The FAA's Center of Excellence for UAS Research

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A.5 UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations

Task 2: Update Maintenance & Repair Prototype Database

28 October 2016

Project Number: 15-C-UAS-A5

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KANSAS STATE POLYTECHNIC

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1 Introduction

The purpose of this document is to provide the FAA with information about the deliverable for Task 2, an updated Maintenance and Repair (M&R) Prototype Database (referred to as "M&R database"). This document also provides recommendations to utilize the M&R database more effectively. The objective of Task 2 is to provide an updated database with analytical tools. This document is not required by the statement of work, but has been created to provide additional context and recommendations.

The key components of this research subtask include:

1) Acquire maintenance logbook information including some of the following: inspection schedules, Remove & Replace (RR) Line Replaceable Units (LRU) frequency, and modification for maintenance data.
2) Acquire maintenance manual samples to understand the level of fidelity of component replacement on the line including some of the following manuals: Aircraft Maintenance Manual (AMM), Illustrated Parts Catalog (IPC), Component Maintenance Manual (CMM), Structure Repair Manual (SRM), etc.
3) Acquire information to support other deliverables within the A5 project. For example, in the level 3 survey, UAS operator and maintainer contact information is to facilitate surveys in Task 3 at a later date.

All of the data compiled in the M&R database are useful for understanding the current state of UAS maintenance practices. Although a limited amount of data is currently contained within the spreadsheets, they are useful for understanding and developing solid, justifiable recommendations to the FAA on how UAS should be maintained to support the FAA's roadmap to integration of unmanned aerial systems (UAS) into the National Airspace System (NAS). A healthy sample test case for research is traditionally in the 5% range in quantity. Based on the volunteer nature of this project for the UAS Original Equipment Manufacturer (OEM) and operator participation, this database is closer to the 1% range.

The M&R prototype database was originally provided to Kansas State University (KSU) in the form of scripts to be read using Oracle and other equivalent software applications. For this task, the database fields were cloned into two Excel spreadsheets: 1) The UAS Maintenance Procedural Profile, and 2) The UAS Maintenance Record Profile. A spreadsheet is not a true database since each "Record" does not utilize a unique 'key' field to identify that unique record entry. Rather, each record will be a horizontal row, or series of rows, that populate specific data fields within the columns provided. This will lead to repetitive content entries. Although Excel is not a superior solution to Oracle, it was necessary to create in order to capture the data quickly for Task 2. This prevented the requirement to write a software code or purchase an Oracle database tool required to manage the database. It is expected that the FAA will use the original Oracle database for their purposes.

This document includes background on the M&R Prototype Database, methods for collecting data and populating the database, database content and analytical tools, discussion, recommendations, and future work.

1.1 Background

The M&R Prototype Database was generated in 2013 as a result of the FAA's desire to collect OEM technical maintenance and inspection practices as well as in-service difficulty reporting in an effort to be alerted to trends that may require FAA communication and action. The purpose and function of the database was to fill a purpose and function similar to the existing incident and accident reporting methods for Type Certificated (manned) aircraft. The existing manned aircraft incident and reporting system could not be used for three key reasons: (1) The construction materials and methods of control and propulsion differ greatly with manned aircraft, (2) Unmanned systems are not designed under any civil aviation regulations or standards and therefore do not have a requirement for a continued airworthiness program, and (3) Unmanned systems include systems not found in manned aircraft such as launch and recovery systems, ground control systems (GCS), and Command and Control (C2) systems.

The intent was to have the M&R database populated on a voluntary basis by OEMs and operators to build a technical library of standard maintenance practices, inspection intervals, and failure records for UAS systems. At present, the M&R database is not populated with many UAS examples, and of those examples, the data are being withheld due to intellectual property (IP) concerns. However, it is believed in the absence of this information, an effective set of recommendations can be provided by the A.5 research to reach the FAA's goals to (1) achieve M&R database population over time and (2) be used as a tool to capture in-service events and trends within an UAS operational environment. There is potential that small UAS (sUAS) are obsolete before any effective maintenance trend can be established for that specific airframe and/or risk class.

2 Methodology

The activities listed in Table 1 were performed to support Task 2: Maintenance and Repair Prototype Database. The following sections describe the work performed in each subtask.

Table 1. Task 2 Work Breakdown Structure

Task	Description	Team
Task 2	**Update Maintenance and Repair Prototype Database**	KSU
Task 2a	Update existing M&R database with newly collected information from Task 1 (Prerequisite: Task 1d)	KSU
Task 2b	Develop new analytical tools for the M&R database to extract information	KSU
Deliverable	*Updated database with analytical tools*	KSU

During Task 2a, information from participants surveyed during Task 1 "Review of Existing Maintenance Programs and Data" was populated into the M&R database. Additional data was solicited from OEMs and operators using a combination of publicly available data, data volunteered through online surveys, face-to-face meetings, and information acquired by email solicitations. Some of the data sources for Task 2 included the following: UAS conferences (attendees and sponsors), Association for Unmanned Vehicle Systems International (AUVSI) members, ASSURE scholastic partners with UAS programs, and UAS airfield operators and test facilities.

During Task 2b, three analytical tools were created for the M&R database: a record filter, a dashboard with seven high level charts for the Maintenance Record Profile, and a second dashboard for the Maintenance Procedural Profile. The purpose of these tools is to shortcut the analysis of the data contained in the database. The dashboard aggregates key important fields of data while the record filter provides a quick and easy method for the researcher to dive deeper into the information beyond the initial incites provided in the dashboard. These tools are explained in detail in the Results section of this report.

3 Results - Maintenance and Repair Prototype Database

The M&R database contains maintenance records and procedural maintenance manual information. The following Excel spreadsheets contain this information representing the M&R database and are submitted in conjunction with this report:

- "UAS Maintenance Record Profile – M&R.xlsx" (referred to as “MRP”)
- "UAS Maintenance Procedural Profile – M&R.xlsx" (referred to as “MPP”)

3.1 Maintenance Record Profile

The Maintenance Record Profile (MRP) contains the analytical tools described in the following sections – a Record Filter and a Dashboard. The data are generated from the UAS OEM and operator maintenance logbook information. Some records include performing unscheduled maintenance for failed Line Replaceable Units (LRU), calibrating systems, modification for maintenance and more. The spreadsheet contains the following visible tabs (refer to Figure 1):

- **Instruction**: Provides detailed instructions on how to use the MRP workbook.
- **Dashboard**: Displays seven charts summarizing the information contained in the *Consolidated Forms* tab.
- **Record Filter**: Contains the master Pivot Table to easily filter data for research purposes.
- **Consolidated Forms**: Contains all of the information from the logbook data in one location.

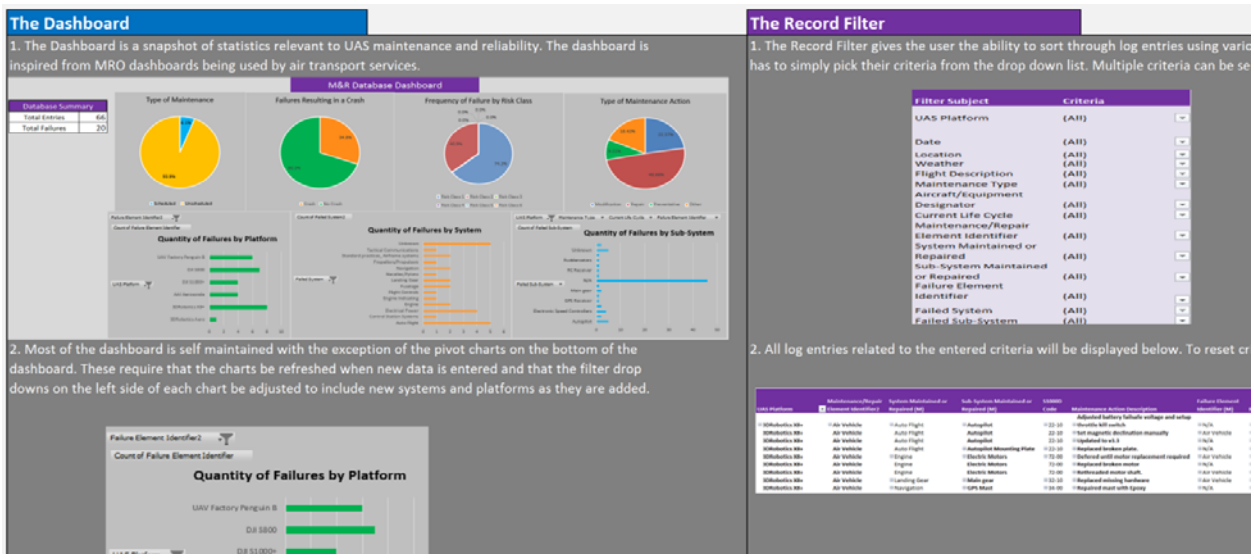

Figure 1. MRP Spreadsheet

3.1.1 MRP Record Filter

The MRP Record Filter (Figure 2) was created to quickly filter the desired criteria in the MRP. Select the criteria from the list on the top left and an output with a list of specific and total entries will be generated.

The Record Filter can be used to pull up records under a vast number of criteria combinations. A few examples of how the Record Filter can be used include:

- Searching for failure patterns in a specific UAS platform
- Determining if aircraft are being maintained according to OEM recommendations
- Determining the lifespan of life-limited and wear parts
- Identifying problematic systems or sub-systems

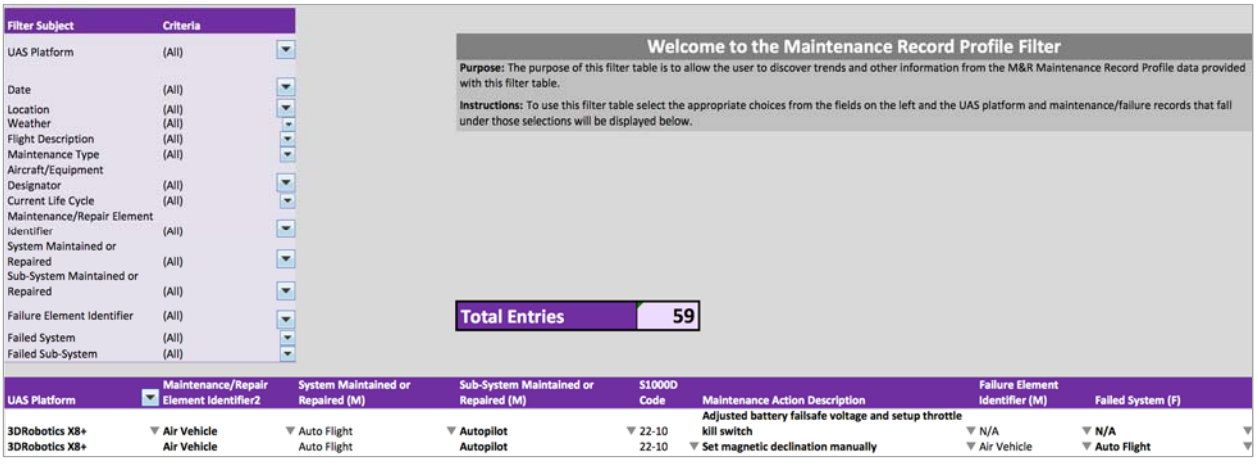

Figure 2. Record Filter for the MRP

3.1.2 MRP Dashboard

The MRP Dashboard (Figure 3) contains two tables and six graphs that provide key statistics of the information contained in the MRP. The tables and graphs are as follows:

- Total entries in the database
- Total entries with a failure recorded
- The ratio of scheduled to unscheduled maintenance among the entries
- The percentage of failures that induced a crash of the aircraft
- The distribution of failures across risk classes in the database
- The distribution of failures across UAS platforms
- The amount of failures per S1000D system
- The amount of failures per S1000D sub-system

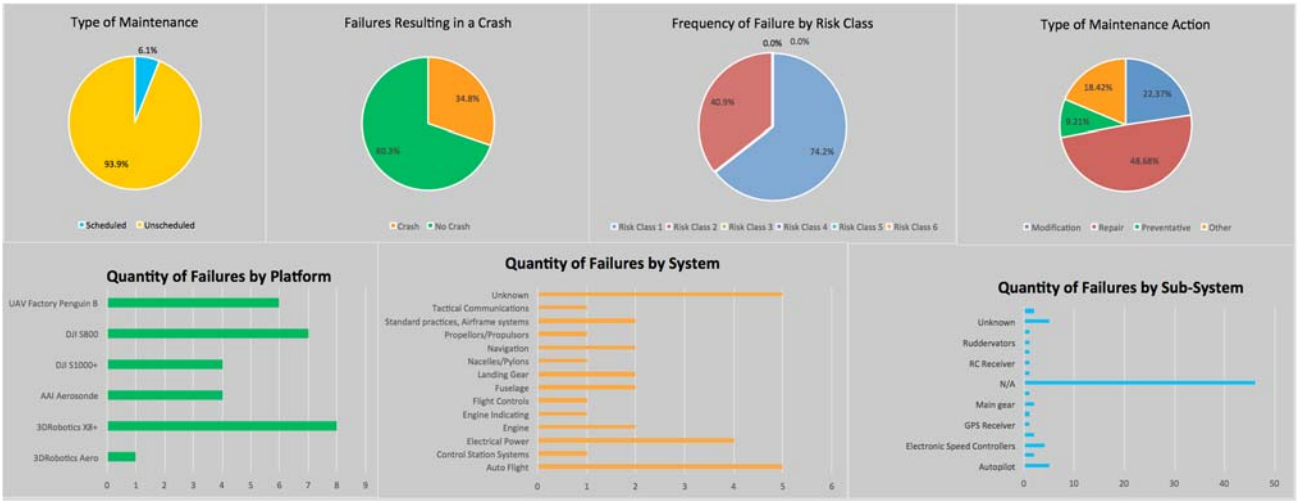

Figure 3. MRP Dashboard

3.2 Maintenance Procedural Profile

The Maintenance Procedural Profile (MPP) provides a list of maintenance tasks and their subsequent intervals along with other pertinent information for each UAS platform, as detailed within the technical documentation for that platform. The tabs in the Excel document represent each UAS platform. The MPP also contains a dashboard that summarizes the information in the spreadsheet. In addition to the tabs for each UAS platform, the spreadsheet contains the following visible tabs (refer to Figure 4):

- **Instruction**: Provides detailed instructions on how to use the MPP workbook.
- **Dashboard**: Displays charts summarizing the information contained in the *Data Forms* tab.
- **Data Form**: Contains most data from each UAS platform tab in one location.
- **UAS Platform Tabs**: Contains procedural maintenance information specific to the UAS Platform indicated by the name of each tab.

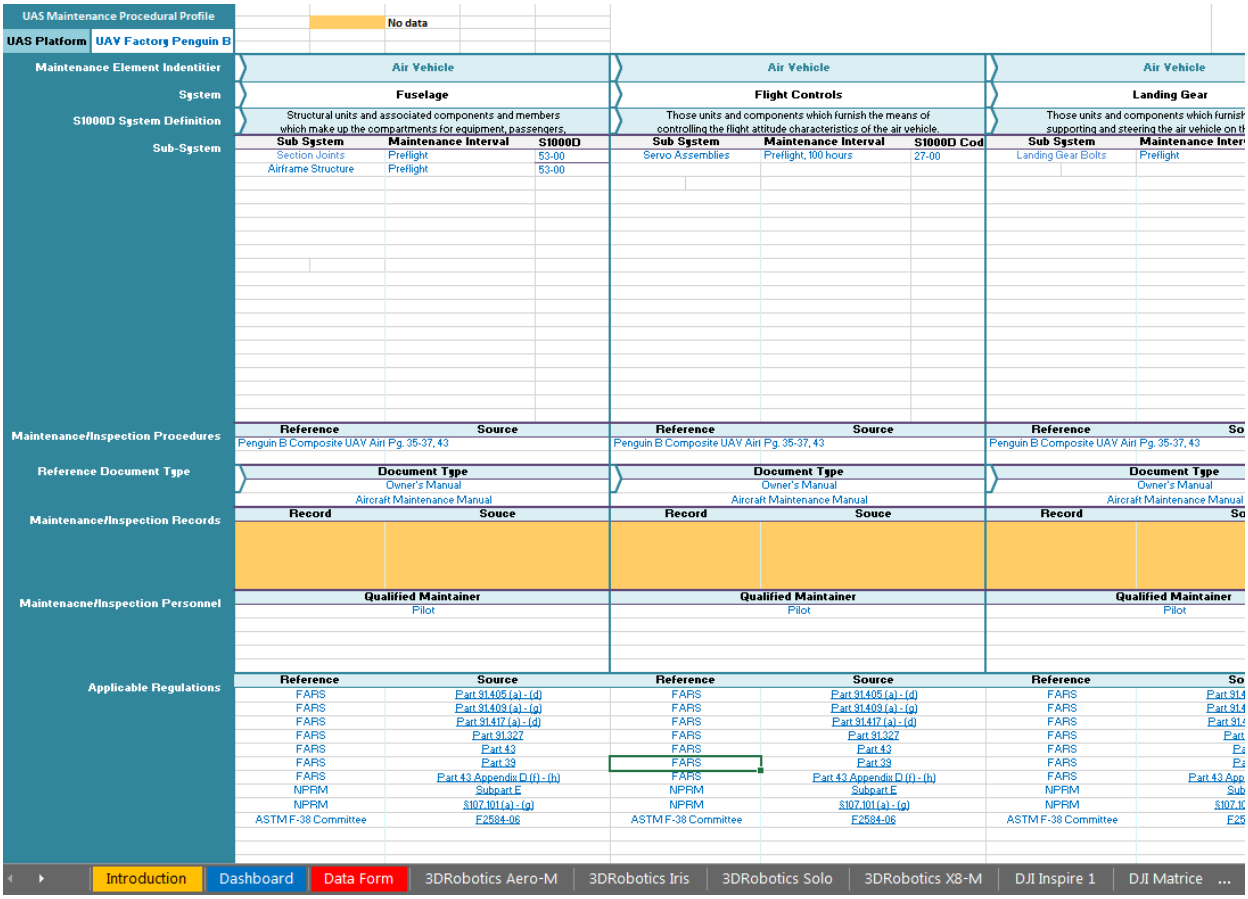

Figure 4. MPP Spreadsheet

3.2.1 MPP Dashboard

The MPP dashboard contains two graphs that provide statistics derived from the information contained in the MPP. The tables and graphs are as follows (refer to Figure 5):

- Total Aircraft Compared to Tasks and Documentation: The number of platforms in the MPP compared to the number of technical documents between those platforms, the number of systems covered, and the number of individual maintenance tasks.
- Distribution of Technical Documents: The distribution of technical documents across all platforms.

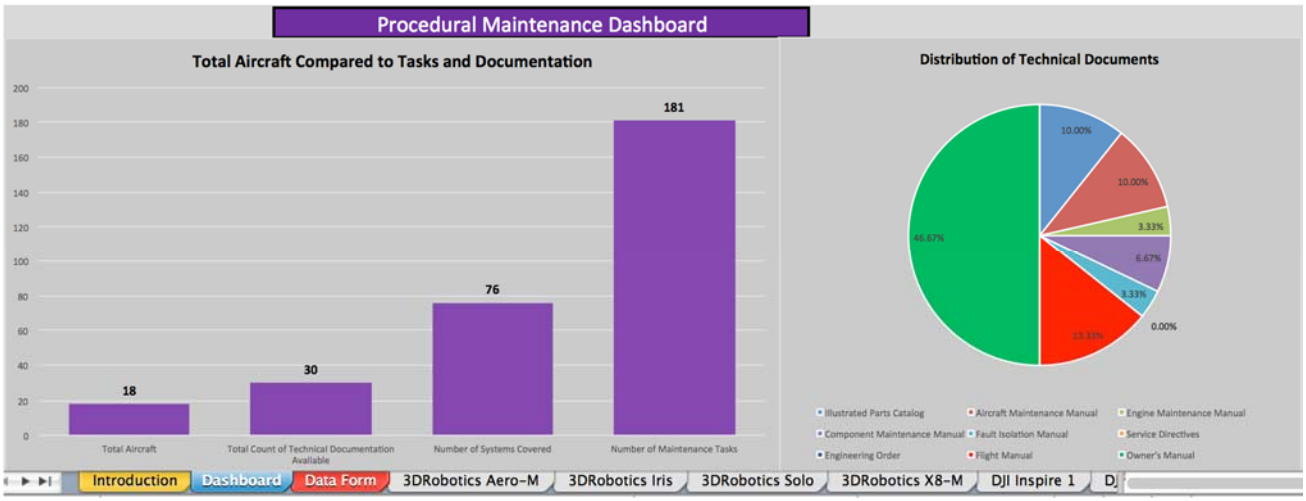

Figure 5. MPP Dashboard

4 Discussion

An initial analysis of the data shows that most maintenance performed on UAS is unscheduled. This could be for many reasons such as poor reliability of UAS vehicles or systems for the certain operations, lack of maintenance or operations training, or a lack of the maintenance manuals.

Some important considerations for this research will include discovering trends in the data between multiple operators using the same UAS chassis while defining the maintenance manual sets between the operators. Was there a major impact in the maintenance induced failures due to lack of maintenance manuals? Which ones?

The M&R database needs to receive more inputs from UAS with risk class variance to increase the accuracy of the type of data collected. This is an effort that will require a long period of time, and a stronger push to collect data in a user-friendly manner. Due to some of the initial concerns with data variance and the difficulty in analyzing a more complete data set, KSU has defined four recommendations for the M&R database: 1) Consolidation of the FAA's UAS maintenance databases 2) Qualify data fields 3) Reduce complexity of the MPP and 4) Create publicly accessible analytical tools.

4.1 M&R Database Recommendations

Reaching beyond the scope of work for this research project, KSU recommends the following to improve the long-term effectiveness of the M&R database. These recommendations entail substantial revisions to the structure of the database that would improve interoperability with other databases and increase effectiveness and sustainability of maintenance data collection. These suggestions would need to be implemented by the FAA, although future work could support the creation of forms or web-based programs to collect data more effectively from UAS operators and maintainers.

1) Consolidate the database with other FAA UAS maintenance reliability databases.

- Merge the Certification of Authority (COA) Online and Mission Logging System (MLS) reporting programs into a single, monolithic incident/accident reporting, data repository, and data reporting methodology. Appendix 1 provides a side-by-side comparison of the data fields in the COA reporting form and M&R Database.
- Merge incident and accident reporting forms to include data fields that can be completed by the operator based upon the event that occurred. One form will lead to more frequent use and better data collection for FAA use.

2) Use higher qualification of data fields.

- Simplify the entry form by reducing the number of required form fields to complete.
- Make form fields open/close based upon event data being populated into the report form. This allows for quicker report completion and higher frequency of compliance if the time component for report completion is reduced.

3) Reduce complexity of the MPP.

- Remove unnecessary or potentially out-of-scope data fields in the UAS Maintenance Procedure Profile (MPP).
- Populate database voluntarily or through reported incidents/accidents.
- Components and systems with their associated maintenance and inspection intervals need not be reported and included in the database until an issue has arisen that warrants its inclusion for tracking.

4) Create publicly accessible analytical tools.

- Allow analytical tools access to both the FAA and the public (data redacted as appropriate).
- Allow industry and operators visibility to database trends, which will allow them to react appropriately to resolve issues before the FAA issues mandatory service directives.

5 Future Work

The M&R database will be delivered to the FAA with this detailed report completing the Task 2 requirements, but more data will be added to the database as operators continue to provide their information beyond the due date for Task 2. This updated M&R database will be provided to the FAA at the end of the A5 project to provide a current picture of the UAS industry.

Additionally, if the FAA intends to support the M&R database initiative, future work should be conducted to support the recommendations made above. This work would focus on defining a simpler reporting platform that encourages volunteer data entry and is utilizes the data from other online reporting forms.

6 References

M&R Prototype Database Sources:

1. Mike Lazlo, Sr. Oracle Database Administrator, General Dynamics Information Technology, William J. Hughes FAA Tech Center. Egg Harbor Township, New Jersey 08234, Phone: 609-485-4981, Email: Michael.Ctr.Lazlo@faa.gov, Email: Michael.Lazlo@gdit.com
2. Charles (Cliff) Johnson, General Engineer, System Safety Section, ANG-E272, Aviation Research Division, NextGen WJHTC Office, Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City International Airport, NJ 08405, Phone: (609)-485-6181, Email: charles.c.johnson@faa.gov

AUVSI Database Source:

3. David R. Arterburn, Director, Rotorcraft Systems Engineering and Simulation Center Von Braun Research Hall, M-67, University of Alabama in Huntsville, Huntsville, AL 35899, Email: arterbd@uah.edu, Phone: (256) 824-6846 (O) (256) 642-9047 (C), Website: http://www.auvsi.org/auvsiresources/exemptions

Appendix 1: Relational Matrix between COA Reporting and M&R Database

User Interface						FAA Accessible	
COA Form						M&R Database	
Current COA Fields	**Field Entry Type**	**Format Description or Selection Options**	**Recommended COA Fields**	**Field Entry Type**	**Format Description or Selection Options**	**M&R Maintenance Record Profile Fields**	**Notes/Explanation**
Date of Accident	Open, formatted	MM/DD/YYYY	Date of Accident	Open, formatted	MM/DD/YYYY	Date	
Time of Accident	Open, formatted	hr:mm, am/pm, local/zulu	Time of Accident	Open, formatted	hr:mm, am/pm, local/zulu		
COA#	Open		COA#	Open			
			Maintainer	Open		Authorized Person/Entity	
Proponent	Open		Operating Entity	Open		Data Origin	Adjusted to wording to better match M&R.
Contact	Open		Contact Information	Open			
Aircraft Type	Open, formatted	make, model, series	UAS Platform	Selection /Open	[Select from list of vehicles or enter custom platform name]	UAS Platform	Adjusted to wording to better match M&R.
Location of Accident	Open		Location of Incident/Accident	Open		Location	
Latitude	Open		Latitude	Open			
Longitude	Open		Longitude	Open			
Altitude	Open		Altitude	Open, formatted	AGL		
Ground Control Station Type	Open		Ground Control Station Type	Open			
Ground Control Station Location at Time of Accident	Open		Ground Control Station Location at Time of Accident	Open			
Flight Number on Day of Accident	Open		Flight Number on Day of Accident	Open			
Flight Duration	Open		Flight Duration	Open, formatted	hr:mm		
Total Number of Flights/Time on System	Open		Total Number of Flights/Time on System	Open, formatted	Cycles or hr:mm	Current Life Cycle	
Flight Details	Open		Flight Details	Open			
Flight Details	Open		Weather Conditions	Selection	Open	Weather	Split Weather Details off from Flight Details to suit M&R data field population.
Flight Details	Open		Purpose of Flight	Selection	• Test Flight • Training • Aerial Photography/Cinemetography • Aerial Data Collection • Public Safety/Fire • Search and Rescue • Other	Flight Description	Split Purpose of Flight off from Flight Details to suit M&R data field population.
Additional	Open		Additional	Open			

Additional Information/Comments	Open		Additional Information/Comments	Open			
Type of Deviation	Open		Type of Deviation	Open			
Description	Open		Description	Open			
Control Link Involved	Open		Control Link Involved	Open			
Description	Open		Description	Open			
Malfunction	Selection	• Navigation system failures • Aborted takeoff or landing due to system failure • Takeoff or landing damage to aircraft • Fires – aircraft or control station • Control Station – Environmental system	Failed Equipment Identifier	Selection	Air Vehicle, Takeoff System or Landing System	Failure Element Identifier	Replaced malfunction field from original COA form and broke it down into the three levels seen in the M&R database.
Malfunction	Selection		Systems that Malfunctioned/Failed	Selection	Pick from list of S1000D systems	Failed System	
Malfunction	Selection		Sub-Systems that Malfunctioned/Failed	Open		Failed Sub-System	
Description	Open		Failure Description	Open		Failure Description	
			Did Aircraft crash?	Selection	Yes or No	Crash?	
Aircraft Collision Description	Open		Aircraft Collision Description	Open			
Description	Open		Description	Open			
Property Damage and Injuries	Open		Property Damage and Injuries	Open			
Immediate Fix	Open		Immediate Fix	Open			
Long Term Action Plan	Open		Long Term Action Plan	Open			
Additional Information/Comments	Open		Additional Information/Comments	Open			
			Equipment Identifier	Selection	Air Vehicle, Takeoff System or Landing System	Maintenance/Repair Element Identifier	
			Systems Requiring Maintenance/Repair	Selection	Pick from list of S1000D systems	System Maintained or Repaired	
			Sub-Systems Requiring Maintenance/Repair	Open		Sub-System Maintained or Repaired	
			Description of Maintenance Actions Required to Return Aircraft to Service	Open		Maintenance Action Description	