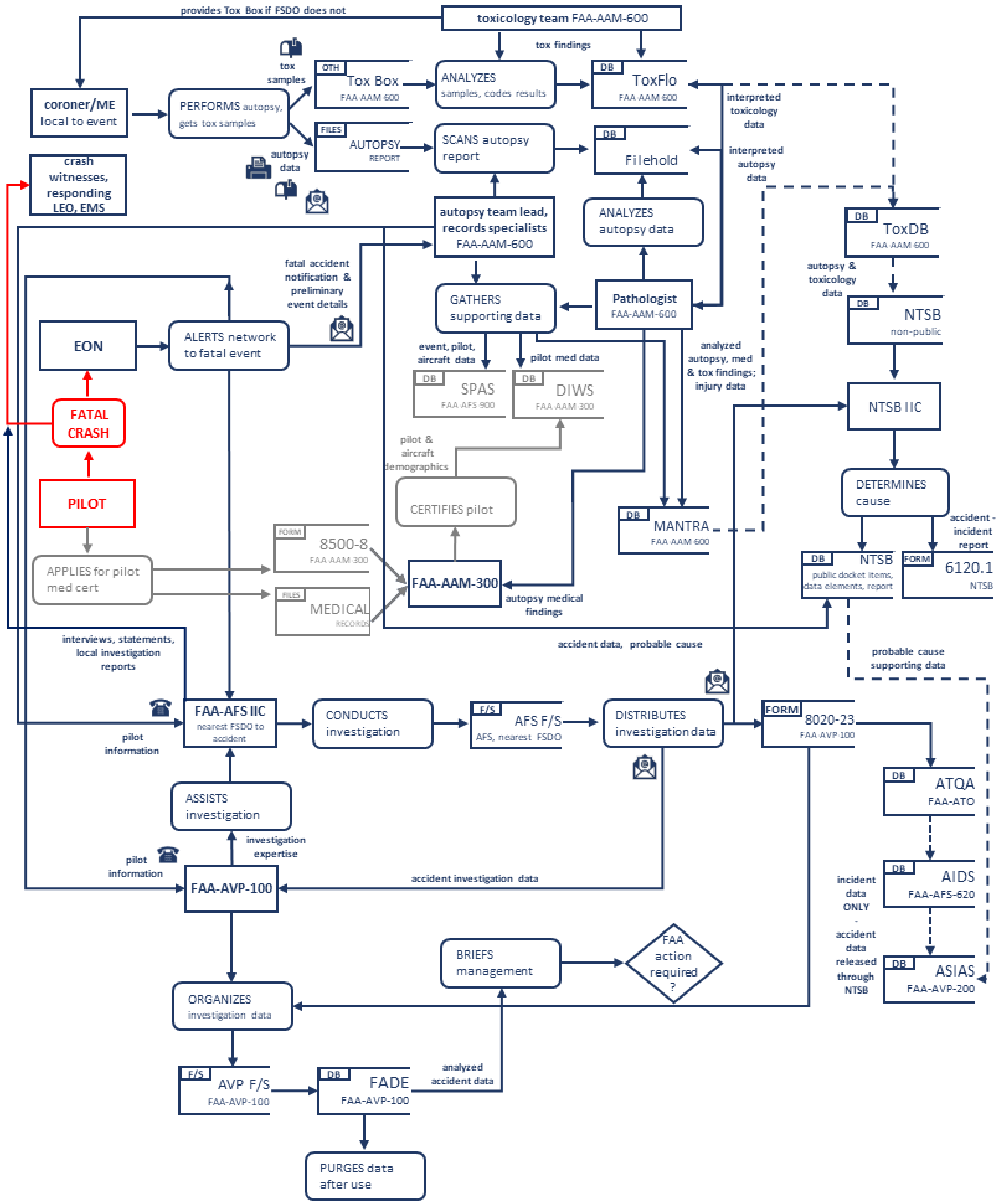

Figure 2: • Typical FAA GA Accident & Injury Data Collection Processes

GA/AAM CIREN IMPLEMENTATION PLAN

This GA/AAM CIREN program implementation plan is presented in four phases evocative of typical project management lifecycle actions (i.e., initiate, plan, execute, close) [10]. It provides a path for FAA-AAM to (1) convene experts, (2) define a pilot study sample, (3) conduct a pilot study, and (4) assess the pilot study results to evaluate its potential for long-term research feasibility. These phases establish a logical course of action for the FAA to leverage existing expertise and data to conduct injury causation analyses and research.

Phase 1: Convene experts

Objective: Socialize the pilot study program model and implementation plan with experts and potential stakeholders to refine the approach, gather procedures and tools to support extended investigations, and eventually conduct the pilot study and assess its results (Table 2).

SME interviews (see Appendix C) that guided the development of this GA/AAM CIREN research program were supportive of these efforts, but no resources or personnel were identified to help formalize its pursuit. FAA-AAM-600 should re-engage (and potentially identify additional) experts to review the proposed study and ensure it most efficiently leverages existing resources, processes, and workflows.

FAA-AVP-100, NTSB, FAA-AFS field office, and Transportation Safety Institute (TSI) personnel consulted in this phase should share relevant accident investigation standard operating procedures (SOPs), guides, measurement templates, or other tools that would facilitate the collection of data for this purpose. Of particular importance is finding experts to determine if BioTab[4] is an appropriate method of aviation injury causation analysis or if another method should be identified. Experts in other areas of accident analysis like crashworthiness could expand the program focus and increase the research value of the data collected.

Table 2: GA/AAM CIREN Implementation Plan Phase 1 Steps

<table>
<tr><td colspan="4">1.1 FAA-AAM-600 re-engages FAA-AVP-100 as core GA/AAM CIREN program support</td></tr>
<tr><td>1.1.1 Seek pilot study support, refinement, and program participation commitment</td><td>1.1.2 Develop plan to engage AFS field office(s) for participation in GA/AAM CIREN pilot study</td><td>1.1.3 Explore access to Fatal Accident Database (FADE) or file share drive for GA/AAM CIREN program</td><td>1.1.4 Solicit any FAA-AVP-100 Standard Operating Procedures (SOPs), guides, templates, tools, etc. that could support GA/AAM CIREN data collection</td></tr>
<tr><td colspan="4">1.2 FAA-AAM-600 re-engages NTSB experts</td></tr>
<tr><td>1.2.1 Seek pilot study support, refinement, and potential program participation</td><td>1.2.2 Solicit any NTSB SOPs, guides, templates, tools, etc. that could support GA/AAM CIREN data collection</td><td colspan="2">1.2.3 Socialize BioTab method of injury causation to determine its potential for use in GA/AAM CIREN</td></tr>
<tr><td colspan="4">1.3 FAA-AAM-600 and FAA-AVP-100 engage FAA-AFS field offices to identify GA/AAM CIREN field investigation partner(s)</td></tr>
<tr><td>1.3.1 Seek pilot study support, refinement, and program participation commitment</td><td>1.3.2 Assess level of effort and any additional resources required for GA/AAM CIREN data collection</td><td colspan="2">1.3.3 Solicit any FAA-AFS SOPs, guides, templates, tools, etc. that could support GA/AAM CIREN data collection</td></tr>
<tr><td colspan="4">1.4 FAA-AAM-600 engages with other data collection and analysis expertise</td></tr>
<tr><td>1.4.1 Engage biomechanics experts to</td><td>1.4.2 Engage Transportation Safety</td><td>1.4.3 Engage FAA-AIR structural and</td><td>1.4.4 Consider engaging with external organizations</td></tr>
</table>

[4] BioTab is an approach developed by experienced CIREN participants to systematically track the sources of victim injuries in cases studied [16]. Its hallmark is the development of Injury Causation Scenarios (ICS) that ascribe and document occupant injuries along with the related sources of crash energy and vehicle components involved [16].

evaluate use of BioTab [16] *method of injury causation determination within GA/AAM CIREN*	*Institute (TSI) personnel to identify any SOPs, guides, templates (cabin safety seat measurement template, others), or tools that could support GA/AAM CIREN data collection*	*crashworthiness experts to assess their potential role in GA/AAM CIREN program*	*having expertise to contribute to a GA/AAM CIREN program, such as GAJSC, GAMA, AOPA, and others*
1.5 Additional Phase 1 activities			
1.5.1 Update MANTRA [15] *fields to accommodate BioTab* [16] *method of injury causation if determined to have potential for GA/AAM CIREN analysis*		*1.5.2 Identify AIS coding expertise or software to support BioTab method*	

Phase 2: Define pilot study sample

Objective: Finalize a method to identify and capture accident data for a GA/AAM CIREN pilot study (Table 3).

The small fatal GA crash population [2] and geographically diverse accident locations make identifying events for investigation in a GA/AAM CIREN program challenging. A pilot study to assess the feasibility of executing a larger effort may need to be conducted as a sample of convenience through one or more engaged FAA-AFS field offices.

Ideally, the crash types, conditions, and occupant injuries most valuable to study in the context of accident and injury mitigation would be well-understood prior to program initiation. Given that knowledge, events with desired characteristics for study could be captured under GA/AAM CIREN. The available fatal GA crash and injury data are not easily analyzed, however, making a targeted pre-identification of crash types to study somewhat difficult. Experts may be able to define some broad accident characteristics to pursue for research where statistical patterns are not easily attainable.

Table 3: GA/AAM CIREN Implementation Plan Phase 2 Steps

2.1 Engaged FAA-AFS field office approach			
2.1.1 Target certain crashes over a determined amount of time through selected FAA-AFS field office(s). Pilot study size and length is dependent on crashes occurring, which are random and rare events		*2.1.2 A simply understood metric of selecting crashes appropriate for aviation survivability studies -like container, restraints, environment, energy absorption, and post-crash factors (CREEP) - could be used* [17]	
2.2 Additional target data sample refinement			
2.2.1 Use GA/AAM CIREN experts to inform crash and injury characteristics indicatory of research priorities	*2.2.2 Study common injuries and crash conditions as described in aviation injury causation literature*	*2.2.3 Analogize approaches from CIREN and other highway safety research directives*	*2.2.4 Consult data analysts responsible for NTSB, FADE, MANTRA, or other databases to determine ability to identify trends*

Phase 3: Conduct pilot study

Objective: Collect accident, toxicology, and autopsy data to support injury causation analysis (Table 4).

FAA-AVP-100 and other experts should finalize which SOPs, templates, and tools the FAA-AVS IIC will use to collect GA/AAM CIREN data. FAA-AVP-100, along with the FAA-AFS IIC assigned to the investigation in question, use the method established during Phase 2 to determine that an event constitutes an appropriate GA/AAM CIREN case. Photographs and data to support an injury causation analysis are collected in the field and stored in FADE for access after autopsy and toxicology data are processed. Many of the current procedures are maintained. The high-level processes for collecting fatal GA accident and injury data to build a GA/AAM CIREN case are shown in Figure 3 as Steps 1-9, followed by a clarification of process roles and responsibilities in Table 5.

NOTE: The pilot study concept was designed to be as minimally disruptive to existing work and dataflows as possible. The broad data collection steps are designated as existing processes (E) and new processes (N). Step numbers correspond to the GA/AAM CIREN program model diagram.

Table 4: GA/AAM CIREN Implementation Plan Phase 3 Steps

3.1 Finalize any SOPs or templates needed to support GA/AAM CIREN field data collection
3.1.1 Consult FAA-AVP-100, FAA-AFS, and/or others as needed.

3.2 Collect GA/AAM CIREN accident and injury data for the desired number of events and/or study period			
3.2.1. Step 1a: FAA-AVP-100 and FAA-AFS IIC determine crash from EON alert meets GA/AAM CIREN target criteria (N)	*3.2.2. Step 1b, 2: FAA-AFS IIC, with FAA-AVP-100 guidance (E), gathers crash scene data and photos to support injury causation analysis (N) along with their support of the NTSB and other FAA investigation activities (E)*	*3.2.3. Step 3: FAA-AFS IIC distributes data to all investigative parties for their individual business needs (E)*	*3.2.4. Step 4: FAA-AVP-100 adds FAA-AFS IIC investigation data to FADE database (E)*

3.3 Maintain or accelerate autopsy report collection, coding, and analysis process		
3.3.1 Steps 5, 9: FAA-AAM-600 autopsy team lead and records specialists execute current fatal case process to initiate and populate GA/AAM CIREN pilot demographics and other case detail in MANTRA (E)	*3.3.2. Step 7: Request & receive autopsy report from local coroner/ME per current cadence, or engage earlier and more often (N)*	*3.3.3. Step 8: FAA-AAM-600 pathologist conducts current autopsy report processes in MANTRA*

3.4 Maintain toxicology sample collection, coding, and analysis process	
3.4.1. Step 6a: Request & receive Tox Box from local coroner/ME (E)	*3.4.2. Step 6b: FAA-AAM-600 toxicology team conducts current processes involving sample screening, coding, and interpretation of toxicology results (E)*

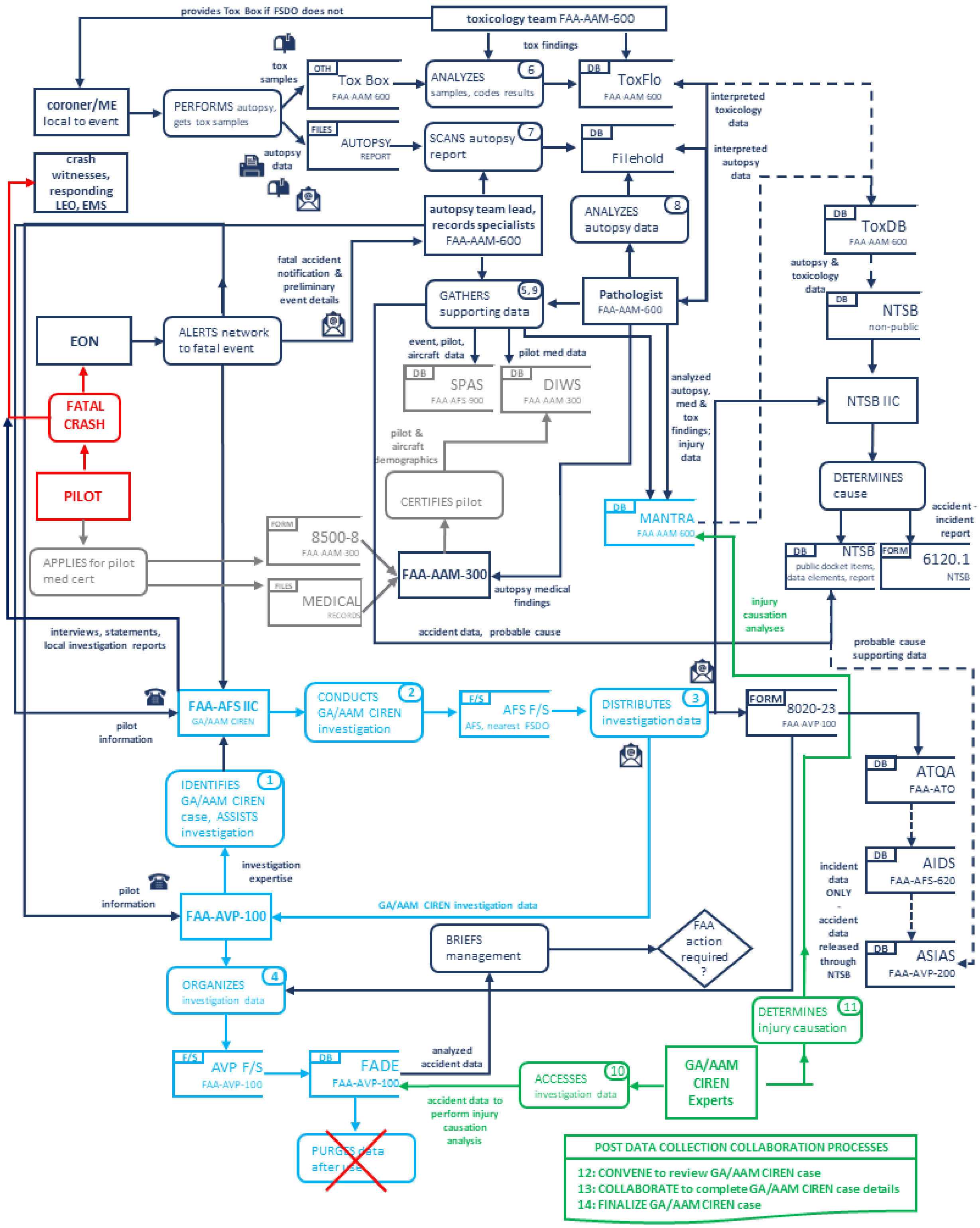

Figure 3: GA/AAM CIREN Program Data Process Flow Diagram

Table 5: GA/AAM CIREN Data Flow Process Steps and Roles

STEP #	Process Description	GA/AAM CIREN Role	FAA Position
1	IDENTIFIES GA/AAM CIREN case, ASSISTS investigation	Principal Investigator, Crash	FAA-AVP-100
2	CONDUCTS GA/AAM CIREN investigation	Crash Investigator	FAA-AFS IIC
3	DISTRIBUTES investigation data	Crash Investigator	FAA-AFS IIC
4	ORGANIZES investigation data	Principal Investigator	FAA-AVP-100
5	GATHERS supporting data	Autopsy Team	Team Lead, Records Specialists
6	ANALYZES samples, codes results	Toxicology Team	Toxicologist, Records Specialists
7	SCANS autopsy report	Autopsy Team	Team Lead, Records Specialists
8	ANALYZES autopsy data	Pathologist	Pathologist
9	GATHERS supporting data	Autopsy Team	Team Lead, Records Specialists
10	ACCESSES investigation data	GA/AAM CIREN Experts[5] AIS coding specialist Biomechanical engineer to generate the initial injury causation scenario	To be determined
11	DETERMINES injury causation	GA/AAM CIREN Experts Biomechanical engineer that generated the injury causation scenario Principal Investigator to finalize injury causation scenario for discussion	To be determined
12**	CONVENES to review GA/AAM CIREN case	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11
13**	COLLABORATES to complete GA/AAM CIREN case details	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11
14**	FINALIZES GA/AAM CIREN case	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11

Phase 4: Assess pilot study results

OBJECTIVE: Determine if pilot study data successfully supports injury causation analyses and a longer term, larger scale program (Table 6).

GA/AAM CIREN experts can conduct injury causation analyses once the required case accident, autopsy, and toxicology data are collected and processed. After GA/AAM CIREN experts generate the initial injury causation scenarios for a case, the team who generated the related data can participate in collaborative review sessions to finalize the details of causation. After an accumulation of cases, the FAA can determine whether the data collection efforts sufficiently supported the injury causation analyses and whether the results justify broader or extended GA/AAM CIREN efforts. The high-level processes to support GA/AAM CIREN injury causation analysis process are shown in Figure 3 as Steps 10-14, with a clarification of roles and responsibilities in Table 5.

[5] Assumes GA/AAM CIREN follows the BioTab injury causation analysis approach.

Table 6: GA/AAM CIREN Implementation Plan Phase 4 Steps

<table>
<tr><td colspan="6">4.1 GA/AAM CIREN experts perform injury causation analyses</td></tr>
<tr><td colspan="3">4.1.1. Step 10: GA/AAM CIREN experts access accident, autopsy, and toxicology data to begin the injury causation analysis process (N)</td><td colspan="3">4.1.2. Step 11: GA/AAM CIREN experts develop and code preliminary injury causation scenarios using BioTab [16] or other desired method in MANTRA (N)</td></tr>
<tr><td colspan="6">4.2 Hold collaborative GA/AAM CIREN meeting to finalize injury causation in each case</td></tr>
<tr><td colspan="2">4.2.1. Step 12: All contributors to case data collection – accident, autopsy, toxicology, injury causation, and other experts as needed are convened by the Program Manager to review and finalize the injury scenarios (N)</td><td colspan="2">4.2.2. Step 13: GA/AAM CIREN experts share crash and injury particulars with other case contributors, who review the results and offer additional opinions and insights (N)</td><td colspan="2">4.2.3. Step 14: After the presentation and discussion, all contributors finalize outstanding items and reach consensus on any remaining issues (N)</td></tr>
<tr><td colspan="6">4.3 Assess value of pilot study results</td></tr>
<tr><td colspan="3">4.3.1 Was the data collected during the GA/AAM CIREN pilot study sufficient for developing injury causation scenarios?</td><td colspan="3">4.3.2 Do the injury causation scenarios and other results inform FAA research priorities?</td></tr>
</table>

"Future" Phase: Towards a More Ideal GA/AAM CIREN Program

Objective: Reduce inefficiencies and duplicative efforts in data collection and distribution. Expand pilot medical data and increase researcher access to investigation media. Leverage EIM to better inform research priorities. Consider tools to improve the dissemination of injury and accident data to improve medical and investigation outcomes (Table 7).

If the GA/AAM CIREN pilot study suggests a longer-term program is feasible, additional steps should be taken to reduce current process inefficiencies. Accident data collected by FAA-AFS IICs and other permissioned parties to the investigation could be directly uploaded to nonpublic area of the NTSB database to eliminate the current manual exchanges and duplication of information. Data could be made more accessible to invited researchers. Given the limitations of autopsy data, the FAA could also pursue additional medical data for pilots and potentially other passengers to support injury causation analyses. The high-level processes to support a more ideal and efficient GA/AAM CIREN injury causation research program are shown in Figure 4 with a clarification of roles and responsibilities in Table 8.

The FAA is moving to an Enterprise Information Management (EIM) approach to data management [18]. The key databases used in this process are scheduled for inclusion, potentially alleviating the current challenges in being able to analyze crash and investigation data holistically to inform areas for study. Finally, the FAA should consider the use of simple photographic tools that can be used in the field to share critical information more quickly.

Table 7: GA/AAM CIREN Implementation Plan Future Phase Steps

<table>
<tr><td colspan="2">5.1 Pursue an agreement with NTSB to access nonpublic aviation accident database</td></tr>
<tr><td colspan="2">5.1.1. FAA-AFS IICs and other parties to the investigation directly upload data to the non-public area of the NTSB database through permissioned access.</td></tr>
<tr><td colspan="2">5.2 Expand collection of pilot medical data</td></tr>
<tr><td>5.2.1. Acquire hospital records if patient was treated before fatality to further support injury causation analysis</td><td>5.2.2. Explore avenues such as NTSB or FAA subpoena power to compel additional medical records for all fatal GA pilots and potentially other fatal and nonfatal crash victims</td></tr>
<tr><td colspan="2">5.3 Use EIM to analyze accident and injury data regularly and holistically to better inform target GA/AAM CIREN investigations</td></tr>
</table>

<table>
<tr><td colspan="2">5.3.1. Data scientists should regularly and holistically assess aviation accident and injury trends, such as quarterly or annually, to inform research priorities under this program</td></tr>
<tr><td colspan="2">5.4 Consider guided post-crash photography applications similar to TraumaHawk [19] to improve medical outcomes for aviation accident victims and more quickly ascertain crash particulars</td></tr>
<tr><td>5.4.1 Prototype phone applications sending advanced photographic notification of victim injuries to hospitals prior to their arrival have been shown to "help improve triage and transportation of the victims, assist the trauma center staff in better predicting injuries and treatment options, and even aid the implementation of remote treatment [19]"</td><td>5.4.2 Similarly, very timely photographic evidence from the scene could help FAA-AVP-100 and the FAA-AFS IIC more easily identify crash characteristics and the experts needed for analysis earlier in the accident data collection process</td></tr>
</table>

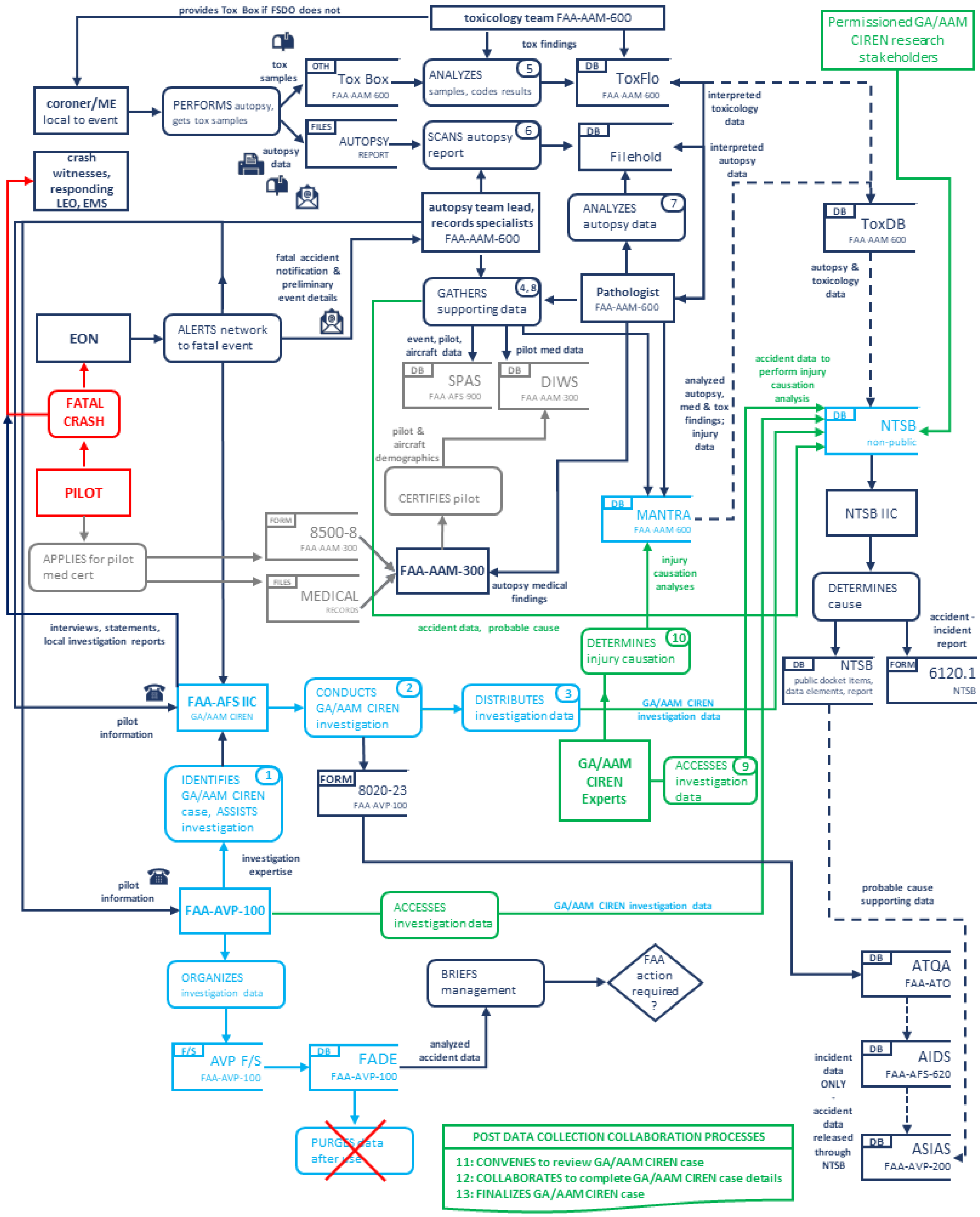

Figure 4: Future GA/AAM CIREN Program Data Process Flow Diagram

Table 8: Future GA/AAM CIREN Data Flow Process Steps and Roles

STEP #	Process Description	GA/AAM CIREN ROLE	FAA Position
1	IDENTIFIES GA/AAM CIREN case, ASSISTS investigation	Principal Investigator, Crash	FAA-AVP-100
2	CONDUCTS GA/AAM CIREN investigation	Crash Investigator	FAA-AFS IIC
3	DISTRIBUTES investigation data	Crash Investigator	FAA-AFS IIC
4	GATHERS supporting data	Autopsy Team	Team Lead, Records Specialists
5	ANALYZES samples, codes results	Toxicology Team	Toxicologist, Records Specialists
6	SCANS autopsy report	Autopsy Team	Team Lead, Records Specialists
7	ANALYZES autopsy data	Pathologist	Pathologist
8	GATHERS supporting data	Autopsy Team	Team Lead, Records Specialists
9	ACCESSES investigation data	GA/AAM CIREN Experts[6] AIS coding specialist Biomechanical engineer to generate the initial injury causation scenario	To be determined
10	DETERMINES injury causation	GA/AAM CIREN Experts Biomechanical engineer that generated the injury causation scenario Principal Investigator to finalize injury causation scenario for discussion	To be determined
11**	CONVENES to review GA/AAM CIREN case	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11
12**	COLLABORATES to complete GA/AAM CIREN case details	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11
13**	FINALIZES GA/AAM CIREN case	GA/AAM CIREN Program Manager, all contributors to steps 1-11	FAA-AAM-600 Manager, all contributors to steps 1-11

Note: FAA = Federal Aviation Administration; AAM = Advanced Air Mobility; CIREN = Crash Injury Research and Engineering Network; GA = general aviation; AFS = Flight Standard Services; IIC = investigator in charge.

CONCLUSION

The FAA has accident, autopsy, and toxicology data collection processes that can support a general aviation crash injury causation analysis program (GA/AAM CIREN). However, given the existing data collection and storage realities and the small, geographically diverse fatal crash population, the FAA should undertake some enabling activities before creating a full-scale program. The pilot program model and the suggested four-phase implementation plan provide a starting point for the FAA to begin more regularly and holistically evaluating injuries and assigning causation in fatal aviation accidents. In the future, an ideal version of the program per the final

[6] Assumes GA/AAM CIREN follows the BioTab injury causation analysis approach.

phase outlined in this work could be implemented to continue supporting injury causation research and examine the performance of new entrants to the market, such as AAM.

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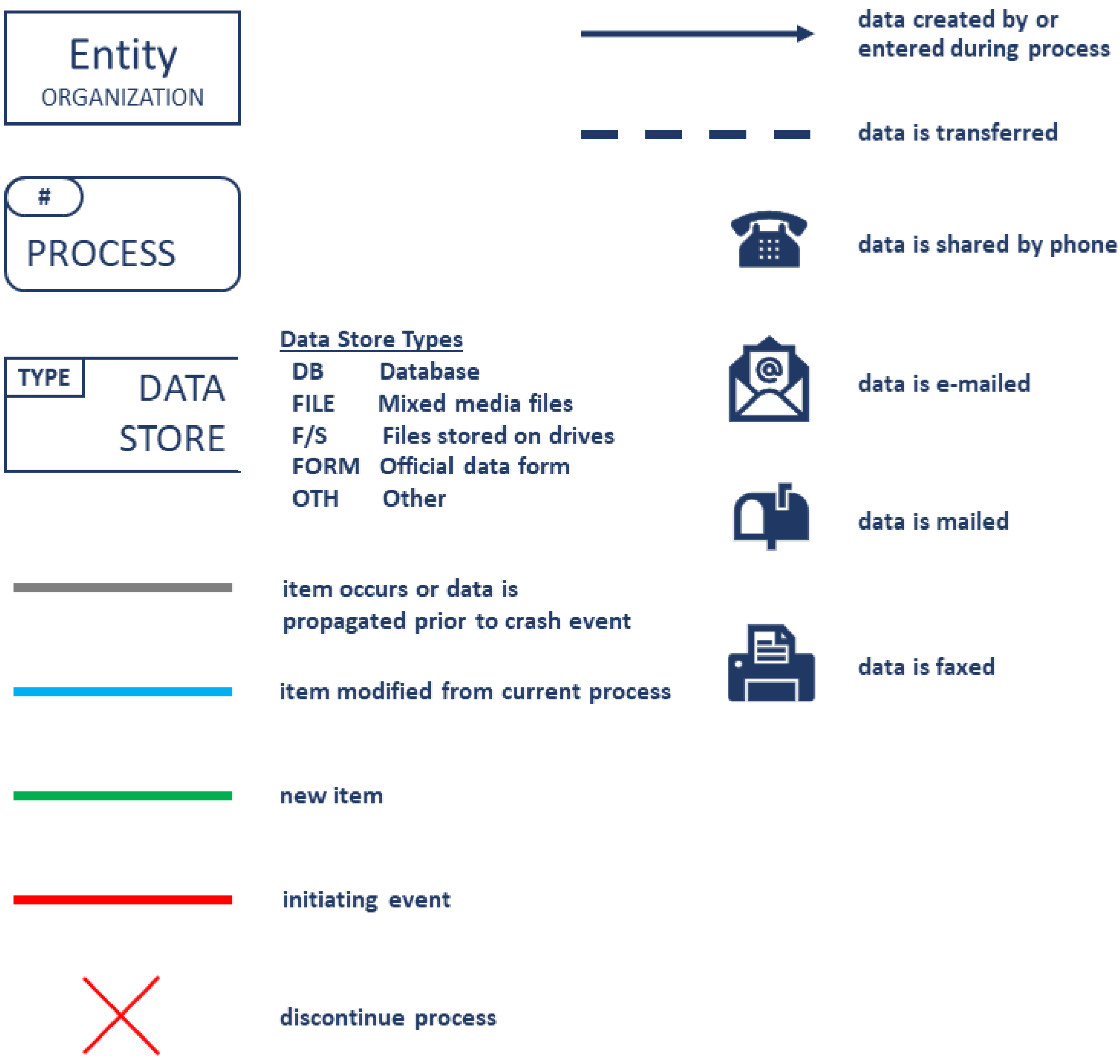
APPENDIX A: ACRONYMS

AAM	Advanced Air Mobility
AIDS	Accident and Incident Data System
AOPA	Aircraft Owners and Pilots Association
BRC	Body Region Contacted
CAMI	Civil Aerospace Medical Institute
CIREN	Crash Injury Research Engineering Network
EIM	Enterprise Information Management
EON	Emergency Operations Network
FAA	Federal Aviation Administration
FAA-AFS	Flight Standards Service Office of Safety Standards
FAA-AAM-600	Office of Aerospace Medical Research
FAA-AVP-100	Office of Accident Investigation & Prevention, Accident Investigation Division
FAA-AVP-200	Office of Accident Investigation & Prevention, Analytical Services Division
FAA-AVS	Office of Aviation Safety
GA	General Aviation
GAJSC	General Aviation Joint Safety Committee
GAMA	General Aviation Manufacturers Association
ICS	Injury Causation Scenario
IIC	Investigator in Charge
IPC	Involved Physical Component
LOB	Line of Business
MANTRA	Medical Analysis and TRAcking
ME	Medical Examiner
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SME	Subject Matter Expert
SOP	Standard Operating Procedures
TSI	Transportation Safety Standard Operating Procedure Institute

APPENDIX B: DATA PROCESS FLOW DIAGRAM KEY



APPENDIX C: SUBJECT MATTER EXPERT INTERVIEWS

Date	Attendee, Title, Affiliation	Communication Mode
2022-11-08	**Richard McCluskey**, MD, Pathologist/Medical Officer, FAA CAMI **Heather Hunn**, Autopsy Program Team Lead, FAA CAMI **Cory Yeager**, NAS Systems Support Team, FAA **Scott Nicholson**, Biomedical Sciences Supervisor, FAA **Stacy Zinke**, Manager, Protection and Survival Research Branch, FAA **Anthony P. Tvaryanas**, MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call
2022-11-29	**Matt Cabak**, Team Lead, Accident Investigations Division, FAA **Anthony P. Tvaryanas**, MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call
2023-01-18	**Matt Cabak**, Team Lead, Accident Investigations Division, FAA **Anthony P. Tvaryanas**, MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call
2023-01-27	**Jeff Carter**, Manager, Safety Analysis, Office of Accident Investigation and Prevention, FAA **Anthony P. Tvaryanas**, MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call
2023-02-03	**Loren Groff**, Chief Data Scientist at National Transportation Safety Board **Jeff Carter**, Manager, Safety Analysis, Office of Accident Investigation and Prevention, FAA **Anthony P. Tvaryanas**, MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call
2023-02-23	**Russell "Rusty" Lewis**, Ph.D., F-ABFT, Forensic Sciences Supervisor, FAA Forensic Sciences Laboratory	Telephone
2023-02-24	**Eric Meyn**, Senior Aircraft Accident Investigation Instructor at the National Aircraft Accident Investigation School	Telephone
2023-03-21	**Steve Keesey**, ASI FAASTeam Program Manager, FAA **Anthony P. Tvaryanas,** MD, PhD, MPH&TM, Manager, Aerospace Medical Research Division, FAA	Video call

APPENDIX D: BIOTAB-SUPPORTIVE INJURY CAUSATION DATA ELEMENTS FOR MANTRA

MANTRA data elements and media capture capabilities can be expanded to include injury causation information generated using CIREN's BioTab method [16]. Additional data fields to document the BioTab recommended injury causation analysis method should be appended to either the *Autopsy Information and Review* Tab or the *AIS Coding* Tab.[7] The ability to "clip" supporting photographs and other information, as is done with autopsy data, should also be extended.

Field Name	Content	Data Type	Options
Body region injured	Indicates the body region that was injured	Dropdown	*From BioTab:* - Head/face - Neck (other than cervical spine) - Cervical spine - Thoracic spine - Lumbar spine - Shoulder - Arm - Elbow - Forearm - Wrist - Hand - Chest (thorax) - Abdomen - Pelvis/sacrum - Hip - Thigh - Knee - Leg - Ankle - Foot
Source of energy	Describe the specific event that resulted in the transfer of energy to/from the occupant that caused the tissue damage constituting the clinically significant injury	Free text field	
Involved Physical Component (IPC) Configuration	Describe the IPC Configuration of the injury in question	Dropdown	*Per BioTab:* - Isolated - Tandem - Critical
Body Region Contacted (BRC)^	Describe the body region that was directly contacted by the IPC	Dropdown	Same options as Body Region Injured
IPC Area^	Describes the broad area or component in the aircraft that caused the injury ("interior," "restraint," "seatback," etc.)	Drop down with free text field	Menu of options, "other" with free text field

[7] Because of reviewer tracking requirements in the MANTRA workflow, it would be most efficient to add these additional data fields to the *AIS Coding Tab* if that reviewer will also be developing the injury causation scenario.

IPC^	Describe the physical component in the aircraft that caused the injury in question	Free text field	
Path^	Describe the path by which force was transmitted from the body region(s) contacted, through body components, to the site of injury	Free text field	
IPC Evidence^	Describe the crash scene evidence used to determine the IPC, as required by the BioTab methodology	Free text field, supporting photo	Describe and attach photos of IPCs or other evidence
IPC Confidence^	Indicate the assessing experts' confidence this was the IPC that caused the injury	Dropdown	*Per BioTab:* - Certain - Probable - Possible
Contributing Factor(s)	Indicate any additional medical or crash factors that contributed to this injury occurrence	Free text field	
Regional Mechanism(s)	Indicate the specific mechanism of injury to this body region	Drop down with free text field	Develop list of injury mechanisms as options – bending, compression, etc., plus "other" with free text field
ICS Evidence	Indicate medical and/or crash evidence that support the ICS	Free text field, supporting photo	Describe and attach photos of ICS or other evidence
ICS Confidence	Indicate the assessing experts' confidence in their determination of the ICS.	Dropdown	*Per BioTab:* - Certain - Probable - Possible
ICS Notes	Indicate additional supporting notes about the ICS	Free text field	

^ Include "primary" and "secondary" versions of these data fields

APPENDIX E: CIREN AND OTHER HIGHWAY SAFETY INITIATIVE RESEARCH CRITERIA

To maximize its resources and derive patterns from small, diverse populations, NHTSA's CIREN [12] primarily focuses on developing cases involving defined crash types, directions, conditions, and occupant injuries:

- Crash types: frontal, side, rear (well-understood crash conditions, frequently injurious crash types)
- Injured occupants: at least one AIS 3+ (Serious) injury, two AIS 2+ (Moderate) injuries, or one AIS 2+ injury from a specified list (traumatic amputation, skull fracture, etc.)
- Occupants must have been wearing seat belts, and appropriate airbags must have deployed

CIREN rejects cases it considers incomplete or inappropriate to use[8] for biomechanical injury causation since that is the focus of the research program:

- Occupant cases with incomplete radiology records
- Vehicle crashes with limited occupant survival space (characterized by "compartment intrusions of generally more than 50% of the original distance in any direction")
  - Crash survivability in any mode is dependent on sufficient room to manage crash forces
- Vehicle crashes with fire damage to the occupant compartment[9]

Broad areas of research in CIREN and other highway programs [20] per Table 1 could potentially be analogized for a GA/AAM CIREN program (Table 9).

Table 9: Which CIREN-like criteria could inform a GA/AAM CIREN data sample?

Broad Criteria	CIREN/Highway Safety Approach	Potential GA/AAM CIREN Analogy	Potential GA/AAM CIREN Research Questions and/or Priorities
Crash type	• Frontal, side, rear – vehicle damage profile	• Minimal structural damage *with* fatality • Excessive structural damage *without* fatality • Runway rollover	• Study injuries in common, understood crash types • Study crashworthiness of aircraft
Crash speed	• Under 40 mph	• Manageable crash speeds for human injury tolerance levels	• Study injuries in survivable crashes with forces at or below human injury tolerance levels
Occupant	• Children in car seats • Belted, in-position adults	• Pilot-rated autopsy data • Non-pilot-rated injury data	• Study injuries to improve outcomes in vulnerable populations with a more limited understanding of injury causation
Occupant medical and	• Medical frailty • Pregnancy outcomes	• Drug use (prescribed, illicit, emerging) • Pregnancy outcomes	• Study effects of health conditions, medicines, implanted medical devices

[8] GA/AAM CIREN, in establishing its knowledge base and case repository, could choose to collect data from all available accidents to improve the sample size.

[9] Fire can destroy other evidence and its analysis requires expertise outside the biomechanical focus of CIREN, but it is a pervasive factor in aviation accidents and should not necessarily be excluded from a GA/AAM CIREN research program.

health conditions	• Loss of consciousness	• Loss of consciousness • Pacemaker performance	
Injury type	• Any disabling injuries • Severe head injury with airbag deployment	• Spinal and limb injuries • Loss of consciousness • CO_2 poisoning • Burns	• Study-specific disabling injuries occurring in modern aircraft designs • Study performance of active carbon monoxide detectors • Study automatic fire detection systems
Restraint use	• Belted occupant with proper airbag deployment • Child restraint in use	• Occupant outcomes when advanced restraints used • Advanced restraint performance	• Study occupant injury outcomes in proper, ideal restraint conditions
Vehicle age/design	• 2017+ model year	• Newer aircraft • New technology (like AAM) • Crashworthy designs	• Study occupant outcomes in ideal crashworthy designs • Study performance of emerging aircraft designs
Vehicle equipment	• Takata airbag deployments • Advanced Driver Assistance Systems (ADAS) performance • Seatback collapse	• Anti-collision, terrain warning sensors • Ballistic airframe parachutes	• Study performance of suspected defective field equipment • Study performance of emerging or rare equipment
Aftermarket equipment	• Tire failures • Phony airbags	• Electronic Flight Bags (EFBs) as projectiles	• Study the performance of aftermarket equipment in the field

APPENDIX F: PHOTOGRAPHIC DOCUMENTATION GUIDANCE

Importance of Photography in CIREN

Photographs are among the most critical scene investigation evidence used in a CIREN-style injury causation analysis. Per NHTSA's CIREN photo addendum:

> *"Assessment of injury causation in CIREN relies heavily on photographic evidence from the case vehicle and scene, so extensive, high-quality photographic documentation is a critical responsibility of the CIREN field investigators. In CIREN, the photographic requirements are focused most heavily on the objects and areas that the case occupant may have interacted with during the crash events. The field investigator shall approach the photographic documentation task with this in mind and seek to acquire comprehensive photographic evidence to support the case review process and subsequent research needs. CIREN field investigators are encouraged to capture any potentially useful photographic evidence during the inspections, as questions frequently arise in case review sessions that may be answered by reviewing case photos* [7]."

FAA Order 8020.11D

- FAA Orders 8020.11D [5] and 8900.1 [21] guide the FAA's investigative approaches. Order 8020.11D specifies a general list of photographs the investigators should consider when investigating an aviation accident.
    - This list is specific enough to guide an investigator to the event items and information they should capture but is not overly prescriptive. This allows the scene information and the FAA IIC's experience to capture photographs and other information needed to represent the event and support the investigation. The on-scene IIC also takes pictures in response to any requests from other parties in the investigation.
- Photographic prompts in Chapter 3, Section 11g of 8020.11D support FAA field investigators' capture of the evidence needed to support GA/AAM CIREN injury causation data collection activities [5]. The following are of particular relevance:
    - *"Prior to moving or disturbing the wreckage, photograph the accident scene including the path the aircraft took to get to its final resting place and any impact scars.*
    - *Printed labels placed in the photographed scene (#1, #2, L, R, South, West, etc.) should be used to ensure detailed and permanent records of identification and orientation. Document these views while walking in a circular fashion to ensure that a 360-degree view of the main wreckage scene is completed with a series of 6 photographs; i.e., 12, 2, 4, 6, 8, and 10 o'clock positions. If possible, mark photographs to be easily identifiable (direction of flight, forward, aft, left, right).*
    - *Take photographs of any major structural component or flight controls no longer attached to the main wreckage.*
    - *External "macro" views of the main body of the wreckage.*
    - *Surrounding terrain.*
    - *Ground scars leading up to the wreckage*
    - *Tree strikes or other object damage (if any).*
    - *Airframe ice (if any is adhering to leading edges of aerodynamic surfaces).*
    - *Wings and tail.*
    - *Control surface positions.*
    - *Control surface actuator positions (if possible).*
    - *Trim tab settings (cockpit indications and also airframe trim tabs/actuators).*
    - *Flap and flap lever positions.*
    - *Landing gear and lever positions.*
    - *External views of engine(s) and associated engine controls.*
    - *Turbocharger ducting and clamp positions (if installed).*

- *Control cables and associated hardware (marked prior to being cut by recovery personnel).*
- *Overall view of cockpit.*
- *Close-up view of cockpit instruments (no more than 4 instruments to a photograph).*
- *Electrical switch positions and circuit breakers.*
- *Throttle quadrant.*
- *Fuel selector switch.*
- *Magneto switch position(s).*
- *Seat belts.*
- *Medications, medical devices, or drugs and other substances found on site should be handled the following way:*
  - *Photograph bottles and packages*
  - *Photograph close-up views of individual pills including both sides of pills;*
  - *Document relative size of pills by taking photos next to a common object of known size such as a ruler or coin.* [5]"
    - Order 8020.11D also notes that the IIC should "*forward photos and descriptions of medications or medical devices to the CAMI Medical Case Review Physician for analysis; and… for fatal accidents the information can be forwarded via the Autopsy Team for analysis* [5]."
- Other investigative photographic guidance in Order 8020.11D [5]:
  - "*Measuring tape (50-foot or longer) and 6-inch ruler to be used to depict the scale of items that are photographed"*
  - *"When it is necessary to move aircraft wreckage, mail, or cargo:*
    - *"Make sketches, descriptive notes and/or take photographs if possible, of the original positions and conditions of the wreckage and any significant impact marks."*
  - *"Enlist the cooperation of local authorities to obtain comprehensive photographic documentation of human remains prior to removal, if practical. If local authorities remove remains before photographic documentation can be accomplished, the investigator should note the location of the remains and describe the injury(s*)."

NHTSA and CIREN investigation photography resources

- Highway crash investigator training classes teach general investigative photography techniques and best practices.
  - Similarly, an FAA IIC must complete the TSI's introductory course, Basic Aircraft Accident Investigation" which includes "[f]undamental techniques and procedures of field investigations of accidents and incidents such as accident photography [5]."
- NHTSA publishes a *Field Crash Investigations Digital Photography Guide* [22] for investigators collecting on-scene data for any of their crash data collection programs.
- NHTSA also publishes the *CIREN Photo Addendum to NHTSA Field Crash Investigations Digital Photography* [7] to support the acquisition of the more detailed photographs needed to support the program's injury causation analyses.

Injury causation determination photography techniques

In CIREN investigations, the occupant's anthropometry, injuries, and position in the crash are typically known to crash investigators, who focus their attention on gathering information from the relevant areas of the vehicle.

Details about the occupant and their injuries should be shared with the GA/AAM CIREN IIC to guide photography of the cockpit, instrument panel, seat, restraints, and other components with which the occupant may have interacted. FAA-AFSs IIC will benefit from understanding the following injury causation scenario photography guidance adapted from the CIREN-employed BioTab method [16] to an aviation-focused use case, where:

- BRC = Body Region Contacted,
- IPC= Involved Physical Component, and
- ICS = Injury Causation Scenarios

1. Marks on the IPC or IPC damage (scuffs, cloth transfers, damaged interior components, spider web cracks in windscreen, makeup transfers, hair, bruises on other occupants, etc.) provide physical evidence gathered from the aircraft and/or scene inspection.

- *Not all marks on aircraft interior components are caused by occupant contacts.*
- *Marks on aircraft interior components can occur from intrusion or buckling of the aircraft structure, extrication, or contact with free moving cargo.*
- *Also, lack of visible deformation or damage to an aircraft component does not necessarily indicate a lack of contact.*
- *Many components are highly elastic and recover to their precrash shape and location after deforming substantially in a crash.*
- *For similar reasons, a dynamic crush of the aircraft and dynamic intrusion into the occupant compartment in a crash will almost always be greater than or equal to the post-crash crush and intrusion.*
- *Also note that blood transfers can be indicative of the final resting position or the post-crash motion of the occupant but are not directly indicative of contact with an IPC (although the final resting position of the occupant can support the occupant kinematics required for contact with an IPC or an ICS).*

2. Spatial consistency between the initial position/posture, the crash dynamics, and the resulting occupant kinematics, as established by the ICS-level elements and the IPC that was contacted, is based on a combination of physical, electronic, testimonial, and scientific evidence.

- *The crash dynamics must support the occupant kinematics required to move the body region contacted from its precrash posture/location into the IPC.*
- *Initial position and posture may not be known with certainty, but physical and/or interview evidence may help establish the occupant's position at the time of impact.*
- *An important consideration in establishing the initial position is whether prior aircraft dynamics, either from precrash maneuvers or prior impact events, may have affected the occupant's positioning.*

3. Biomechanical consistency between superficial injuries to the occupant at the BRC (e.g., contusions or skin abrasions/ lacerations), the underlying pattern of injury, the IPC contacted, and the loading mechanism applied by contact with the IPC is based on a combination of physical and scientific evidence.

- *Contact evidence on the occupant includes contusions, abrasions, or lacerations.*
- *Consistency between the marks on the occupant, patterns of injury, the IPC contacted, and the loading mechanism can only be achieved if the IPC that loads the BRC is capable of producing the observed patterns of superficial injuries and if the mechanism of loading applied from contact with the IPC can cause the injury that is being coded.*
- *For example, a left orbit fracture in a left-sided (9 o'clock) impact with a tree would be considered consistent if (1) abrasions on the skin were consistent with contact with a tree or side glass (i.e., if there was glass or bark in the wound) and (2) the pattern of the orbit fracture was consistent with the facial compression that occurred from contact with the tree.*

APPENDIX G: PROGRAM IMPLEMENTATION PLAN EXPANDED OUTLINE

This program implementation plan outline reflects and expands upon the tables presented in each phase.

1. PHASE 1: CONVENE experts

1.1. FAA-AAM-600 re-engages FAA-AVP-100 as core GA/AAM CIREN program support

1.1.1. Seek pilot study support, refinement, and program participation commitment

- Socialize program model, pilot study, and implementation plan for feedback and input

1.1.2. Develop plan to engage AFS field office(s) for participation in GA/AAM CIREN pilot study

- FAA-AVP-100 familiarity with FAA-AFS can help locate engaged, trained (advanced GA investigation and cabin safety classes, multiple years of field experience) field personnel and/or locations to support the field data collection needed for a GA/AAM CIREN pilot study

1.1.3. Explore access to FADE database or file share drive for GA/AAM CIREN program

- Currently, the FAA-AFS investigator in charge (IIC) emails field investigation photographs and data to FAA-AVP-100 for capture in the FADE database and storage on file-sharing drives. FADE[10] can store GA/AAM CIREN materials while autopsy reports are being generated by the local coroner/ME and have yet to be received by FAA-AAM-600
- GA/AAM CIREN should gain direct access to the FADE database or FAA-AVP-100's file-sharing drives to access the data needed to complete the injury causation analysis

1.1.4. Gather any FAA-AVP-100 investigative SOPs, guides, data templates, photography guides, etc., that further inform GA/AAM CIREN investigation data collection and methods

1.2. FAA-AAM-600 re-engages NTSB experts

1.2.1. Seek pilot study support, refinement, and potential participation

1.2.2. Solicit any NTSB SOPs, guides, templates, tools, etc., that could support GA/AAM CIREN data collection

1.2.3. Socialize BioTab method of injury causation to determine its potential for use in GA/AAM CIREN

1.3. FAA-AAM-600 and FAA-AVP-100 engage FAA-AFS field offices to identify GA/AAM CIREN field investigation partner(s)

1.3.1. Seek pilot study support, refinement, and program participation commitment

- Socialize program model, pilot study, and implementation plan for feedback and input

1.3.2. Assess level of effort and any additional resources required for field data collection

1.3.3. Gather any FAA-AFS SOPs, guides, investigative templates, tools, etc., that further inform GA/AAM CIREN investigation data collection and methods

1.4. FAA-AAM-600 engages with other data collection and analysis expertise

1.4.1. Locate biomechanics experts to evaluate the use of BioTab [16] *method of injury causation determination within GA/AAM CIREN*

1.4.2. Engage Transportation Safety Institute (TSI) personnel to identify any SOPs, guides, templates (cabin safety seat measurement template, others), or tools that could support GA/AAM CIREN data collection

- Socialize program model, pilot study, and implementation plan for feedback and input

1.4.3. Engage FAA-AIR structural and crashworthiness experts to assess their potential for a role in GA/AAM CIREN program

1.4.4. Consider engaging with external organizations that have the expertise to contribute to a GA/AAM CIREN program, such as GAJSC, GAMA, AOPA, and others

1.5. Additional Phase 1 activities

[10] FAA-AVP-100 uses FADE data to develop regular briefings to convey the initial details surrounding fatal GA (and other) accidents to FAA upper management. These briefings help determine whether the Administration needs to take further regulatory or other actions based on the initial facts of the crash.

1.5.1. Update MANTRA [15] *fields to accommodate BioTab* [16] *method of injury causation if determined to have the potential for GA/AAM CIREN analysis*

- Add data fields in MANTRA to capture the injury causation determination in the Autopsy Information and Review Tab or the AIS Coding Tab, as recommended in Appendix D
- Add functionality in MANTRA ("clipping") to accommodate photographs that support injury causation determination

1.5.2. Identify AIS coding expertise or software to support BioTab method if determined to have the potential for GA/AAM CIREN analysis

2. PHASE 2: DEFINE pilot study sample

2.1 Engaged FAA-AFS field office approach

2.1.1 Target certain crashes over a determined amount of time through selected FAA-AFS field office(s). Pilot study size and length depend on crashes occurring, which are random and rare events.

2.1.2 A simply understood metric of selecting crashes appropriate for survivability studies—like container, restraints, environment, energy absorption, and post-crash factors (CREEP)—could be used [17]

2.2 Additional target data sample refinement

2.2.1 Use GA/AAM CIREN experts to inform crash and injury characteristics indicatory of research priorities

- Discussions with knowledgeable internal and external stakeholders (FAA-AVP-100/200, FAA-AIR, FAA-AFS field office personnel, the FAAST, GAJSC, GAMA, NTSB, etc.) could shape an appropriate study sample for a GA/AAM CIREN program
  - Experts can suggest areas of study where statistical data may not exist and potentially extend the program research value proposition beyond the singular focus of CIREN's biomechanical analyses
  - Analyses of emerging aircraft, equipment, accident modes, or common injuries may be appropriate areas of study (e.g., the potential crash and injury population that could develop from future aircraft designs like AAM)

2.2.2 Study common injuries and crash conditions as described in aviation injury causation literature

- Literature in the field of aviation injury causation often focuses on potentially survivable accidents [23] [24]
  - The GAJSC Safety Enhancement (SE) 41 – Survivability report published in October 2017 identifies stakeholders who have recently examined these issues with sparse public NTSB data. The FAA may want to consult contributors to that work to better inform the GA/AAM CIREN data sample
  - Fatal Aircraft Accidents, Mechanisms of Injury in Aircraft Accidents [25]
    - Head injury: "very common in aviation accidents… seen in two-thirds of our cases…"
    - Spinal injury: "present in 45% of intact aircraft fatalities"
    - Thoracic injury: "injuries to the bones… occur in 80% of all accident victims"
    - Abdominal injury: "more than two thirds of the fatalities had abdominal injury"
    - Limb injuries: "only 20% of fatalities from aviation escape limb fracture"
  - Adapted from Basic Principles of Crashworthiness, Shanahan 2004 [26]:
    - Injury in aircraft crashes can be considered to arise from three distinct sources: (1) excessive acceleration forces; (2) direct trauma from contact with injurious surfaces, and; (3) exposure to environmental factors such as fire, smoke, water, and chemicals resulting in burns, drowning, or asphyxiation

2.2.3 Analogize approaches from CIREN and other highway safety research directives

- Determine if broad highway safety research areas could have applicability to GA/AAM CIREN and as outlined in Appendix E

2.2.4 Consult data analysts responsible for NTSB, FADE, MANTRA, or other databases to determine the ability to identify trends

- Injury trends
  - Medical findings in the MANTRA [15] database can be consulted, or the Filehold document management system that stores autopsy reports can be directly examined.
  - Potentially collaborate with FAA-AAM-300 to determine opportunities for reviewing pilot injuries from reported nonfatal accidents
- Accident trends
  - MANTRA
    - Several fields in the MANTRA User Guide [15] refer to their use in trend analysis, including Type of Accident, CAMI Probable Cause, CAMI Causal Factors, and others
  - FAA-AVP-100's FADE database
  - FAA-AVP-200's Accident and Incident Data System (AIDS) database
  - Public NTSB Aviation Accident Database
    - The literature demonstrates that it is possible, though not ideal, to assess aviation occupant survivability based on limited crash and autopsy data in NTSB factual reports [23] [27]

3. PHASE 3: CONDUCT pilot study

3.1 Finalize any SOPs or templates needed to support GA/AAM CIREN field data collection

3.1.1 Consult FAA-AVP-100, FAA-AFS, and/or others as needed.

3.2 Collect GA/AAM CIREN accident and injury data for the desired number of events and/or study period

3.2.1 Step 1a: FAA-AVP-100 and FAA-AFS IIC, through existing interaction processes (E), determine crash from Emergency Operations Network (EON) alert meets GA/AAM CIREN target criteria (N). The FAA-AFS-IIC, as the on-scene crash data collector, interacts with the assigned FAA-AVP-100 IIC

3.2.2 Step 1b, 2: FAA-AFS IIC, with FAA-AVP-100 guidance[11] (E), gathers crash scene data and photos to support injury causation analysis (N) along with their support of the NTSB and other FAA investigation activities (E)

- Additional photographic guidance is included as Appendix F.
- Physical and other accident evidence, if collected, is stored per existing FAA or NTSB procedures

3.2.3 Step 3: FAA-AFS IIC distributes data to all investigative parties for their individual business needs (E)

3.2.4 Step 4: FAA-AVP-100 adds FAA-AFS IIC investigation data to FADE database (E

- Data expected to be used for GA/AAM CIREN analysis should not be subject to purging activities (N) while awaiting receipt of the autopsy report from the coroner local to the crash

3.3 Maintain or accelerate autopsy report collection, coding, and analysis process

3.3.1 Steps 5, 9: FAA-AAM-600 autopsy team lead and records specialists execute current fatal case process to initiate and populate GA/AAM CIREN pilot demographics and other case details in MANTRA (E)

3.3.2 Step 7: Request and receive autopsy report from local coroner/ME per current cadence, or engage earlier and more often (N)

3.3.3 Step 8: FAA-AAM-600 pathologist conducts current autopsy report processes in MANTRA

3.4 Maintain toxicology sample collection, coding, and analysis process

3.4.1 Step 6a: Request and receive Tox Box from the local coroner/ME (E)

3.4.2 Step 6b: FAA-AAM-600 toxicology team conducts current processes involving sample screening, coding, and interpretation of toxicology results (E)

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[11] FAA-AVP-100 investigators often remotely support the field office investigators on-scene, acting as expert guidance for potentially less-experienced IICs.

4. **PHASE 4: ASSESS pilot study results**
   - **4.1 GA/AAM CIREN experts perform injury causation analysis**
     - *4.1.1. Step 10: GA/AAM CIREN experts access accident, autopsy, and toxicology data to begin the injury causation analysis process (N)*
     - *4.1.2. Step 11: GA/AAM CIREN experts develop and code preliminary injury causation scenarios using BioTab* [16] *or other desired method in MANTRA (N)*
       - Photos and other information attributing each injury to accident circumstances and aircraft components are added using extended MANTRA "clip" capabilities (N)
   - **4.2. Hold collaborative GA/AAM CIREN meeting to finalize injury causation in each case**
     - *4.2.1. Step 12: All contributors to case data collection – accident, autopsy, toxicology, injury causation, and other experts as needed are convened by the Program Manager to review and finalize the injury scenarios (N)*
       - Technical oversight of the CIREN program is the responsibility of the CIREN Program Manager. Since the role is internal to NHTSA, the agency does not explicitly define educational and experiential requirements for the CIREN Program Managers it does for the contracted staff that perform the data collection and analysis [28].
         - However, NHTSA notes that the position is responsible "for the content of this document [the *Crash Injury Research and Engineering Network CIREN Phase IV Process and Coding Manual* [12]] and other CIREN-specific process documents, and shall ensure the content provides appropriate guidance. Questions or concerns about […] requirements […] shall be directed to the NHTSA CIREN Program Manager [12]." These responsibilities require a thorough understanding of the program and its processes to perform the required management and oversight activities.
     - *4.2.2. Step 13: GA/AAM CIREN experts share crash and injury particulars with other case contributors, who review the results and offer additional opinions and insights (N)*
     - *4.2.3. Step 14: After the presentation and discussion, all contributors finalize outstanding items and reach a consensus on any remaining issues (N)*
       - The Program Manager has the final say in any disputes. The case is final after this process. (N)
   - **4.3. Assess the value of pilot study results**
     - *4.3.1. Were the data collected during the GA/AAM CIREN pilot study sufficient for developing injury causation scenarios?*
       - Did the autopsy report contain injury data sufficient for executing BioTab (or other predetermined methods) of injury causation?
       - Were the additional photographs and investigation data sufficient for identifying the physical components in the aircraft that contributed to occupant injuries (i.e., were they sufficient for executing the BioTab or other injury causation method used)?
     - *4.3.2. Do the injury causation scenarios and other results inform FAA research priorities?*

5. **"FUTURE" PHASE: Towards a More Ideal GA/AAM CIREN Program**
   - **5.1. Pursue an agreement with NTSB to access nonpublic aviation accident database**
     - *5.1.1. FAA-AFS IICs and other parties to the investigation could upload data to the nonpublic area of the NTSB database through permissioned access*
       - Directly uploading accident photos and other media eliminates person-to-person and duplicative file sharing that occurs during investigations
       - The NTSB tracks specific users' access and change to official documents, which ensures quality, enhances security, and reduces inappropriate actions with data. This functionality could be extended to investigation data to maintain security and privacy
       - Stakeholders from the FAA, in this case the GA/AAM CIREN program, could also be provided access to these media for ongoing research and business activities
   - **5.2. Expand collection of pilot medical data**

5.2.1. Acquire hospital records if a patient was treated before fatality to further support injury causation analysis

- If treated by emergency medical services or a hospital prior to fatality, acquire radiological and other imaging records to support injury causation analyses

5.2.2. Explore avenues such as NTSB or FAA subpoena power to compel additional medical records for all fatal GA pilots and potentially other fatal and nonfatal crash victims

- Expanding the program beyond fatalities to include seriously injured occupants as in CIREN could increase the ability to develop mitigative strategies that result in crash injury reductions.

5.3. **Use EIM to analyze accident and injury data regularly and holistically to better inform target GA/AAM CIREN investigations**

5.3.1. Data scientists should regularly and holistically assess aviation accident and injury trends in EIM, such as quarterly or annually, to inform research priorities under this program

- Databases relevant to the proposed GA/AAM CIREN program are slated for inclusion in the common data-sharing environment. Individual program offices would still maintain the data in MANTRA, ToxFlo, FADE, ToxDB, and NTSB databases, but the information is shared to a common environment where they may be shared, fused, and analyzed across locations

5.4. Consider guided post-crash photography applications similar to TraumaHawk [19] **to improve medical outcomes for aviation accident victims and more quickly ascertain crash particulars and the expertise required to evaluate them**

5.4.1. Prototype phone applications sending advanced photographic notification of victim injuries to hospitals prior to their arrival have been shown to "help improve triage and transportation of the victims, assist the trauma center staff in better-predicting injuries and treatment options, and even aid the implementation of remote treatment [22]"

5.4.2. Similarly, very timely photographic evidence from the scene could help FAA-AVP-100 and the FAA-AFS IIC more easily identify crash characteristics and the experts needed for analysis earlier in the accident data collection process