

**IDENTIFICATION OF KNOWLEDGE, SKILLS,
AND ABILITIES REQUIRED FOR AIRCRAFT
ELECTRONICS TECHNICIANS**

By

CHRISTOPHER L. BYCROFT

Bachelor of Science Industrial Operations Management
Northeastern State University
Tahlequah, Oklahoma
2005

Master of Business Administration
Northeastern State University
Tahlequah, Oklahoma
2011

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF EDUCATION
December, 2018

IDENTIFICATION OF KNOWLEDGE, SKILLS, AND
ABILITIES REQUIRED FOR AIRCRAFT
ELECTRONICS TECHNICIANS

Dissertation Approved:

Dr. Chad Depperschmidt

Dissertation Adviser

Dr. Timm Bliss

Dr. Jon Loffi

Dr. Bridget Miller

Name: CHRISTOPHER L. BYCROFT

Date of Degree: December, 2018

Title of Study: IDENTIFICATION OF KNOWLEDGE, SKILLS, AND ABILITIES
REQUIRED FOR AIRCRAFT ELECTRONICS TECHNICIANS

Major Field: APPLIED EDUCATIONAL STUDIES

Abstract

Advances in electronics technology have transformed the cockpits of large and small modern aircraft. This transformation has created new challenges for the aviation electronics industry and the technicians that support and maintain aircraft. To meet these challenges, it is important to know the knowledge skills, and abilities required by these new technologies. The primary goal of this study is to determine the knowledge, skills, and abilities currently used by aircraft electronics technicians as defined by the technicians and managers working in the aviation industry. A secondary goal is to determine the differences in knowledge, skills, and abilities used in the commercial and general aviation industry segments. A third goal is to determine the type of training being used for initial training and required new training of these technicians. The study limited participants to only those actively working as technicians or actively supervising technicians. Participants were sought from all business sectors through personal contacts and professional trade organizations, by means of mass emailing and personal solicitations. A booth was also setup at the 2017 Aircraft Electronics Association national conference in New Orleans to solicit qualified participants. Study findings identified fiber optics and MEMS represented new advances in technology that will increase in use on modern aircraft for years to come. Establishment of these elements of new technology will result in a need for new knowledge, skills, and abilities for the modern technicians. Additionally, in the commercial and regional airlines segment of the industry avionics technicians with A & P certificates and the most experience are promoted to bench technician positions that do not work directly on-aircraft.

TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION.....	1
Introduction	1
Statement of Purpose	4
Research Questions	5
Significance of the Study	6
Definitions of Terms	7
Assumptions and Limitations	13
II. REVIEW OF LITERATURE.....	16
Historical Perspective	16
Avionics Development.....	16
Aircraft Technicians Shortage	18
Infrastructure.....	20
GPS	20
ADS-B.....	22
Training.....	23
KSA's.....	24
Part 147 -Aviation Maintenance Technician Schools.....	28
FAR Part 65 Subparts D and E	32
NCATT	37
Publications.....	38
Avionics Textbooks	38
Industry Publications	41
III. METHODOLOGY	44
Methods used for Assessment of KSA's	44
Distribution of the Survey.....	47
Participant Population and Sample	48
Analysis of the Data	49
Access to the Survey.....	50
Survey Content	51

Chapter	Page
Survey Instrument Development	52
Basic Assumptions.....	52
Advanced Avionics Systems.....	53
New Expectations in Flight.....	54
FAA General Curriculum Subjects.....	54
IV. FINDINGS.....	56
Industry Sector	56
Airframe and Powerplant Certificate Requirement	57
Services Provided In Avionics Shops	58
Commercial and Regional Airlines	59
General and Business Aviation	59
Manufacturing.....	60
Training Requirements	61
Initial Training Source	61
Commercial and Regional Airlines	61
General and Business Aviation	62
Type of Training Used For New Technical Training	62
Electronics Advances and New Training Requirements	62
Commercial and Regional Airlines	63
General and Business Aviation	64
Manufacturing.....	65
FAA 2020 Mandate for ADS-B	66
Commercial and Regional Airlines	66
General and Business Aviation	67
Manufacturing.....	69
Avionics Systems	69
Basic Avionics Systems.....	70
Communications Systems	70
Dependent Navigation Systems	78
Autonomous Navigation Systems.....	87
Basic Aircraft Systems	95
Pulse Systems	103
Advanced Avionics Systems.....	112
Shop Tools, Equipment, and Processes	122
Shop Tools	122
Shop Equipment	130
Soldering and Wiring Processes	141
Generals Objectives	149
Basic Aviation Maintenance Requirements	149
Mathematics	158
Basic Physics	162

Processes and Materials	165
Aircraft Ground Operations	168
V. CONCLUSION.....	171
Summary of Research Method and Survey Design	171
Summary of Participants	173
Summary of Demographics Data.....	173
Summary of Services	174
Summary of Training Requirements.....	177
Initial Training	177
Continuing Education	177
Training and the FAA 2020 Mandate for ADS-B	177
Summary of Avionics Systems.....	178
Communications Systems.....	178
Dependent Navigation Systems	180
Autonomous Navigation Systems.....	181
Basic Aircraft Systems.....	183
Pulse Systems.....	184
Summary of Advanced Avionics Systems.....	185
Summary of Shop Tools Equipment and Processes	187
Summary of Generals Objectives	188
Conclusions and Discussions.....	190
Research Question I.....	190
Research Question II.....	193
Research Question III	197
Recommendations for Future Research	199
REFERENCES	201
APPENDICES	208
Appendix A: IRB Approval Letter	209
Appendix B: Consent Information Sheet.....	211
Appendix C: Request for Participation.....	213
Appendix D: Aircraft Electronics Technician Survey	215

LIST OF FIGURES

Figure	Page
1 Shops Working On-Aircraft Compared To Those Requiring an A & P License	58
2 The Type of Services Offered In Each Sector	60
3 Types of Training Used For New Technology Advances Over the Last Decade by Sector	65
4 Communications Systems Installed, Serviced, or Repaired By Sector	71
5 Communications Systems Knowledge Levels From the Commercial and Regional Airlines	73
6 Communications Systems Performance Levels From the Commercial and Regional Airlines	74
7 Communications Systems Knowledge Levels From General and Business Aviation.....	76
8 Communications Systems Performance Levels From General and Business Aviation.....	77
9 The Dependent Navigation Systems Installed, Serviced, or Repaired By Sector	79
10 Dependent Navigation Systems Knowledge Levels From Commercial and Regional Airlines	81
11 Dependent Navigation Systems Performance Levels From Commercial and Regional Airlines	83
12 Dependent Navigation Systems Knowledge Levels From General and Business Aviation	85
13 Dependent Navigation Systems Performance Levels From General and Business Aviation	86
14 Autonomous Navigation Systems Installed, Repaired, or Serviced By Sector ..	89
15 Autonomous Navigation Systems Knowledge Levels From Commercial and Regional Airlines	90
16 Autonomous Navigation Systems Performance Levels From Commercial and Regional Airlines	92
17 Autonomous Navigation Systems Knowledge Levels from General and Business Aviation Sector	93
18 Autonomous Navigation Systems Performance Levels from General and Business Aviation Sector	94
19 Basic Aircraft Systems Installed, Repaired, or Serviced By Sector	97

Figure	Page
20 Basic Aircraft Systems Knowledge Levels From Commercial And Regional Airlines.....	98
21 Basic Aircraft Systems Performance Levels From Commercial and Regional Airlines.....	100
22 Basic Aircraft Systems Knowledge Levels from General And Business Aviation Sector	101
23 Basic Aircraft Systems Performance Levels from General And Business Aviation Sector	103
24 Aircraft Pulse Systems Installed, Repaired, or Serviced By Sector	105
25 Aircraft Pulse System Knowledge Levels From the Commercial and Regional Airlines Sector	107
26 Aircraft Pulse Systems Performance Levels From Commercial and Regional Airlines.....	108
27 Aircraft Pulse Systems Knowledge Level from the General and Business Aviation Sector	110
28 Aircraft Pulse Systems Performance Levels for General and Business Aviation Sector	111
29 Advanced Avionics Systems Installed, Repaired, or Serviced By Sector	114
30 Advanced Avionics Systems Knowledge Levels From Commercial and Regional Airlines	116
31 Advanced Avionics Systems Performance Levels From Commercial and Regional Airlines Sector	118
32 Advanced Avionics Systems Knowledge Levels for General and Business Aviation.....	120
33 Advanced Avionics Systems Performance Levels from General and Business Aviation.....	121
34 Shop Tools Applicable To Avionics Shops by Sector.....	124
35 Shop Tools Knowledge Level from the Commercial and Regional Airlines Sector	125
36 Shop Tools Performance Levels From the Commercial and Regional Airlines Sector	127
37 Shop Tools Knowledge Levels from the General and Business Aviation Sector	128
38 Shop Tools Performance Levels from the General and Business Aviation Sector	129
39 Shop Equipment Applicable To Avionics Shops by Sector	132
40 Shop Equipment Knowledge Levels From the Commercial and Regional Airlines Sector	134
41 Shop Equipment Performance Levels From the Commercial and Regional Airlines Sector	136
42 Shop Equipment Knowledge Levels from the General and Business Aviation Sector	138
43 Shop Equipment Performance Levels from the General and Business Aviation Sector	140

Figure	Page
44 Soldering and Wiring Processes Data Applicable To Avionics Shops by Sector	142
45 Soldering and Wiring Process Elements Knowledge Level Data from the Commercial and Regional Airlines Sector	144
46 Soldering and Wiring Process Elements Performance Level Data from the Commercial and Regional Airlines Sector	145
47 Soldering and Wiring Process Elements Knowledge Level Data from the General and Business Aviation Sector.....	147
48 Soldering and Wiring Process Elements Performance Level Data from the General and Business Aviation Sector.....	148
49 Basic Aviation Maintenance Requirements Applicable to Avionics Shops by Sector	151
50 Basic Aviation Maintenance Requirements Knowledge Level Data from the Commercial and Regional Airlines Sector	153
51 Basic Aviation Maintenance Requirements Performance Level Data from the Commercial and Regional Airlines Sector	154
52 Basic Aviation Maintenance Requirements Knowledge Level Data from the General and Business Aviation Sector	156
53 Basic Aviation Maintenance Requirements Performance Level Data from the General and Business Aviation Sector.....	157
54 Mathematical Operations Performance Level Data from the Commercial and Regional Airlines Sector	159
55 Mathematical Operations Performance Level Data from the General and Business Aviation Sector	161
56 Physics Knowledge Level Data from the Commercial and Regional Airlines Sector	163
57 Physics Knowledge Level Data from the General and Business Aviation Sector	164
58 Processes and Materials Requirements Performance Level Data from the Commercial and Regional Airlines Sector	166
59 Processes and Materials Requirements Performance Level Data from the General and Business Aviation Sector.....	168
60 Aircraft Ground Operations Performance Level Data by Sector	170

CHAPTER I

INTRODUCTION

Aircraft electronics technicians, also known as avionics technicians, install, troubleshoot, and repair complex electronic systems and equipment which are critical to the safe operation and navigation of today's modern aircraft. These technicians can be found in a variety of environments, including small privately-owned general aviation repair centers or large corporate jet service centers. Technicians trained under the same designation may be found in the shop of a new upstart electronics entrepreneur or world renowned major electronics factory. Many of these technicians are employed by major airlines and work in shops ranging from depot-level overhaul centers to mid-level black box repair centers, as well as front-line aircraft service shops. The educational institutions responsible for training aircraft electronics technicians include universities and colleges, community colleges, aviation technical schools, and the military.

Technology in the cars we drive and the phones we carry are evidence to the rapid advancements and changing capabilities of electronics in the modern world. Electronic technology in aviation has also dramatically changed over the last two decades. Microprocessors, also known as computer processors have been integrated into all facets of electronics including aircraft communications, navigation, and control systems (Sparks, 2007). The integration of computer systems in aircraft has reached the level

where the fear of aircraft being hacked is now prevalent in the public eye (Burnside, 2015). The integration of computer technology allows these systems to communicate with each other using serial data lines, similar to the ways computer networks communicate in the typical office environment. Setting up and programming these airborne communication networks can be difficult for technicians without the proper training. Advanced technologies have brought with them changes in diagnostics, troubleshooting, and test equipment (Sparks, 2007).

It is the purpose of this research to identify the knowledge, skills, and abilities (KSA's) required to install, troubleshoot and repair modern aircraft electronic systems. The electronic systems used in aircraft have changed as a result of the advances in electronic technology. The aviation electronics industry needs to know the technicians taking care of critical flight systems have the knowledge skills, and abilities needed to meet the challenges of these new technologies found in today's aircraft.

The Federal Aviation Administration (FAA) published a final rule in the federal register in May of 2010 which mandated the use of Automatic Dependent Surveillance-Broadcast (ADS-B) technology as the new means for Air Traffic Control surveillance for all aircraft operating in United States airspace (Federal Aviation Administration, 2010). This technology will require the installation of new electronics equipment on every aircraft, commercial and general aviation. The mandate requires new equipment to be installed and operational by the year 2020 (Federal Aviation Administration, 2010). Delays by aircraft owners to shoulder the expense of new equipment installations have resulted in a flood of aircraft still needing avionics installation work before the 2020 deadline. Avionics shops

large and small currently inundated with work and as a result of these changes are hiring many new technicians to fill the demand (Aylward, 2015).

The use of advanced technology in the general aviation (GA) market has increased dramatically in recent years (Federal Aviation Administration, 2009). Decreases in the costs of flat screen displays and micro electro-mechanical systems (MEMS) technologies has led to an explosion in the advanced technology approved for use in smaller GA aircraft. Many general aviation aircraft manufacturers such as Cessna and Beechcraft are now offering glass cockpits with advanced systems such as attitude and heading reference systems as standard equipment on all their small single-engine aircraft (Cessna Aircraft Company, 2015; Beechcraft Textron Aviation, 2016). The advances in technology, now common in what were traditionally less sophisticated aircraft, may be changing the types of problems faced by electronics technicians working in this segment of the industry.

Small privately-owned avionics shops typically have the same technician who troubleshoots sophisticated electronic systems, removes and reinstalls interior, and may also be responsible for fabricating antenna supports or cutting new instrument holes. These additional tasks, which seem common for the electronics technician in the smaller shops of the general aviation segment, may not be required of electronics technicians in the larger shops of commercial or manufacturing environments. The additional tasks required for small GA shops may dictate different or additional training to prepare technicians for positions in this segment of the industry.

Aircraft electronic technician training programs provide future technicians with instruction including basic electronics theory, basic electronics skills, and some additional

knowledge and skills specific to aircraft electronics systems. Most avionics training regimens will include aircraft specific knowledge such as basic aircraft structure and aircraft safety. Some programs may offer exposure to aircraft sheet metal work or assembly and disassembly processes. A few colleges may offer aircraft electronic technician training in combination with an airframe or airframe and powerplant certificate program. In order to produce technicians qualified to work in the modern industry, training providers need to have a clear understanding of the knowledge, skills, and abilities used by technicians across all industry segments. Ensuring students are spending time and money learning what is needed for the workplace is important to the education institutions and to the industry they serve. Students, educators and industry stakeholders need to know exactly what KSA's are being utilized in today's avionics shops.

Statement of Purpose

The purpose of this study is to identify the knowledge, skills, and abilities needed by aircraft electronics technicians in the aviation industry. This study also seeks to identify differences in technician requirements across specific segments of the aviation industry. A study of the current KSA's being used by technicians in various segments of the aviation industry will provide a basis for developing new aircraft electronics technician training objectives that more closely meet the requirements of the industry. The information gathered from various industry segments can be used to develop continuing education requirements for technicians in specific industry segments.

This study will also identify current employee training methods and practices used to meet continuing education requirements in the different segments of the aviation

maintenance industry. Identifying the methods used to provide training to existing aircraft technicians will allow organizations employing the technicians and the educational institutions serving them to better plan and deliver required continuing education needs. The insight gained by this study may assist the industry in establishing more accurate standards for technician certifications. The study of KSA's of the technicians maintaining the sophisticated and complex systems in today's aircraft will help to ensure adherence to the highest levels of quality and safety which are essential to the aircraft maintenance process. The study of technicians' KSA's in avionics shops across the industry will provide valuable information to educators, government regulators, the aviation industry, and the public they serve.

Research Questions

The massive scope and breadth of technology used in aviation and the knowledge required of technicians working in this field make studying these areas difficult. The following research questions were developed to focus and guide this research in more clearly defined directions.

- What are the knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry?
- Do the knowledge, skills, and abilities required for aircraft electronics technicians differ depending on the industry segment they are working in: commercial or general aviation, aircraft or component manufacturing, aircraft or component servicing?

- When meeting the need for continuing education on advanced aircraft electronic systems, what are the current methods of delivering technical training used in the different segments of the aircraft electronics industry?

Significance of the Study

Rapid development and application of new technologies in all segments of the aviation industry places technical training programs in difficult situations. The need to provide meaningful hands-on training balanced against the need to keep education cost within reach of those who need it requires up-to-date information on the KSA's used by technicians. The significance of this study is in identifying the current requirements for knowledge, skills, and abilities of aircraft electronics technicians working in different segments of the modern aviation industry. The establishment of these KSA's should provide a foundation for aircraft electronics training intuitions to design or modify their aircraft electronics education programs in accordance with current industry practices. The study outcome may aid in the development of new more relevant textbooks and training programs which should result in more effective technicians.

The study will also provide demographic information correlating KSA's to specific industry segments. This may allow training institutions to offer options for students to target their education towards specific segments of the industry. Standards agencies may find the demographic information of this study useful when reviewing the knowledge, skill, and ability requirements for developing certification standards for the aviation industry.

This study will also identify the training methods used to deliver continuing education to existing technicians. The identification of training methods currently used may be significant to organizations planning training budgets and time allotted for training. This information may also help training institutions prepare and offer more effective less expensive training solutions.

Definitions of Terms

Aircraft Electronics Technician or Avionics Technician: An individual trained in the repair and servicing of electronic systems used in airborne operations. These individuals typically have a good understanding of electronics theory, as well as advanced training in systems specifically used in airborne operations. The aircraft electronics technician will also have training in how the airborne environment can affect installation, operation, and servicing of electronic systems.

ASTM International: A worldwide standards organization involved in all facets of industry. According to their website ASTM.org, (2016) ASTM was formed in 1898 by a chemist with the railroad named Charles Dudley, (ASTM International, 2016). The organization was originally known as the American Society for Testing and Materials before the name was changed to ASTM International in 2001 (ASTM International, 2016). ASTM has as its membership some of the “world’s top technical experts and business professionals representing 140 countries” (para 2). (ASTM International, 2016). ASTM “members create the test methods, specifications, classifications, guides and practices that support industries and governments worldwide” (ASTM International, 2016). ASTM NCATT exams are offered through Credential Testing

Services (CTS), a division of SpaceTEC Partners, Inc. (Credential Testing Services, 2018).

Attitude and Heading Reference System: An aircraft system consisting of a group of electronic components which sense the aircraft roll, pitch, and yaw attitudes. The system also provides position and navigation information. This information is displayed to the pilots using an artificial horizon type display. This system would be considered part of the autonomous navigation systems category.

Autonomous Navigation Systems: Any system which provides navigation information without depending on signals originating outside the aircraft. Most of these systems use gyroscopes to sense aircraft movement. Some systems utilize accelerometers to sense movement of the aircraft. All of these systems rely on computer processing and use sensor input to calculate current position and other navigation information.

Bench Shop or Bench Repair: Reference to shop, maintenance level, or maintenance activity where components that have been removed from the aircraft are taken to a specialized work center for evaluation and repair.

Black Box (LRU): Any aircraft electronics unit that may be removed and replaced as a single unit is referred to as a line replaceable unit or LRU. Black box was originally a slang term for any LRU. Black Box has evolved to refer specifically to the cockpit voice recorder and flight data recorder when dealing with a crash or emergency situation.

Check - Check means to verify proper operation. (Part 147 Appendix A)

Dependent Navigation Systems: Any navigation system which relies on signals received from outside the aircraft to provide navigational information. Signals may be received from the ground stations, satellites or other aircraft.

Depot Level: Reference to shop, maintenance level, or maintenance activity which deal primarily with complete overhauls, rebuilds and in-depth maintenance. Any facility providing this type of service may be referred to as a depot level maintenance facility or overhaul shop.

Glass Cockpit: Modern aircraft utilize screens similar to television screens to display aircraft information as opposed to using individual gages and dedicated instruments to display this information (Federal Aviation Administration, 2009). These systems allow pilots the flexibility to access many different types of information, or display only the most critical information. Commercial aircraft have used these systems for decades; it is only in the past 20 years that smaller aircraft could afford or have been approved for installation of these types of systems. Today almost all new aircraft are available with glass cockpits.

Flat-Screen Display: An electronic monitor or display having a slim design through the use of technology other than cathode ray tubes. Technologies such as liquid crystal or O-LED have made the heavier and more power hungry cathode ray tube obsolete. Advances in display technology have made the flat-screen display adaptable and affordable for both installed and portable applications.

Industry Segments: Federal Aviation Regulations regarding the servicing of aircraft divide aircraft service in several ways. One set of regulations apply to the commercial or

airline segment of the industry, while a different set of regulations apply to charter services and yet another section is for general aviation. The regulations further divide aircraft service by aircraft size (i.e. 12,500 pounds and under) or by engine type (ie.. jet turbo-prop or non-turbine). Another significant division is that of rotorcraft from fixed wing aircraft. These distinctions do not necessarily require separate business segments, however many businesses limit their focus to specific areas of expertise or separate business units by one or more of these FAR's differentiations. A hard line can be drawn between the commercial or airline industry segment and general aviation segment.

Industry Segments (Commercial): Commercial industry shops service only their aircraft and cannot work on any other aircraft. Each airline organization works directly with the federal aviation administration and the aircraft manufacturers to set guidelines for aircraft maintenance procedures. Those guidelines become the rules under which the airline's maintenance centers must operate.

Industry Segments (General Aviation): In the GA arena different business segments may become less clear. Some general aviation service centers may work on-aircraft large and small with reciprocating engines, turbo-prop engines or jet engines. Other shops may limit their business to only one or two of these segments. The general aviation industry also has another area where businesses may cross over to different segments; rotorcraft versus fixed wing aircraft segments. There are many general aviation service centers that work only on fixed wing aircraft, and some that work only on rotorcraft. There also exist service centers which service both fixed wing and rotorcraft. General Aviation service centers may be further segmented by business

size. Small independent businesses may operate differently than large corporate entities which have many departments and locations.

Industry Segments (Large GA Shops): Large GA shops are large service centers employing more than 50 workers and providing multiple services including avionics to private aircraft owners. These centers typically have the capability to work on all types of privately owned aircraft and often have many different locations.

Industry Segments (Small GA Shops): Small GA shops are independent general aviation service centers, employing less than 50 workers working on privately owned aircraft. Typically these independent shops service small aircraft under 12,500 lbs., turbo-props, and corporate jets under 15 passengers.

Inspect - Inspect means to examine by sight and touch. (Part 147 Appendix A)

KSA's (Knowledge, Skills, and Abilities) - KSA's are a means to describe the different learned information and talent that may be required to do a specific task or job. Often a job requires knowledge of a subject, the physical ability and technical skill to perform a given task. The Veterans Administration (VA) uses knowledge, skills and abilities as a means to more clearly identify specific job prerequisites. The VA gives the following definitions of each.

- Knowledge - an organized body of information, usually factual or procedural in nature.
- Skill - the proficient manual, verbal, or mental manipulation of data or things.
- Ability - the power or capacity to perform an activity or task.

Together these three elements can describe all that is necessary to be competent at a specific job or task within an occupation description.

LRU: Any aircraft electronics unit that may be removed and replaced as a single unit is referred to as a line replaceable unit or LRU.

NCATT: National Center for Aerospace and Transportation Technologies is a standards organization which has developed standards for certification of aerospace professionals. Although it began separately the NCATT organization was absorbed into ATSM in 2014 (Credential Testing Services, 2018). ASTM placed responsibility for the testing of NCATT certification with Credential Testing Services (CTS), a division of SpaceTEC Partners, Inc. (Credential Testing Services, 2018).

On-Aircraft: Term which references shop or maintenance level where technicians work directly on the aircraft, as opposed to those shops or maintenance levels where technicians work on components that have been removed from the aircraft.

Overhaul: Overhaul means to disassemble, inspect, repair as necessary, and check. (Part 147 Appendix A)

Repair: Repair means to correct a defective condition. Repair of an airframe or powerplant system includes component replacement and adjustment, but not component repair. (Part 147 Appendix A)

Service: Service means to perform functions that assure continued operation. (Part 147 Appendix A)

Teaching Levels: (Part 147 Appendix A)

Teaching Level 1 requires: Knowledge of general principles, but no practical application, No development of manipulative skill, Instruction by lecture, demonstration, and discussion.

Teaching Level 2 requires: Knowledge of general principles, and limited practical application, Development of sufficient manipulative skill to perform basic operations, Instruction by lecture, demonstration, discussion, and limited practical application.

Teaching Level 3 requires: Knowledge of general principles, and performance of a high degree of practical application, Development of sufficient manipulative skills to simulate return to service, Instruction by lecture, demonstration, discussion, and a high degree of practical application.

Troubleshoot - Troubleshoot means to analyze and identify malfunctions. (Part 147 Appendix A)

Assumptions and Limitations

This study is investigating KSA's of aircraft electronics technicians. It is therefore assumed that all segments of the aviation industry which employ aircraft electronics technicians expect the technicians to know and understand basic electronics. Basic electronics training is assumed to include theory and application of:

- Direct Current
- Alternating Current
- Electronic Circuits and Amplifiers

- Digital Circuits
- Electronic Communications

All electronics technicians should have been trained and tested on these basic concepts. The survey used to collect data in this research will not include questions on these basic knowledge elements.

Basic electronics training is also assumed to include sufficient practice in the skill and technique of soldering so as to prepare a technician for removing and installing through-hole components to printed circuit boards. Advances in miniaturization of components and automated manufacturing processes utilize surface mount soldering and components to produce smaller more capable modern electronic devices. Surface mount soldering and components require changes in equipment and materials needed to remove and replace soldered in components. Many manufacturing organizations no longer condone component level repair outside of the factory. Many shops no longer conduct component level repair, replacing cards or modules only. Modern electronic devices typically utilize surface-mount components and soldering techniques instead of the through-hole components and processes. Questions concerning skills and abilities in both standard through-hole soldering and the more advanced surface mount soldering will be included in the survey.

The survey will focus on electronics technology related to recent advances or changes in aircraft systems. The survey includes questions in areas of basic electronics that could be considered obsolete and the same may apply to some older types of aircraft electronics systems. These questions will be provided in order to give participants the opportunity to include or exclude these older knowledge and skillsets as still relevant or necessary KSA's.

The researcher assumes that enough participants will contribute to allow the data to be generalized to the greater populations of the aviation industry. The researcher further assumes the participants will be truthful in their responses. The researcher realizes with the large number of companies and organizations that make up the aviation electronics industry that this research may not represent an accurate depiction of each segment of the industry and all needs and positions of some segments may not be represented. This research may only be a starting point which helps to emphasize the need for larger more detailed studies.

This study is limited to determining the KSA's currently used in the industry as defined by technicians and managers working in those shops. The accuracy of their interpretations is clearly a limitation of this study. Experienced technicians may underestimate or overestimate the depth or level of knowledge in much the same way and experienced teacher may assume a student's base knowledge is greater or less than it actually is. The accuracy of the study is limited by the ability of the participants to accurately interpret the question and to accurately relate the conditions in their individual environments.

The training required to become an aircraft electronics technician is in-depth in many different areas of study. Multiple studies would be required in order to accurately identify all the elements that go into making a competent technician. Elements such as personality and past experiences may play important roles in determining a technician's skill or effectiveness. This study is limited to only identifying the knowledge, skills, and abilities of technicians as defined by those closest to the work.

CHAPTER II

REVIEW OF LITERATURE

Historical Perspective

The Wright Flyer sparked a process of invention and innovation that continues today. As long as there have been aircraft there have been those who seek to modify and improve them. The use of radios in aircraft can be traced back to 1911 when a 29 pound radio telegraph was held in the lap of a passenger on a Model B Wright Flyer (Inman, 2012). Since that time, new designs in aircraft were equipped with new designs in radios. The aircraft got heavier and more powerful, and the radios got lighter and more powerful.

Avionics development.

Many of the innovations and much of development that occurred in aviation was due to military development. World War II saw dramatic increases not only in aircraft manufacturing, but in the development of radio technology. According to Henderson, (1993) “The basic VHF communications and navigation systems that are used in aviation were developed in the 1940s” (p. 103). Developed during this period; “The very high frequency omnirange or VOR system is the standard IFR navigation system for cross-country flying in the U.S.” (Henderson, 1993, p. 125). This system became widely operational in the 1940’s and was the primary navigation for all aircraft until the approval

for IFR use of GPS in the mid 1990's (Henderson, 1993).

Another major aircraft system developed during war time was radar. Radar was developed by Great Britain and the United States during World War II to track enemy aircraft and ships (Eismin, 1995). Soon after the war, radar was adapted for use in weather detection and avoidance by the commercial aviation industry (Eismin, 1995).

Many of the modern systems of navigation and communications were first found in commercial aircraft. More advanced equipment was available in large commercial aircraft long before the advances in technology reduced the costs and weight to what smaller private aircraft could accommodate or afford. Aircraft Instruments and Avionics for A&P Technicians (Henderson, 1993) lists Flight Management Systems (FMS) and Traffic and Collision Avoidance Systems (TCAS), as advanced systems found on commercial aircraft of the day and now these systems are common on many smaller private aircraft.

Aircraft Electricity & Electronics (Eismin, 1995) uses the instrument panel of an Airbus A-320 commercial jumbo-jet to illustrate a six-screen Cathode Ray Tube (CRT) electronic flight instrument system or glass cockpit. A smaller four screen system is described as "found on many corporate aircraft" (Eismin, 1995, p.357). Today aircraft of all types and sizes are equipped with or are being upgraded to electronic flight instruments. The literature also states that "electronic flight instruments became possible with the development of a sunlight-readable CRT display and sophisticated aircraft computer interface systems" (Eismin, 1995, p. 357). It is the more recent developments of micro-processors and flat-screen display technology that has transformed the cockpit

to a theater presentation of relevant information. There is little doubt that the development of and continued advances of computer technology have had a great impact on the development of electronic systems in and out of the cockpit.

The continued advances in display and computer technologies have allowed the development of lightweight, low cost, highly sophisticated, electronic systems that are now available for use in all aircraft; including small privately owned aircraft. Today's newer systems have digital circuitry and microprocessors. The new flat screen display systems are lighter, use less power, and are interfaced using digital communication formats (Helfrick, 2015). A communications radio is still a communications radio much the same way an AM/FM radio in a car is still an AM FM radio. However, the way that radio works to receive and decode information has changed dramatically by the use of digital signals and digital processing technology (Helfrick, 2015). In much the same way that every aspect of the family car has been transformed by digital electronics, so has every aspect of the modern aircraft.

Aircraft technician shortage.

World War II saw dramatic increases in aviation workers. After World War II, there was a boom in the birth rates. Those born in the time period between 1946 and 1964 are commonly referred to as baby boomers (Brandon, 2014). The next big military action to prompt increases in aircraft manufacturing and training of aircraft workers was the Vietnam War era of the mid fifties through the mid seventies. The Vietnam era provided military training for many of the baby boomers and they became the aviation technicians that would support aviation in the U.S. for the next 40 years.

Baby Boomers and their children inspired by jet powered aircraft and rocket powered space-flight learned to fly, build, and work on the advanced technology of aviation and space-flight. Time passed and aircraft and spacecraft technology seemed less inspiring. The space shuttle program was the last big aerospace technology to inspire future technicians. The end of the shuttle program seemed to mark the end of excitement around aviation and aerospace technology. Each of the following generations seems to have lost the inspiration to embrace flying machines or the technology behind them. In the article *New Maintenance Techs Short on Numbers, Skills*, the director of maintenance training business development for FlightSafety International; Mike Lee is quoted, saying “Aircraft are not seen as high-tech by Generation X and Y” (Adams, 2014, para. 9). Lee attributes this to a lack of “hands-on experience with automobiles and tractors” (Adams, 2014, para. 9). Much of generation X and beyond is moved or inspired by software and the virtual reality of artificial imagery gaming can provide. These generations no longer seem excited by the actual performance and capabilities found in the fine machinery and the advanced technology that is modern aviation.

Today a large percentage of the baby boomer aviation workforce is nearing retirement and there are not adequate numbers of trained technicians to replace them (Adams, 2014). By 2022, the demand for commercial aviation maintenance technicians will out number the supply and by 2027 that gap is expected to peak at about nine percent (Prentice & Costanza, 2017). In a highly quoted 2016 report by Boeing Company, it is estimated that over the next 20 years the commercial airline industry will need 127,000 airline maintenance technicians in North America with the demand reaching 679,000 globally (Welch, 2017).

Infrastructure

The radio navigations and communications that were designed in the forties and fifties to support aviation are older than the technicians that now maintain them. VOR navigation systems require a ground station emitting specialized radio signals around the clock. Airports handling large numbers of commercial and general aviation aircraft are generally equipped with instrument landing systems. These systems require elaborate antenna arrays and specialized transmitters that require regular maintenance and upkeep. Airports that wish to attract larger aircraft and larger volumes of aircraft typically have radar tracking system to maintain surveillance and control over the flow of air traffic. These ground based air traffic control systems are all paid for and maintained by the Federal Aviation Administration, a division of the U.S. Department of Transportation.

Tasked with maintaining air navigation systems, the FAA has retired older systems of navigation such as Omega, VLF, and Loran C while maintaining and upgrading current systems like VOR and radar (Helfrick, 2015). Plans were in place to replace existing instrument landing systems with a new generation system called microwave landing systems or MLS (Helfrick, 2015; Underwood, 2001). Unfortunately for MLS, FAA order 8260.38A in 1995 established the civilian use of the GPS satellite network for aircraft non-precision instrument approaches and changed the FAA course going forward (Federal Aviation Administration, 1995).

Global Positioning System.

GPS offered instrument landing approaches with little or no requirement to install additional ground equipment. The convenience and relatively low cost of GPS combined

with the new features it offered attracted many aircraft owners. These new systems had many advantages over VOR and ILS with few disadvantages. GPS is a form of area navigation (Inman, 2012). Area navigation allows a pilot to select any point in space within an area of navigation and have the navigation system provide guidance directly to that point (Inman, 2012). Accomplishing this level of navigation using a VOR signal would require a specialized RNAV receiver in combination with a second system known as DME or distance measuring equipment system (Inman, 2012). These units were costly and complex to repair. A major advantage of area navigation systems is that a system which provides outputs for indicator guidance can also provide outputs for autopilot guidance. The relatively low cost GPS systems could provide autopilot guidance to any point anywhere.

GPS operates by receiving satellite signals with timing information and up to date satellite positions. The GPS receiver uses the timing signals to calculate the distance from each of several satellites and thus calculate its position in relation to them (Helfrick, 2015). An updatable navigation database in the receiver provides surface maps, airport information, and aviation navigation information. The system can calculate airspeed and altitude information as well. The FAA is able to fly multiple approach patterns for a given runway with specialized aircraft that record the flightpath information. The information is then added to the GPS database and any aircraft GPS equipped with that database is able to track and fly the exact route on command. This provides an instrument controlled approach to the runway without adding any equipment on the ground. The only limitation to this system is the accuracy of the GPS position information.

The GPS satellite system has been augmented with a secondary satellite system known as wide area augmentation system or WAAS (Helfrick, 2015). This system uses ground based receivers to monitor the accuracy of the GPS signals and generate a correction signal. The correction signal is broadcast by two geostationary satellites to WAAS equipped GPS units (Helfrick, 2015). This system provides accuracy near the precision of the older ILS approach giving the aircraft the capability of landing in most low visibility conditions (Helfrick, 2015). Changes in technology often lead to changes in rules. The development of GPS technology and the enhancements to GPS accuracy have lead to a major change in the way air traffic control will locate and track aircraft.

Automatic Dependent Surveillance –Broadcast.

The FAA has been using radar to locate and track aircraft in order to provide air traffic control (ATC) services for many years. The accuracy of the WAAS enabled GPS onboard aircraft to locate and track the aircraft movement is great enough that the FAA decided to use the onboard GPS as the primary means to locate and track aircraft for air traffic control operations. In the FAA publication of the ADS-B final rule (G.P.O. Publication No. 30160) the FAA mandated that all aircraft operating in controlled air space of the United States national air space (NAS) would be required to be equipped with ADS-B out systems by January 1, 2020 (Federal Aviation Administration, 2010). This publication established a mandate to equip all aircraft with a specialized system to transmit the current location of the aircraft continuously for the purpose of ATC (Federal Aviation Administration, 2010). There are two options for type of transmitter required; a 1090 MHz ES (extended squitter) transponder, and a universal access transmitter (UAT) transponder (Federal Aviation Administration, 2010).

The new ADS-B systems will operate automatically without pilot intervention and provide a constant signal that ATC can track. The advantage to the pilot and aircraft owner is that with the purchase of the additional ADS-B in equipment the aircraft can see all other air traffic without the need to pay for any type of subscribed traffic services. The additional ADS-B in equipment can also receive updated weather information or other significant safety related information from ATC without additional costs.

The major issue this program creates for aircraft electronics technicians is equipping all aircraft in the NAS within the deadline. All shops capable of installing ADS-B systems are being swamped with these installations as the deadline approaches (Knauer, 2018). The combination of extreme demand for installations with a rapidly retiring workforce creates an overwhelming need for competent training programs to produce technicians ready to go to work. According to a 2017 report, the industry may have to increase pay and benefits to attract potential workers and prevent them from entering other industries (Prentice & Costanza, 2017).

Training

The position of aircraft electronics technician requires knowledge, skills, and abilities in many areas. The federal government has listings describing qualifications for every job they offer including aircraft electronics technician. The FAA has three sections which directly address the issue of training of aircraft technicians. The FAA has explicit regulations in Part 147 regarding the training facilities and curriculum used to train aircraft mechanics (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). The FAA also has specific regulations regarding required knowledge, skills, and

experience of mechanics in Part 65 subpart D- mechanics (Electronic Code of Federal regulations, Part 65, Subpart D, 2018). Finally the FAA addresses the repairman certificate in Part 65 subpart E (Electronic Code of Federal regulations, Part 65, Subpart E, 2018). Many textbooks have been written for the purpose of training aircraft electronics technicians and the aviation industry has several publications aimed at improving the knowledge and skills of technicians. These publications provide information fundamental to understanding aircraft electronics technician training requirements. There may be different training requirements for different segments of the aviation electronics industry. Many different opinions can be found on what should be included in the training of aircraft electronics technicians.

Knowledge, Skills, and Abilities.

The U.S. Department of Veterans Affairs (2009) webpage on knowledge, skill, and abilities describes what KSA's are and how the U.S. government uses them to screen job applicants. The site lists the following definitions:

- Knowledge - an organized body of information, usually factual or procedural in nature.
- Skill - the proficient manual, verbal, or mental manipulation of data or things.
- Ability - the power or capacity to perform an activity or task.

Examples of responses to specific KSA's were given in each definition (U.S. Department of Veterans Affairs, 2009). The material stated "KSAs are used to distinguish the 'qualified candidates' from the 'unqualified candidates' for a position" (U.S. Department of Veterans Affairs, 2009). Additional information on this webpage included the

importance of KSA's to the government job application process, how to write responses to KSA's during the application process, and several "DOs and DON'Ts" associated with KSA responses (U.S. Department of Veterans Affairs, 2009). Information on the Veterans Affairs website indicated more information specifically about avionics technician KSA's could be found on the Bureau of Labor Statistics website (U.S. Department of Veterans Affairs, 2009).

The U.S. Department of Labor, Bureau of Labor Statistics, (2017) *Occupational Outlook Handbook*, for avionics technicians provided general statistical information. Statistics given included; 2017 median pay of \$61,260 per year or \$29.45 per hour, the number of jobs in 2016 of 149,500, and the 10 year job outlook for 2016 through 2026 at 5% (U.S. Department of Labor, 2017). Additionally, there were links to training sites, state and area statistics, and similar occupations (U.S. Department of Labor, 2017). One other link of interest was provided to a site called "O'Net", which was described as "a source on key characteristics of workers and occupations" (U.S. Department of Labor, 2017).

The National Center for O'NET Development (2018) webpage summary report 49-2091.00 – avionics technicians, provided a complete list of knowledge, skills, and abilities for avionics technicians as defined by the bureau of labor statistics. Under the heading of knowledge, ten elements were listed. The knowledge list encompassed generalized areas of study but not specific areas which applied only to avionics technicians. The areas listed included knowledge of:

- Computes and electronics
- Mechanical

- Engineering and technology
- Customer and personal service
- Design
- Telecommunications
- Mathematics
- Education and training
- Public safety and security

Each of these knowledge areas included descriptive elements that were broad and inclusive without being specific to the job of avionics technician (National Center for O*NET Development, 2018). An example of this would be the descriptors included for mechanical knowledge: “Knowledge of machines and tools, including their designs, uses, repair, and maintenance” (National Center for O*NET Development, 2018). These descriptors do reflect knowledge that an avionics technician needs to have, yet they lack the specifics that apply only to avionics technicians.

The listing for skills included 18 elements and each was detailed in identifying a skill that may be required by an avionics technician. The areas listed included skills of:

- Equipment maintenance
- Repairing
- Troubleshooting
- Critical thinking
- Operation monitoring
- Quality control analysis
- Complex problem solving
- Active listening
- Speaking
- Judgement and decision making
- Reading comprehension
- Writing
- Monitoring
- Time management
- Active learning
- Coordination
- Equipment selection

- Systems Analysis

The descriptors given with each skill were accurate in describing what is included in the individual skill, however they are generalized. Some skill descriptors could be applied directly to avionics technician work. The skill descriptions are designed to be non-specific to one job and therefore not detailed to the specific needs of a specific job like avionics technician. An example of this non-specific design is the descriptor for troubleshooting: “determining causes of operating errors and determining what to do about it” (National Center for O*NET Development, 2018). These descriptors do reflect skills that an avionics technician needs to have, yet few identify the skill specifics as it would apply to avionics technicians.

The abilities section of the site listed 20 elements (National Center for O*NET Development, 2018). These abilities all seem to directly relate to abilities needed by avionics technicians. The list included abilities of:

- Written comprehension
- Information ordering
- Near vision
- Oral comprehension
- Problem sensitivity
- Deductive reasoning
- Inductive reasoning
- Written expression
- Oral expression
- Arm-hand steadiness
- Control precision
- Manual dexterity
- Visualization
- Speech clarity
- Speech recognition
- Category flexibility
- Perceptual speed

- Selective attention
- Visual color discrimination

Each of these abilities is a requirement of most avionics technician positions. The non-specific design of the descriptions is the same as those mentioned above. The abilities listed could be applied to many different job descriptions.

FAR Part 147 -Aviation maintenance technician schools.

Federal Aviation Regulation Part 147 aviation maintenance technician schools “prescribes the requirements for issuing aviation maintenance technician school certificates and associated ratings and the general operating rules for the holders of those certificates and ratings” (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). The specifications included in appendix B of this section include general curriculum subjects which are required to have at least 400 hours of instruction (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). This section also lists the level of proficiency to which each subject is to be taught. Most of the subjects in appendix B were included in this study as elements of the survey. Appendix C to Part 147 comprises airframe curriculum subjects. Some of these are part of the standard subjects covered in most avionics training curriculum and were included in the survey for this study. The subjects in Appendix C of the airframe curriculum which are considered part of the typical avionics curriculum include:

D. AIRCRAFT INSTRUMENT SYSTEMS

- (1) 36. Inspect, check, service, troubleshoot, and repair electronic flight instrument systems and both mechanical and electrical heading, speed, altitude,

temperature, pressure, and position indicating systems to include the use of built-in test equipment.

(2) 37. Install instruments and perform a static pressure system leak test.

E. COMMUNICATION AND NAVIGATION SYSTEMS

(1) 38. Inspect, check, and troubleshoot autopilot, servos and approach coupling systems.

(1) 39. Inspect, check, and service aircraft electronic communication and navigation systems, including VHF passenger address interphones and static discharge devices, aircraft VOR, ILS, LORAN, Radar beacon transponders, flight management computers, and GPWS.

(2) 40. Inspect and repair antenna and electronic equipment installations.

G. AIRCRAFT ELECTRICAL SYSTEMS

(2) 48. Repair and inspect aircraft electrical system components; crimp and splice wiring to manufacturers' specifications; and repair pins and sockets of aircraft connectors.

(3) 49. Install, check, and service airframe electrical wiring, controls, switches, indicators, and protective devices.

(1) 50. a. Inspect, check, troubleshoot, service, and repair alternating and direct current electrical systems. (Electronic Code of Federal regulations, Part 147, Appendix A, 2016, p. 8).

The level to which each of these is taught is the number in parentheses at the beginning of each item. Level three, the highest level in practical application and requiring the highest level of understanding, is applied only to item 49 which addresses electrical wiring, controls, switches, indicators, and protective devices (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). All other elements of the airframe curriculum require knowledge of general principles and little or no practical application of that knowledge (Electronic Code of Federal regulations, Part 147, Appendix A, 2016).

A statement in a 2016 white paper prepared by the Aviation Technician Education Council (ATEC) proclaims, “Under the existing Part 147 regulations, current maintenance training is tied to a rigidly enforced accounting of student attendance with consideration for student competency left to the integrity of the individual AMTS (aviation maintenance technician school) ” (Dyen & Hall, 2016, p.4). The document reports the rapidly increasing need for aviation maintenance technicians, citing a statistic of 609,000 technicians needed over the next 20 years and promotes the idea of competency-based education or CBE over the credit hour requirements called for by Part 147 (Dyen & Hall, 2016). The document provides the definition of Competency-Based Training as “Training delivered and evaluated based upon the amount of training each individual needs to achieve ‘mastery’ of required tasks” (Dyen & Hall, 2016, p.5). The ATEC white paper also provides the following definition of credit hours, a format used by most colleges, including Part 147 certified institutions, to meet requirements of accounting and academic accreditation.

Credit hours are an educational method of quantifying an amount of learning for the purpose of charging a monetary fee. A credit is not only an instructional hour,

but an amount of learning within that allotted time frame. If a student does not reach the required amount of learning (competency) within the allotted time frame the student does not earn the credit, regardless of the hours. This holds true in any educational area of study. (Dyen & Hall, 2016, p.8)

Dyen and Hall reference FAA advisory circular 120-16F dated 11/15/2012 in a section titled “the current regulatory and system environment for maintenance training” (Dyen & Hall, 2016). The FAA website indicated the most current version of this document to be AC No. 120-16G (Federal Aviation Administration, 2016). This advisory circular is intended to provide explanation of the “scope and content of air carrier aircraft maintenance programs” (Federal Aviation Administration, 2016, p. 1). In this advisory circular, chapter 10 refers to personnel training and provides guidance to air carrier operators about training requirements (Federal Aviation Administration, 2016). The advisory circular suggest all training should be based on an assessment of training needs which reflects the knowledge, skill, and ability required to properly complete a given task of function (Federal Aviation Administration, 2016). The advisory circular also suggest that identifying the need for additional competency-based training may come from employment testing, job performance, or quality control program monitoring (Federal Aviation Administration, 2016).

According to Welsh in his article *Mind the Gap: Innovations in Talent Acquisition*, the Boeing Company’s annual report of 2016 stated 679,000 technicians will be needed globally over the next 20 years with 127,000 airline technicians needed in North America for the same period, (Welsh, 2017). The talent shortage and skills gap are major issues facing those trying to fill these positions. In this article, Welch explains how

ExpressJet is utilizing total company involvement and developing a “National Talent Supply Chain” utilizing an organization called Talent Solutions Coalitions (Welsh, 2017, p. 2). The talent supply chain is working to reduce the talent acquisition cost and improve technical skills in applicants (Welsh, 2017). Talent Solutions Coalitions is also helping to develop training for the existing workforce (Welsh, 2017).

Welch describes the gap created by the “increasing complexity of the newest generation of aircraft” and the current skills taught to aviation maintenance technicians (Welsh, 2017, p. 1). The Talent Solutions Coalitions organization worked with ExpressJet to define and develop a job-task analysis or JTA (Welsh, 2017). “The JTA details ExpressJet’s priorities and requirements in three areas: workplace behaviors, advanced technical skills, and regulatory knowledge” (Welsh, 2017, p. 4). Talent Solutions Coalitions shares this information with education institutions that are using this link with industry to “develop new modularized content to enhance existing offerings” (Welsh, 2017).

FAR Part 65 subparts D and E.

In the article *Aircraft Maintenance Technology*, (Sparks, 2007) the fact that the FAA does not recognize or certify avionics technicians provides the basis for exploration of the European Aviation Safety Agency’s (EASA) avionics rating and the FAA’s Part 65.81(b) technicians requirement for understanding systems (Sparks, 2007). EASA is the European equivalent of the FAA and has different methods for rating and certifying aircraft technicians from those of the FAA. The FAA with its complex legalese may seem to contradict itself in some of its many publications. Sparks also supplies his own experienced opinion on several of the knowledge requirements of the avionics technician

when working with today's modern aircraft. Sparks acknowledges there are many different roles for avionics technicians such as bench technicians, systems installer, and flight line maintenance and the requirements for each may be different, but they all share in several basic needs (Sparks, 2007).

EASA Part 66 includes two areas describing the *Privilege of Return to Service* that relate to avionics technicians (Sparks, 2007). The category B1 and B2 aircraft maintenance license available through EASA recognize and give license to avionics technicians.

Category B1 aircraft maintenance license shall permit the holder to issue certificates of release to service following maintenance, including aircraft structure, powerplant, and mechanical and electrical systems. Replacement of avionic line replaceable units, requiring simple tests to prove their serviceability, shall also be included.

Category B2 aircraft maintenance license shall permit the holder to issue certificates of release to service following maintenance on avionic and electrical systems. (Sparks, 2007, para. 4-5)

Sparks relates the FAA Part 65.81 general privileges and limitations sections (a) and (b) to illustrate the FAA's requirements for technicians to have experience with and understanding of all systems an A&P certified mechanic is to work with (Sparks, 2007). Section (b) explicitly states "A certificated mechanic may not exercise the privileges of his certificate and rating unless he understands the current instructions of the manufacturer, and the maintenance manuals, for the specific operation concerned" (Sparks, 2007, para. 10). Many of today's modern aircraft incorporate sophisticated

electronics monitoring systems for basic airframe and powerplant systems, systems which A&P mechanics may not have been trained on under Part 147 requirements.

According to Sparks a key element to the ability to troubleshooting any system is a through knowledge of the system operation and the components involved (Sparks, 2007). Finding and resolving complex system problems is an important part of the avionics technician's skill set (Sparks, 2007). Familiarity with the tools of the trade is also essential to successful avionics technicians (Sparks, 2007). The article mentions voltmeters, O scopes, and proprietary pin insertion and extraction tools as well (Sparks, 2007). Sparks includes in his avionics technician knowledge base the need to understand; resistance, capacitance, and inductance, along with transistors and microprocessors and an understanding of binary counting systems (Sparks, 2007). Sparks acknowledges and salutes the efforts of NCATT to establish a certification and curriculum for avionics technicians (Sparks, 2007). The NCATT aircraft electronics technician certification has gained recognition as a means of determining a job applicant's base level of understanding but has not been given any legal status.

The View from Washington a monthly column in *Avionics News* magazine is written by Ric Peri the Vice President of Government and Industry Affairs for the Aircraft Electronics Association. In the recent column titled; Maintenance Technicians Training Standards, Peri addresses the issue of the FAA control of Part 147 schools curriculum standards. The article also addresses the question of performance based technician training and the issue of an avionics technician certification (Peri, August 2018).

Peri's article highlights the FAA's two "categories of technicians: a mechanic and a repairman" which may be certified under current regulations (Peri, August 2018, p. 11). The article's examination of 14 CFR Part 65: Subpart D and Subpart E reveal each is a description of the performance requirements of those seeking the mechanic (Subpart D) certificate or the repairman (Subpart E) certificate (Peri, August 2018).

The FAA has specific requirements for the A&P mechanics regarding knowledge, skills, and experience of those seeking certification. These regulations can be found in Part 65 - certification: airmen other than flight crewmembers subpart D (Electronic Code of Federal Regulations, Part 65, Subpart D, 2016). In the experience requirement § 65.77, the minimum experience level required in order to apply for the mechanic certificate can be found (Electronic Code of Federal Regulations, Part 65, Subpart D, 2016). In the knowledge requirement § 65.75 the requirement to pass a written test covering the construction and maintenance of aircraft and the applicable regulations in § 65, § 91, and § 43 may be found (Electronic Code of Federal Regulations, Part 65, Subpart D, 2016). The written exam must be passed before being eligible to take the oral and practical tests required by the skill requirement § 65.79 (Electronic Code of Federal Regulations, Part 65, Subpart D, 2016). Peri points out that this "is a performance standard for the aviation mechanic" (Peri, August 2018, p. 11). Peri believes that the "discussions surrounding training and qualification of technicians" is in part the fault of the control over curriculum given to the FAA in the regulations (Peri, August 2018, p. 11).

In the article, Peri points out how the FAA regulation on Part 147 schools discourages exceeding the minimum levels of knowledge and skill specified in the curriculum (Peri, August 2018). Peri cites § 147.38 (a) where it states a certificated

school “shall adhere to its approved curriculum” and § 147.38 (b) which states a school “may not change its approved curriculum unless approved in advance” (Peri, August 2018, p. 45). These rules discourage schools from increasing standards or changing curriculum to include new technology (Peri, August 2018). The article states that the FAA will be submitting Part 147 for supplemental rulemaking later this year and Peri insist changes to Part 147.38 must be sought to end the FAA’s micromanagement of the curriculum (Peri, August 2018).

In 14 CFR Part 65: Subpart E the eligibility requirements for the repairman certificate can be found (Electronic Code of Federal regulations, Part 65, Subpart E, 2018). The repairman certificate is used to cover all non- A&P certified aircraft technicians including avionics technicians (Peri, August 2018). Under § 65.101, to be eligible for a repairman certificate, a person must:

- (2) Be specially qualified to perform the maintenance on-aircraft or components thereof, appropriate to the job for which he is employed;
- (3) Be employed for a specific job requiring those special qualifications by a certificated repair station, or by a certificated commercial operator or certificated air carrier, that is required by its operating certificate or approved operations specifications to provide a continuous airworthiness maintenance program according to its maintenance manuals; and
- (4) Be recommended for certification by his employer, to the satisfaction of the Administrator, as able to satisfactorily maintain aircraft or components,

appropriate to the job for which he is employed; (Electronic Code of Federal Regulations, Part 65, Subpart E, 2016).

Peri states in the article that this is clearly performance standards for the repairmen certificate (Peri, August 2018).

The repairman certificate which most avionics technicians work under is only valid while working for the company that submitted it as per the regulation (Electronic Code of Federal Regulations, Part 65, Subpart E, 2016). It is not issued directly to the technician but through the employer. The regulation stated requirement for the repairman certificate is experience or education. The experience portion of the requirement specifies 18 months experience in all aspects of the specific job or, in the training requirement, have completed formal training that is specifically designed to qualify the applicant and that is acceptable to the administrator (Electronic Code of Federal Regulations, Part 65, Subpart E, 2016). Peri states that, “the Aircraft Electronics Association will be petitioning the FAA later this year for acceptance of the NCATT certification as an acceptable means of compliance to 14 CFR 65.101” (Peri, 2018, p. 45). This would provide an avionics certification that would be portable from one employer to the next but not independent of a certified repair facility.

National Center for Aerospace and Transportation Technologies.

The National Center for Aerospace and Transportation Technologies, more commonly known as NCATT (pronounced N-cat) was established through a grant from the National Science Foundation and began working with industry in 1999 to establish an aircraft electronics technician certification (Brewster, 2008). The NCATT mission was

“to provide a forum through which subject matter experts from industry, government, and education develop technical knowledge and skill standards” (Brewster, 2008, p. 24). The first NCATT aircraft electronics technician certification was issued in 2006 (Brewster, 2008).

NCATT in cooperation with industry professionals has developed an Aircraft Electronics Technician (AET) certification program (National Center for Aerospace & Transportation Technologies, 2014). Certification is achieved through written test. The AET certification covers the technical knowledge required for aircraft electronics technicians and the knowledge required to work safely in aviation environments. NCATT has developed four endorsement certifications for specific aircraft systems technologies to compliment the AET base certification (Credential Testing Services, 2018). Those endorsements are onboard communications and safety systems, radio communication systems, autonomous navigation systems, and dependent navigation systems (Credential Testing Services, 2018). NCATT also has certifications for foreign object elimination, aerospace aircraft assembly, and unmanned aircraft systems maintenance (Credential Testing Services, 2018). The AET certifications, with the help of the Aircraft Electronics Association and the many education partners of NCATT, have become much more widely accepted as a valuable means of judging the knowledge level of job applicants. A series of textbooks have been written around the standards and the formats used by NCATT (Inman, 2012). The NCATT standards and formats for determining the level of knowledge and skills were instrumental in the design of the survey in this study.

Publications

Avionics textbooks.

Avionics textbooks were utilized in this study to evaluate the common curriculum available in the training of avionics technicians. By regulation, aircraft operating under instrument flight rules must have “two-way radio communications” (Electronic Code of Federal Regulations, Part 91. 2018). Required communications systems and additional communication systems such as HF transceivers, intercom and interphone, and satellite communications can be found in most avionics textbooks. These books also include the common navigation systems of VOR, localizer, glideslope, and marker beacon and common pulse systems such as transponders, radar and TCAS. The newer textbooks such as *Principles of Avionics* by A. Helfrick (2015) include more recent advanced systems such as inflight entertainment, augmented GPS systems and ADS-B.

Finding textbooks with the right balance between basic fundamental knowledge and an engineering level understanding is difficult for educational facilities. The level of information and the level of application of information students are exposed to will affect the type of employment graduates are prepared for. Installers may only need a basic understanding of the operation of a system and vast knowledge about wire, connector applications, and aircraft structures. A bench technician may need a more detailed knowledge of components, circuits, and test equipment and little knowledge of structure and wire.

Most publishers of aviation texts have complete series available based on the curriculum outlined in Part 147. Jeppesen is a leading supplier of navigation charts and database information and has a series of texts for the Part 147 schools. One of those

books, *A & P Technician Airframe Textbook* (Jeppesen, Sanderson, 2009) was used in this study to evaluate the airframe topics which are relevant to avionics training programs. The FAA also publishes handbooks for those studying for the A&P certifications. *The Aviation Maintenance Technician Handbook: General 2008* (Federal Aviation Administration, 2008) was used in the preparation of the survey in this study. These Part 147 textbooks and the FAA handbooks can be a valuable resource in teaching aviation concepts needed by avionics technicians.

When it comes to avionics textbooks the choices are more limited. The older aviation technology series by Glencoe/McGraw-Hill publishing included *Aircraft Electricity & Electronics* (Eismin, 1995) which provides excellent descriptions of basic systems theory and operation but provides no current or new systems information. *Aircraft Instrument and Avionics* (Henderson, 1993) is similar in that it provides excellent information on most systems considered basic today but were advanced at the time of publication. These older books tend to have single line illustrations and no workbooks. A more recent text, *Avionics Training: Systems Installation and Troubleshooting* (Buckwalter, 2010) is an excellent textbook for avionics systems training. It has helpful full color images and addresses all of the advanced systems available at the time of publishing (Buckwalter, 2010). This text also has a section with several chapters dedicated to installations such as planning the installation, avionics mounting, connectors, and wiring (Buckwalter, 2010). One of the newer textbooks, *Principles of Avionics* by Helfrick (2015) covers most of the latest systems. This text provides accurate information and the most complete coverage of basic and advanced avionics systems (Helfrick, 2015). The text is designed for use in basic avionics programs

and full blown engineering programs (Helfrick, 2015). It is filled with engineering level descriptions and formulas not typically needed by most technicians.

Avotek has an aircraft avionics series of textbooks which follow the NCATT AET certification standards with *Fundamentals of Aircraft Electronics: The Guide to Aviation Electronics Technician Certification* (Kenny, 2013) and the companion text in the series *Avionics: Beyond the AET* (Inman, 2012). *Avionics: Systems and Troubleshooting* (Eismin, 2011) is also in the series available from Avotek. These texts provide excellent information on operations and theory with decent images and have available workbooks. The major complaint with the Avotek series books is the technical mistakes. These books when first published were riddled with minor errors and occasionally larger mistakes. They seem to have improved with more recent editions. One of their best attributes is low cost. The entire set can be purchased for the cost of most single textbooks.

Industry publications.

Avionics News is a monthly news magazine for the avionics industry published by the Aircraft Electronics Association. The Aircraft Electronics Association (AEA) was founded in 1957 to serve the needs of the general aviation avionics community (Aircraft Electronics Association, 2018). Today the AEA represents nearly 1,300 member companies in more than 40 countries (Aircraft Electronics Association, 2018). According to their website “The AEA membership includes government-certified international repair stations, manufacturers of avionics equipment, instrument repair facilities, instrument manufacturers, airframe manufacturers, test equipment manufacturers, major

distributors, engineers and educational institutions.” (Aircraft Electronics Association, 2018).

Since its first issue was published in November 1963, *Avionics News* has been the industry’s source for regulatory updates, technical articles, business news, legislative issues, new products and technologies, professional development, careers and much more (Aircraft Electronics Association, 2018). The magazine features regular articles such as View from Washington, member profiles, and marketplace classifieds. Each year a special education issue is published which highlights educational institutions as well as education issues facing the industry. Another annual special issue is dedicated jobs and income reports.

Duncan Aviation is a business jet aircraft service provider with major service centers in Lincoln, Nebraska, Battle Creek, Michigan, and Provo, Utah. They have been operating since 1956 (Duncan, 2018). Duncan Aviation is a leading provider of all types of aircraft services for business jets including avionics sales and service. In the 1990’s, Duncan began publishing a series of books called *Straight Talk* (Duncan, 2018). These books educate customers and aviation professionals on systems, services, and industry changes. The clear straight forward language in these publications makes it easy to understand complex information and provide guidance for making informed decisions (Duncan, 2018).

Duncan Aviation provides several other free publications as well which are all aimed at informing and teaching customers and any other interested aviation professionals about the technologies, regulations, and possibilities in the world of

business aviation (Duncan Aviation, 2018). The secondary market nature of their business allows Duncan Aviation the freedom to sell and service many brands of equipment and work on many different types of aircraft. Not having restriction to one manufacturer or brand allows Duncan Aviation to openly discuss many equipment options. It is this open sales format and diversity of product and service that have led to these publications which inform and instruct. In this type of educational support Duncan Aviation seems to be unique. Visits to the websites of equipment manufacturers like Garmin and Avidyne reveal many training and instructional publications all naturally aimed at their own products.

CHAPTER III

METHODOLOGY

Knowledge, Skills, and Abilities are a means to describe the different learned information and talent that may be required to do a specific task or job. Often a job requires knowledge of a subject, the physical ability and technical skill to perform a given task. The Veterans Administration (VA) uses knowledge, skills and abilities as a means to more clearly identify specific job prerequisites. The VA gives the following definitions: (United States Veterans Administration, 2009)

- **Knowledge** - an organized body of information, usually factual or procedural in nature.
- **Skill** - the proficient manual, verbal, or mental manipulation of data or things.
- **Ability** - the power or capacity to perform an activity or task.

Together these three elements can describe all that is necessary to be competent at a specific job or task within an occupation description.

Methods used for Assessment of KSA's

Training programs for complex technical subjects require many different

elements of knowledge, skills, and abilities. Not every element must be understood to the same depth or level as other elements. The knowledge required to operate something can be different than the knowledge required to assemble, and different still, the knowledge required to repair it. In order to assess these different levels of understanding it will be necessary to use some type of system to rate each element. There are two different systems commonly used in aviation to assess levels of understanding; the Federal Aviation Regulations Part 147, Appendix A, levels of proficiency and the National Center for Aerospace and Transportation Technologies, Knowledge and Performance Level Chart.

The Federal Aviation Regulations attempt to create a clear understanding of the training requirement for airframe and power plant students by specifying levels or depth of understanding in the “airframe and power plant training center constraints” (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). The specific levels or depth of subject knowledge or skill provides a consistent means for training institutions and students to understand the minimum requirements of the training. The FARs refers to this as “levels of proficiency at which items under each subject in each curriculum must be taught” (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). The FARs describes:

- Level 1 as requiring “knowledge of general principles, but no practical application” and requiring “no development of manipulative skill.”
- Level 2 requires “knowledge of general principles,” and “limited practical application” with “development of sufficient manipulative skill to perform basic operations.”

- Level 3 requires “knowledge of general principles,” and “performance of a high degree of practical application including development of sufficient manipulative skills to simulate return to service” (Electronic Code of Federal regulations, Part 147, Appendix A, para b, 2016).

The FAR levels of proficiency are part of education requirements for airframe and powerplant technician certification training. The Federal Aviation Regulations do not specify training or certification requirements specifically for avionics technicians.

The National Center for Aerospace & Transportation Technologies (NCATT), part of ASTM International recognized worldwide for industrial standards, has established a detailed set of aircraft electronics technician (AET) certification tests (ASTM International, 2016). NCATT AET certifications define levels of proficiency using four levels of task performance, four levels of task knowledge, and four levels of subject knowledge (National Center for Aerospace & Transportation Technologies, 2014). The NCATT format offers more levels of definition for subject knowledge, task knowledge, and skill performance than the FAA levels of proficiency used to describe curriculum in aircraft maintenance training requirements. The increased levels better define the degrees of understanding required in complex aircraft electronics and systems training.

This study used a single survey questionnaire. The KSA section of the questionnaire is divided into several categories according to different areas of study for aircraft electronics technicians. The survey utilizes a level of proficiency format derived from and similar to the NCATT AET certification. The questionnaire was tested on a small group of 5 to 10 avionics shop managers and technicians in general and commercial

aviation and component manufacturing to examine its validity and ease of use. The researcher conducted this research study in accordance with the Oklahoma State University Institutional Review Board (IRB) requirements and obtained IRB approval before collecting data (Appendix A).

Distribution of the Survey

The Aircraft Electronics Association (AEA) is an aviation industry trade organization with more than 1,200 members in 41 countries (Aircraft Electronics Association, 2018). AEA membership is comprised of many aircraft electronics and instrument shops dedicated to the maintenance, repair and installation of avionics and electronics systems. The AEA membership roster includes manufacturers of aircraft, of avionics equipment and aircraft instruments also test equipment manufacturers, parts distributors, and educational institutions (Aircraft Electronics Association, 2018). Most of the segments of the aviation industry were represented at the 2017 national conference. The attendees to the conference included the managers and the most experienced technicians from across the aircraft electronics industry seeking training and knowledge about the latest equipment and industry news.

The survey was introduced at the 2017 National Aircraft Electronics Association convention. A stand at the convention allowed attendees to pick up cards with information to access the survey site from their own devices within 30 days. Additionally, e-mail invitations were sent to a mailing list of the AEA organization members provided by the AEA and to commercial airline shops and aircraft manufacturers. In order to allow ample time to complete the detailed list of knowledge,

skills, and abilities and to facilitate the greatest number of responses ; the questionnaire remained open from March 4 to May 25, 2017. The total number of participants was determined after the questionnaire had been closed.

Participant Population and Sample

The Federal Aviation Administration website indicates approximately 1,500 registered repair stations which have some type of radio repair qualification (Federal Aviation Administration, 2015). The 1,500 identified shops could have any number of technicians employed. This information does not provide enough data to determine an adequate population measurement.

The Bureau of Labor Statistics (BLS) website reports an estimated 17,340 individuals employed in the job designated as avionics technician as of May of 2015 (US Department of Labor, 2017). The BLS indicates 5290 avionics technicians were employed by aerospace product and parts manufacturers while 5240 were employed by support activities for air transportation (US Department of Labor, 2017). An unknown quantity of these technicians will have less than the minimum experience required to meet the criteria for participation in this study. Not all 17,340 avionics technicians listed by the BLS would be eligible as participants in this study. No definite information is available on total number of avionics technicians and their experience levels. Research has not revealed any clear determination of the actual total population that would qualify as participants in this study.

According to Gay and Airasian (2003), for a qualitative research study the sample size may be much smaller than that required for quantitative research. The in-depth

nature of qualitative inquiry can limit willingness of qualified individuals to become participants (Gay & Airasian, 2003). In purposive sampling, the researcher hand picks participants that have the needed qualities of subject knowledge and topic understanding (Gay & Airasian, 2003).

Gay and Airasian (2003) also identify convenience sampling as a means of sample selection. Convenience sampling indicates the selection of participants based on availability or more precisely group availability (Gay & Airasian 2003). This study uses a combination of both of these methods. The researcher in this study has set limits on participants to only those actively working as technicians or actively supervising technicians suggesting a purposive sampling process. The researcher is also took advantage of the large gathering of qualified individuals at the AEA national conference suggesting a convenience sampling process. In addition to the convention participants there was a direct email campaign to solicit participants from commercial airlines and other shops.

Analysis of the Data

The data gathered was analyzed for indicators of the major demographic divisions to determine the industry segments represented. Demographic questions in the work center / shop demographic section of the survey identified the size of the organizations, the type of aircraft, and the type of equipment to help in determining the divisions of the industry segments. Further definition of the industry segments was gained from the type and level of services performed by the organizations. The data from the work center / shop demographic section of the survey was analyzed for commonalities, differences, and

averages to identify the industry segments. Outliers were identified. Using the KSA section of the survey, charts were compiled of the KSA's sorted by industry segment for comparisons. Separate analysis identified demographic specific KSA's. The data was further analyzed to identify any relationships between KSA's and specific demographic data. Information was presented in chart format to more clearly display the findings.

The Qualtrics software used to create and administer the survey has built-in analysis tools. These tools allow for collective and selective statistical analysis of the data. Statistical analysis was conducted to analyze and validate the data. Descriptive statistics were used to analyze the data (Gay & Airasian, 2003). Measures of variability and relative position of the work center / shop demographic section of the survey helped determine demographic separation of industry segments (Gay & Airasian, 2003). Measures of central tendency were used to provide averages of KSA responses or responses within groups while measures of relationships were used to correlate KSA responses to the demographic groups (Gay & Airasian, 2003). Analysis of the KSA section of the survey using measures of relative position helped determine commonalities and distinctions among participant views. Overall analysis is presented in chart form and a detailed report of the findings is presented in chapter four outlining the interpretations of the relationships indicated by the data.

Access to the Survey

The questionnaire was created in a secure internet-based survey site and an access link was given to the participants through personal contact, email or business cards. The opening pages of the survey contain a consent information sheet which had to be

completed in order to gain access to the survey questions. All participants accessed the questionnaire and entered responses via the internet site.

As part of the opening pages of the survey a participant qualification question was required to be answered. The qualification question required all participants to be currently working as an avionics technician in aircraft electronics or in a supervisory role overseeing avionics technicians. Surveys by participants not meeting these minimums were not allowed to continue to the survey. The participant demographics include large and small shops in general and commercial aviation. There was only one participant from the manufacturing segments.

Survey Content

The questionnaire included demographic questions to identify the type and size of the work center or shop and the segment of the industry it is associated with. The KSA section of the questionnaire contains extensive lists of aircraft systems, tools, and equipment, and other knowledge areas relative to working in the avionics industry. The survey has questions on continuing education and training methods used for existing technicians. One section of the questionnaire ask about the current and future effects of the FAA's mandate on ADS-B as related to technician KSA's, training, and manpower requirements.

The participants marked selections in columns representing subject knowledge, task knowledge, and task performance. Participants used an alpha numeric scale to indicate to what proficiency the knowledge, skills, and abilities are used. Each selection in these columns represents a specific level of subject knowledge, task knowledge, or

task performance. The system and the wording of choices is derived from the widely recognized and accepted National Center for Aerospace and Transportation Technologies knowledge and performance level chart, referred to as the NCATT format (see Methods Used for Assessment of KSA's above). Participants were also given an "N/A" option to indicate if a KSA is not applicable to or not used in their environment.

Survey Instrument Development

Basic assumptions.

Employers hiring aircraft electronics technicians will expect a minimum level of training in what is known in the industry as basic electricity and electronics. The focus of this study is to identify the knowledge skills and abilities needed in the aviation industry to effectively install, repair, and troubleshoot modern avionics systems. The need for basic electricity and electronics training will be addressed only in a small group of questions with emphasis in identifying new areas of study that may be needed or older areas of study that are no longer needed.

The requirement of aircraft electronics technicians to know and understand basic aircraft related systems such as communications and navigation can be assumed. The question that needs to be answered is; to what level these communications and navigation systems should be understood. A group of questions deals with the depth of understanding of common aircraft electronics systems and the more modern adaptations of those systems.

The term, technician, may have varied meanings in different environments. Hiring an individual to a position titled technician it may be assumed that the basic use of hand

tools is a minimal requirement. The highly varied segments of the aviation industry may have highly varied definitions of a technician. The knowledge of various types of hand and power tools and the skill levels needed with those tools is an important aspect of technician training. The survey has a section on hand and power tools knowledge, skill, and ability levels.

A basic assumption about electronics technicians should be the ability to use and understand instruments to measure electrical and electronic values such as voltage, resistance, current, and power. There are many test instruments associated with electronics in general and aircraft electronics specifically. The survey has questions aimed at determining the knowledge, skill, and ability levels required for electronic and avionics systems test equipment.

Advanced avionics systems.

Most modern aircraft have some form of advanced display systems. The level of understanding associated with these systems directly correlates with this studies primary research questions. A series of questions are designed probe for knowledge, skill, and ability levels of these types of systems and their theory and operation.

Many modern aircraft electronic systems employ advanced types of sensors and various means of communicating data across digital busses including the use of fiber optics. The depth and extent of knowledge about these modern sensing devices and data transmission options is the focus of several questions.

Utilizing high speed data transfer and advanced sensor design even smaller private aircraft may now have advanced flight planning and flight management systems.

The survey will need to explore the knowledge of these types of systems and the depth to which the theory and operation should be understood by the technicians. Questions have been added which explore advanced flight planning and flight management systems requirements.

New expectations in flight.

The expanding use of the internet for business and pleasure has given rise to the demand for internet connectivity anytime and anywhere. Internet connectivity from the air now has many possibilities, both ground based and satellite based. Several access plans and the equipment required by them are now available and within the reach of many aircraft owners. Cabin management systems, inflight entertainment, and internet connectivity are now a part of many avionics shops lists of available systems for installation, repair, or support. The survey provides questions concerning the knowledge and skill levels needed to handle this relatively new demand.

In the aircraft, electronic systems have the ability to monitor every aspect of a flight including monitoring engine performance and airframe configurations. The installation and configuration of these systems may require some basic and some extensive knowledge of engines and airframes not normally found in avionics training. The survey asks questions to determine the depth of knowledge and the skills in airframe and powerplant that may be required of the aircraft electronics technician.

FAA general curriculum subjects.

The FAA curriculum requirements for the training of airframe and powerplant technicians require that both programs must study material and pass tests relating to what

are known as the generals. Many avionics training programs include some or all of the elements of the generals' curriculum. The curriculum for the generals includes many elements that are part of the everyday life of all aircraft technicians. Some of these elements may or may not apply to aircraft electronics technicians. This study seeks to identify the KSA's required of aircraft electronics technicians and includes a section of questions covering the elements of the FAA general curriculum subjects.

CHAPTER IV

FINDINGS

The survey recorded results from March 4 through May 25 2017. The survey was first opened at the 2017 Aircraft Electronics Association conference in New Orleans. The conference had more than 1,500 attendees. More than 250 survey invitations were handed out. The survey was also sent to more than 500 email addresses of prospective participants. The survey was left open for more than two months to allow all parties the opportunity to participate. The when it was closed the survey had 87 responses listed.

Closer examination revealed five occasions where the surveys had been opened and closed without recording any responses. These responses were deleted from the data set leaving 82 responses. The remaining 82 responses included one which answered yes to the consent and provided no other responses, and one which answered yes to the consent and provided an answer to the experience qualifying question without providing any other responses. One additional response answered no to the consent sheet question and five additional responses answered no to the qualifying experience question. These no responses immediately resulted in a closing statement being presented which thanked the participant for their input, effectively ending the survey for those individuals. There are 74 participants that include answers beyond the consent and qualifier questions and of

those, 63 completed the surveys. Data from the 11 incomplete responses will be included in the analysis of the results.

Industry Sector

Survey participants were required to make a selection between three industry sectors; 1) commercial and regional airlines, 2) general and business aviation, or 3) manufacturing. The design of the survey separates the industry into these three

distinct segments to allow analysis of the knowledge, skills, and abilities by industry sector. Upon examination of the data, it was noted only one participant or 1.4% of the total participants identified as being from the manufacturing sector. The data from the one manufacturing participant will be summarized and presented separately from the other two business sectors. The 74 sets of responses included 26 (35.1%) from commercial or regional airlines sector and 47 (63.5%) from general and business aviation sector.

Airframe and Powerplant Certificate Requirement

One of the fundamental questions this survey addresses is the requirement for an FAA airframe or airframe and powerplant certificate for avionics technicians. The survey question on the requirement for a FAA airframe & powerplant certificate had 74 participant responses. Commercial and regional airlines sector had 26 responses, eight (30.8%) of which included work on-aircraft and only five of 26 (19.2%) requiring the FAA Airframe & Powerplant certificate for avionics technicians. However, these five represent 62.5% of participants working on-aircraft in the commercial and regional airlines sector. General and business aviation had 47 responses with 44 (93.6%) who work on-aircraft and only eight (18.2%) of the 44 requiring the FAA certificate. These eight responses represent 17% of the 47 total participants in general and business aviation sector. The data showed no occurrences of technicians who do not work on-aircraft being required to have an airframe and powerplant certificate.

Figure 1 shows a comparison of the percentage of participants working on-aircraft in each sector to the percentage of participants working on-aircraft in each sector that are required to have an FAA airframe or powerplant certificate. Figure 1 gives a visual

representation of the imbalance in these two data sets. The commercial and regional airlines sector has a smaller percentage of avionics technicians working on-aircraft and has a greater percentage of avionics technicians required to have an FAA certificate. The general and business aviation sector has a greater percentage of avionics technicians working on-aircraft and has a lower percentage of avionics technicians required to have an FAA certificate.

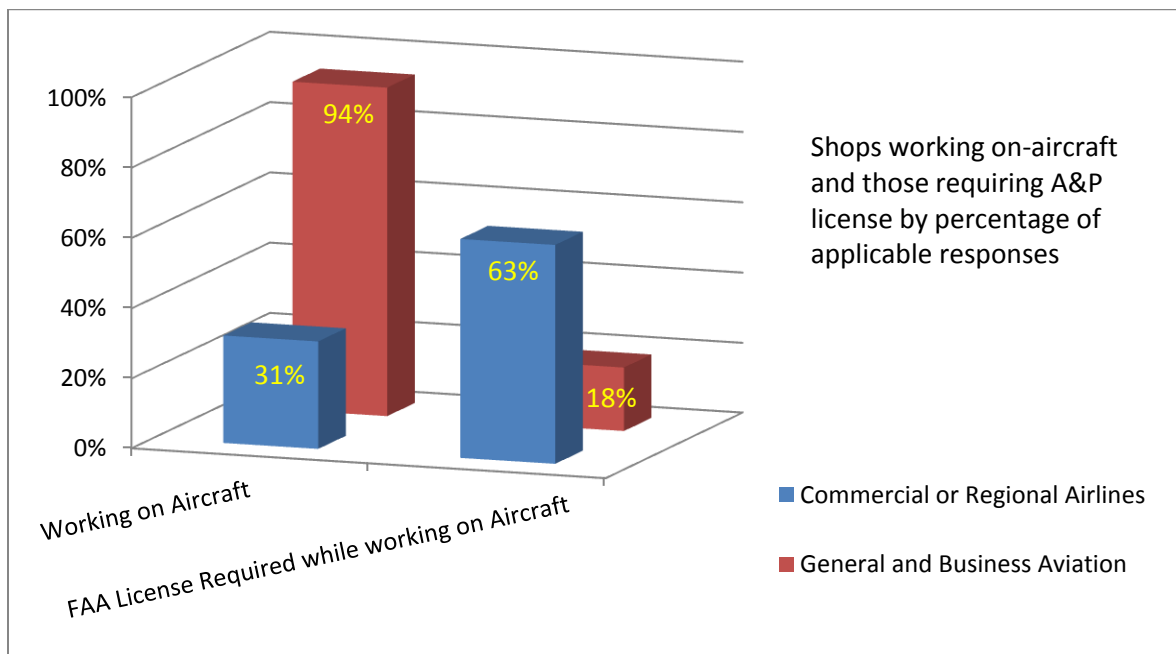


Figure 1. Shops working on-aircraft compared to those requiring an A & P license.

Services Provided in Avionics Shops

The services provided by each shop were divided into two main areas in the survey; services on-aircraft and services on line replaceable units or LRU’s. In the on-aircraft area, the distinction was also made between avionics installations and avionics troubleshooting and repair. The LRU areas had distinctions made the between modular

troubleshooting and repair, component level troubleshooting and repair, and overhaul level troubleshooting and repair.

Regulatory restrictions which further divide on-aircraft activities led to the inclusion of and distinction between two other ranges of services; instrument inspection and repair, also airframe and powerplant inspection and repair. In order to repair items classified as instruments a special repair station certification with an instrument rating is required. Airframe and powerplant inspections and repairs require an airframe or powerplant license to do most of the work and sign the return to service documentation.

Commercial and regional airlines.

The survey data indicated the commercial and regional airlines sector with 26 total participants, seven (26.9%) included avionics installation and eight (30.8%) included avionics troubleshooting and repair as services provided in their shop. In the LRU troubleshooting and repair questions, 23 (88.5%) participants said their shop repaired equipment to the modular level, 22 (84.6%) repaired to the component level and 18 (69.2%) repaired to the overhaul level. Instrument inspections were selected by 17 (65.4%) participants in commercial and regional airlines sector with instrument repair selected by 14 (53.8%). Airframe inspection and repair was selected by six (23.1%) participants while the powerplant inspection and repair was selected by five (19.2%).

General and business aviation.

The survey data showed 47 participants from the general & business aviation sector, of those 43 (91.5%) had avionics installation services and 44 (93.6%) had avionics troubleshooting and repair services provided in their shops. In the LRU troubleshooting

and repair questions 28 (59.6%) participants said their shop repaired to the modular level, 23 (48.9%) repaired to the component level and 13 (27.7%) provided overhaul level services. Instrument inspection services were selected by 40 (85.1%) participants and instrument repair services by 14 (29.8%). Airframe inspection and repair services were selected by 23 (48.9%) participants and powerplant inspection and repair services were selected by 19 (40.4%) participants. Figure 2 illustrates the percentage of shops offering each of these services as related to the total number of participants from each sector.

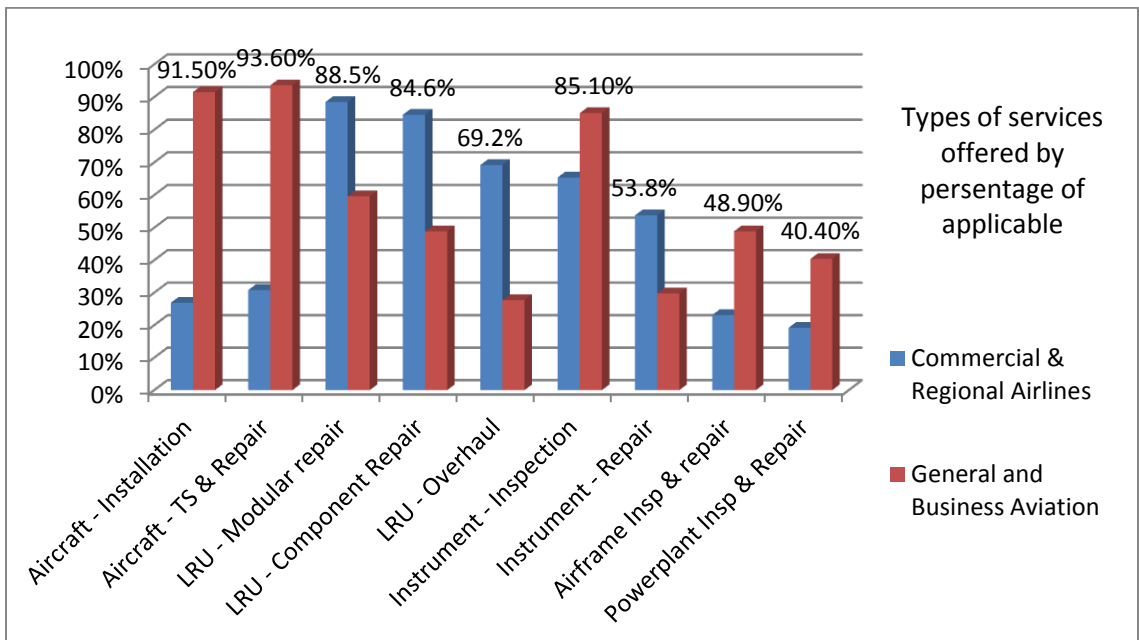


Figure 2. The type of services offered in each sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated no A&P license requirement. Services offered that were selected by this individual included work on-aircraft, avionics installation, avionics troubleshooting and repair services.

Training Requirements

Initial training source.

One of the primary goals of this study was to identify the methods used to deliver technical training to the technicians working on today's modern aircraft. Participants were asked to identify the means they had used to receive previous and current technical training. The first of these questions sought to identify the method used to receive their initial technical training. The question asked participants what was the primary means used to receive their initial training. The options given were military, technical college or training center, public school system, on-the-job training, on-line program, or self study. The second question concerning sources of training focused on the main type of training used to receive new technical information. The options given were on-the-job training, self-study, technical college or training center, technical representatives, and webinars.

Commercial and regional airlines.

The data from the commercial and regional airlines sector indicated 26 responses. The majority of those responses, 13 (50%) attended a technical college or training center for their initial technical training. The data from the 26 responses indicated eight (30.8%) of the participants received their initial training from the military and five (19.2 %) had on-the-job training for their initial training. The data also indicated the overwhelming majority, 21 (80.8%) utilize on-the-job training to receive new technical training. The other six responses were divided with one (3.8%) each in self study, seminars or guest speakers, and webinars. The remaining two (7.7%) participants used technical college or training centers for new technical training.

General and business aviation.

Data from the general and business aviation sector had 47 responses. The majority of those participants, 21 (44.7%) received their initial training at a technical college or technical training center. The next highest percentage of participants 16 (34%) had received their initial technical training from the military. The remaining participants were divided among three areas, with eight (17%) having had on-the-job training and one (2.1%) utilizing self study. A single participant (2.1%) had received their initial technical training from the public school system.

Type of training used for new technical training.

Both sectors overwhelmingly selected on-the-job training as the main type of training used to receive new technical training. The commercial sector had 21 (80.8%) of the 26 participants select on-the-job training, with only two (7.7%) selecting technical college or training center and one each (3.9% each) selecting self-study, seminars or guest speakers, and webinars as the means to receive new technical training. The general and business aviation sector had 31 (66%) of the 47 participants select on-the-job training, with only eight (17%) selecting technical college or training center and three (6.4%) selecting seminars or guest speakers, two each (4.3% each) selecting self-study and webinars, and one (2.1%) selecting technical representatives as the means to receive new technical training.

Electronics advances and new training requirements, types of learning, methods of training.

Commercial and regional airlines.

The data from the commercial and regional airlines sector indicated 20 of the 26 responses selected yes, a decade of advances has generated a need for additional training. The option no was selected by three (11.5%) of the respondents and the remaining three (11.5%) selected unknown. When asked what type of training was required, 10 (50%) of the 20 participants selected all three; learning new subjects, new tasks, and new skills. Only two (10%) participants selected new subjects and new tasks, while one (5%) participant selected new subjects and new skills as the type of training required. New tasks and new skills were selected two times by participants. Single selections were made including two selections for new subjects, two selections for new tasks, and one selection for new skills. A total of 15 selections were made indicating requirements for learning new subjects, 16 selections indicating a requirement for learning new tasks, and 14 selections indicating a requirement for learning new skills.

The participants responding yes, a decade of advances has generated a need for additional training were also asked to identify the primary method used to receive the additional training. This question included the options: on-the-job-training, self-study, technical college or training center, seminars or guest speakers, technical representatives, or webinars. The question design did not restrict the number of responses from each participant.

The responses of the 20 participants from the commercial sector indicated eight (40%) participants selected on-the-job-training only. The data also indicated two (10%) participants selected self-study only, while two (10%) participants selected webinars only

and one (5%) participant selected seminars or guest speaker only as their primary means of training. The data showed seven (35%) participants selecting on-the-job-training and additional selections resulting in three (15%) technical college or training center selections, and three (15%) technical representative selections, three (15%) self study selections and one (5%) seminars and guest speaker selection.

General and business aviation.

Data from the general and business aviation sector indicated a total of 47 responses with all but three (6.4%) answering, yes, a decade of advances has generated a need for additional training. Unknown was selected by the two (4.3%) participants not answering yes, and no was selected by one participant. Data indicates 26 (59.1%) of the 44 remaining participants selected all three types of learning were required; learning new subjects, new tasks, and new skills. There were five (11.4%) responses including only two types of learning. These included one (2.3%) selection for new subject and new tasks, four (9.1%) selections for new subject and new skills, and new tasks and new skills had two (4.5%) selections. Selections made including only one of the options were as follows; new subject five (11.4%), new tasks one (2.3%), and new skills had three (6.8%) selections.

General and Business Aviation participants, indicating the need for additional training were also asked to identify the primary method used to receive the additional training. The 47 responses from the general and business aviation sector indicated 17 (36.2%) participants selected on-the-job-training only. The data also indicated one (2.1%) participants selected self-study only, while six (12.8%) participants selected seminars or

guest speaker only as their primary means of training. Technical college and training center only was selected by five (10.6%) participants and technical representatives only were selected by three (6.4%) participants. The data showed 12 (25.5%) participants selecting on-the-job-training and additional selections. These multiple responses resulted in additional selections of three (6.4%) technical college or training center, eight (17%) technical representative, eight (17%) self study, six (12.8%) seminars and guest speaker, and eight (17%) webinar selections. Figure 3 demonstrates the similarities across the sectors in the types of training used for new technology advances over the last decade.

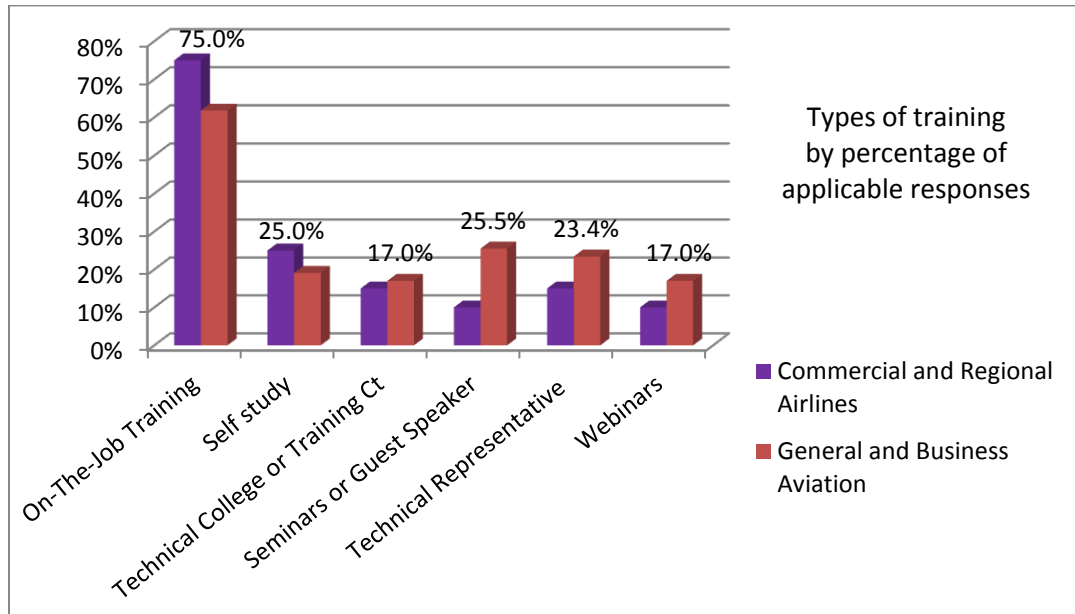


Figure 3. Types of training used for new technology advances over the last decade by sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated initial training was received through a technical college or training center. New

technical training was achieved through on-the-job training. The participant indicated advances in technology had required additional training in learning new subjects, skills, and tasks. This training had been accomplished mainly through technical representatives.

FAA 2020 Mandate for ADS-B

The FAA mandate to equip all aircraft with new ADS-B equipment by the year 2020 has affected many avionics shops across the industry. A series of questions were designed to determine the affects on shop work load, employee hiring, and new training required. The type of training used to meet this requirement was also questioned.

Commercial and regional airlines.

Participants were asked if the 2020 mandate for ADS-B had generated an increased workload in their shop. The 26 commercial and regional airlines sector participants responding to the question; indicated 15 (57.7%) responses as no additional workload at all. A total of 11 (43.3%) participants did see increases in workload with three (27.3%) responding as moderate increases and eight (72.7%) experiencing only a slight increase in workload. The 11 positive responses were further asked if this had generated a need for additional technicians. These responses had six (54.5%) of the 11 replied no, not at all. The five remaining had one (9.1%) participant indicate yes, moderately while the other four (36.4%) indicated yes, slightly.

The responses to the question concerning the need for additional training as a result of the 2020 ADS-B mandate, indicated 11(43.3%) of the 26 did require additional training and 15 (57.7%) that did not require additional training. The 11 responses requiring additional training had three (27.7%) select this as a moderate requirement and

eight (72.7%) responses selected this as a slight requirement. These 11 respondents requiring additional training were also asked if the training required learning new subjects, learning new tasks, or learning new skills. The responses indicated seven (63.6%) of the 11 respondents selected learning new subjects, new tasks, and new skills, while two (18.2%) responses indicated only learning new subjects was required and one (9.1%) response indicated only new subject and new skills were required. An additional response (9.1%) indicated learning only new skills and new tasks were required.

The participants requiring new training were also asked to identify the primary method used to receive the additional training. The options that were given include; on-the-job-training, self-study, technical college or training center, seminars or guest speakers, technical representatives, or webinars. The 11 responses from the commercial sector indicated nine (81.8%) had used on-the-job-training. The data from these 11 participants also indicated two (18.9%) had utilized self study while the remaining three (27.3%) had used webinars to receive the necessary training.

General and business aviation.

Participants were asked if the 2020 mandate for ADS-B had generated an increased workload in their shop. The 47 (100%) general and business aviation sector participants responding to the question all saw increases in their workload. There were 17 (36.2%) responding as excessive increases and 18 (38.3%) experiencing moderate increases with only 12 (25.5%) seeing a slight increase in workload. The 47 respondents were further asked if this had generated a need for additional technicians. In the responses seven (14.9%) replied no, not at all. The 40 (85.1%) remaining yes responses

had, 13 (32.5%) excessively, 18 (45%) indicated moderately while the other nine (22.5%) indicated only slightly increased workloads.

The General and Business Aviation sector participant responses to the question concerning the need for additional training as a result of the 2020 ADS-B mandate, indicated 44 of the 47 (93.6%) did require additional training. There were three (6.4%) of the respondents that selected no additional training was required. The 44 remaining responses had six (13.6%) indicating yes the mandate had generated an excessive need for additional training, while 20 (45.5%) of the participants selected yes, the mandate moderately increased the need for additional training. There were 18 (40.9%) other participants indicated yes, the mandate generated the need for a slight increase in additional training.

The participants that responded yes, additional training was required, were asked to identify the type of training needed. The choices given included; learning new subjects, new tasks, or new skills. Responding to this question, 13 (30.2%) of the 43 participants included learning new subjects, new tasks, and new skills, 10 (23.3%) of the responses indicated learning new subjects, and new tasks only, with two (4.7%) of the responses indicating learning new subjects, and new skills only. There were two (4.7%) other responses indicating learning new tasks, and new skills were required. The responses of 10 (23.3%) of individuals indicated only learning new subjects was required. There were five (11.6%) responses indicating only learning new tasks were required and one (02.3%) response indicated learning only new skills were required.

When asked to identify the primary method used to receive the additional training, the data from 43 participants in the general aviation sector indicated 29 (67.4%) had used on-the-job-training. The data indicated the group using self study included four (9.3%) participants. One response indicated the use of a technical college or training center, with three (7%) participants utilizing seminars or guest speakers to receive training. Technical representatives provided the needed training to the remaining six (14%) participants responding from the general aviation sector and no selections were made for the webinar method of training.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the 2020 mandate for ADS-B did increase work loads slightly. The participant indicated the mandate did not lead to additional technicians being hired. The participant selected yes, slightly, to the question concerning the mandate requiring additional training. The participant indicated this training was to learn new tasks and was accomplished using primarily on-the-job training methods.

Avionics Systems

Determining the knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry requires knowing what avionics systems the shops work on. Question blocks were divided as basic avionics and advanced avionics. Basic avionics included communications systems, dependent navigation systems, autonomous navigation systems, basic aircraft systems, and pulse systems. Each of these basic avionics categories were further divided into individual aircraft systems.

Advanced avionics systems were divided into categories representing modern advances in aircraft electronic systems. These electronics advances included two and three screen electronic flight instrument cockpit design, advanced multi-screen systems, modern data bus formats, fiber optic systems, micro-electro-mechanical-sensors (MEMS), airborne internet connectivity, engine performance analyzers, and fly-by-wire systems.

Basic avionics systems.

Communications systems.

Participants were asked to select each of the communications systems that are applicable to their shops. The choices provided included; VHF communications, HF communications, on-board communications, satellite communications, and in-flight entertainment. Participants were then asked to describe the knowledge and performance levels for technicians performing installation service or repair of each aircraft communications systems selected. Knowledge level was distinguished by selected one of four levels; basic facts and terms, operation and some theory, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data indicated 26 commercial and regional airlines sector participants responded with 12 (46%) selecting VHF communications, 10 (38.5%) selecting HF communications, 10 (38.5%) selecting on-board communications, 8 (30.8%) selecting satellite communications, 8 (30.8%) selecting in-flight entertainment, and 14 (53.8%) selecting communications equipment as not applicable to their shop.

The data indicated 46 general and business aviation sector participants responded with 44 (95.7%) VHF communications, 23 (50%) HF communications, 35 (76.1%) on-board communications, 23 (50%) satellite communications, 32 (69.6%) in-flight entertainment, and no participants selecting communications equipment as not applicable to their shop. Figure 4 provides a visual comparison of the two sectors percentage of participants responses indication the communication systems serviced by their shops.

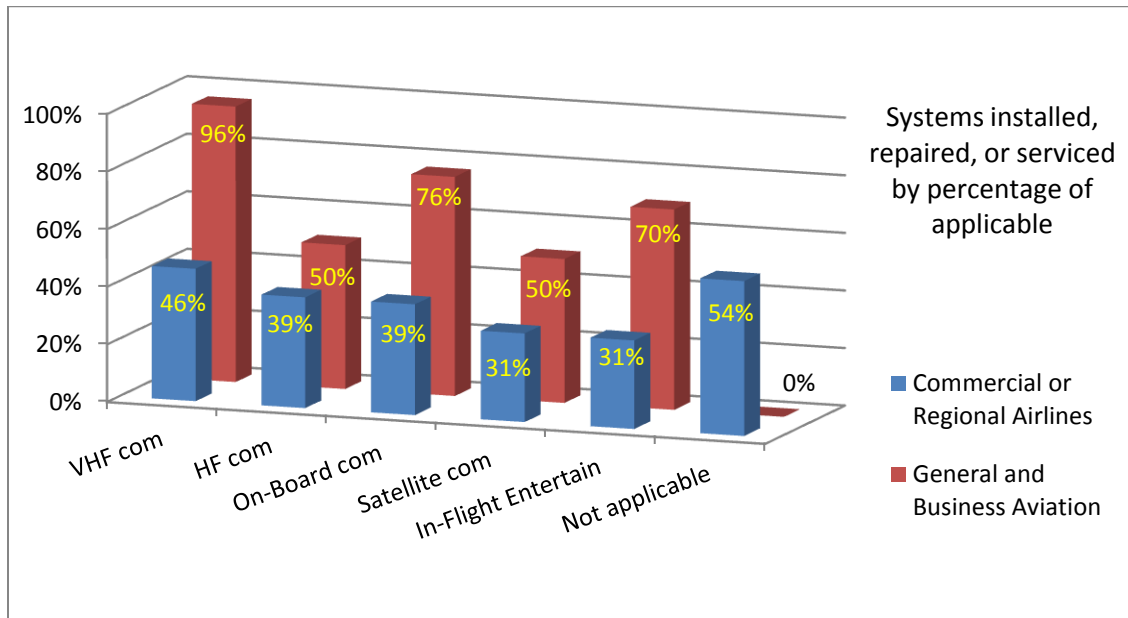


Figure 4. Communications systems installed, serviced, or repaired by sector.

Knowledge level commercial and regional airlines.

VHF communications systems knowledge level responses included: five (45.5%) with advanced theory and troubleshooting knowledge, two (18.2%) having theory and integration knowledge level, two (18.2%) with knowledge of operation and some theory, and two (18.2%) with only knowledge of basic facts and terms. One participant did not complete knowledge or performance level responses for this question or any further

questions. HF communications systems knowledge level responses included: four (36.4%) advanced theory and troubleshooting, three (27.3%) theory and integration, two (18.2%) operation and some theory, and no one selected basic facts and terms. On-board communications systems knowledge level responses included: four (36.4%) advanced theory and troubleshooting, two (18.2%) theory and integration, one (9.1%) operation and some theory, two (18.2%) basic facts and terms. Satellite communications systems knowledge level responses included: four (36.4%) advanced theory and troubleshooting, no one selected theory and integration, one (9.1%) operation and some theory, two (18.2%) basic facts and terms. In-flight entertainment systems knowledge level responses included: four (36.4%) advanced theory and troubleshooting, one (9.1%) theory and integration, no one selected operation and some theory, and two (18.2%) selected basic facts and terms.

Figure 5 provides a visual representation of responses on communications systems knowledge level requirements from the commercial and regional airlines sector. The visual representation of this data depicts a high concentration of advanced theory and troubleshooting knowledge responses across all of these communications systems. Another point exposed by the visual representation is the consistent level of responses for the basic facts and terms knowledge level selections.

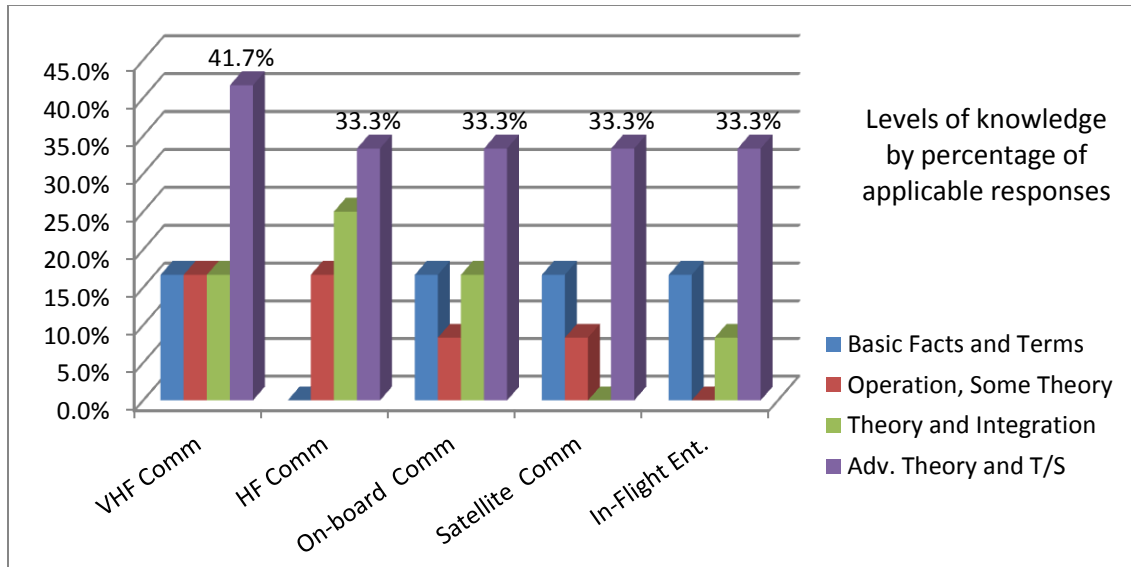


Figure 5. Communications systems knowledge levels from the commercial and regional airlines.

Performance level commercial and regional airlines.

VHF communications systems performance level responses included: four (36.4%) highly proficient, six (54.5%) competent, one (9.1%) partially proficient. HF communications performance systems level responses included: three (27.3%) highly proficient, four (36.4%) competent, two (18.2%) partially proficient. On-board communications systems performance level responses included: two (18.2%) highly proficient, five (45.5%) competent, two (18.2%) partially proficient. Satellite communications systems performance level responses included: two (18.2%) highly proficient, three (27.3%) competent, one (9.1%) partially proficient and one (9.1%) extremely limited. In-flight entertainment systems performance level responses included: two (18.2%) highly proficient, three (27.3%) competent, one (9.1%) partially proficient and one (9.1%) extremely limited.

Figure 6 provides a visual representation of responses on communications systems performance levels from the commercial and regional airlines sector. The visual representation of this data depicts a high concentration of competent performance level responses across all of the communications systems. The next most prevalent response is the highly proficient performance level.

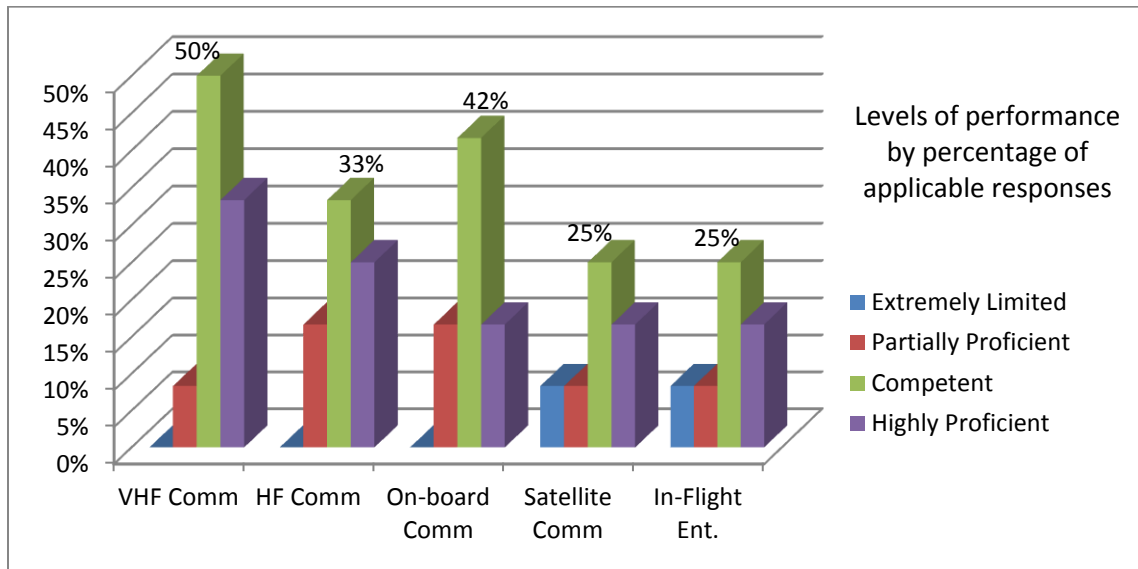


Figure 6. Communications systems performance levels from the commercial and regional airlines.

Knowledge level general and business aviation.

VHF communications systems knowledge level responses included: 15 (32.6%) advanced theory and troubleshooting, eight (17.4%) theory and integration, 16(34.8%) systems operation and some theory, and four (8.7%) selected basic facts and terms. One participant did not complete knowledge or performance level responses for this question or any further questions. HF communications systems knowledge level responses included: six (13%) advanced theory and troubleshooting, six (13%) theory and

integration, five (10.9%) operation and some theory, five (10.9%) basic facts and terms. On-board communications systems knowledge level responses included: 12 (26.7%) advanced theory and troubleshooting, 12 (26.7%) theory and integration, nine (20%) operation and some theory, two (4.4%) basic facts and terms. Satellite communications systems knowledge level responses included: seven (15.6%) advanced theory and troubleshooting, five (11.1%) theory and integration, six (13.3%) operation and some theory, four (8.9%) basic facts and terms. In-flight entertainment systems knowledge level responses included: six (13.3%) advanced theory and troubleshooting, 11(24.4%) theory and integration, eight (17.8%) operation and some theory, six (13.3%) basic facts and terms.

Figure 7 provides a visual representation of responses on communications systems knowledge level requirements from the general and business aviation sector. The visual representation of this data shows no one prominent level of knowledge response applies across the communications systems. The advanced theory and troubleshooting level of knowledge is constantly significant in each system according to the visual representation.

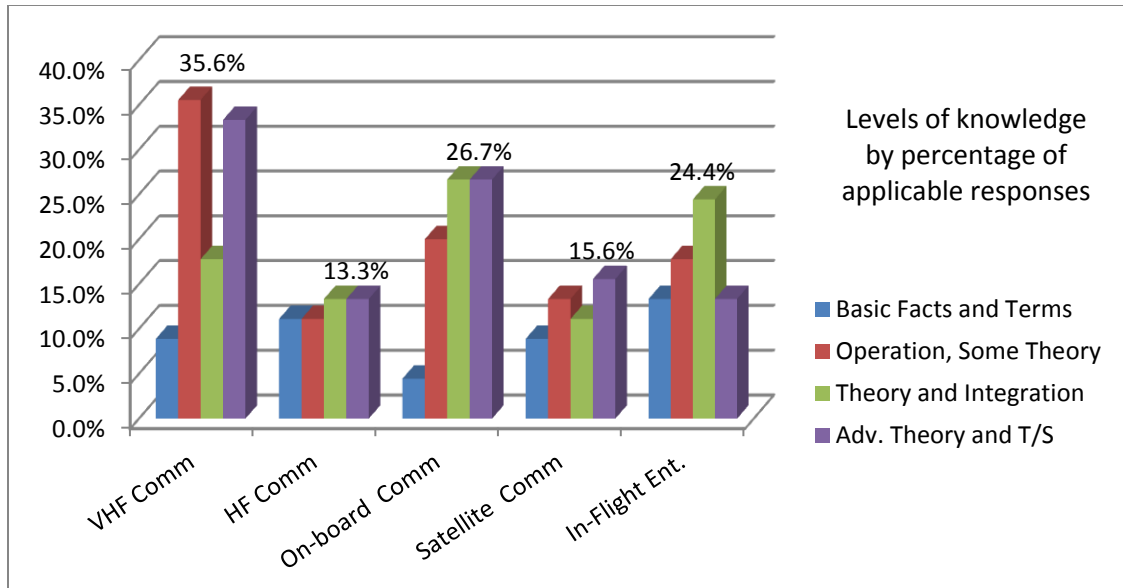


Figure 7. Communications systems knowledge levels from general and business aviation.

Performance level general and business aviation.

VHF communications systems performance level responses included: 18 (40%) highly proficient, 22 (48.9%) competent, three (6.7%) partially proficient. HF communications performance systems level responses included: six (13.3%) highly proficient, 10 (22.2%) competent, four (8.9%) partially proficient and two (4.4%) extremely limited. On-board communications systems performance level responses included: nine (20%) highly proficient, 21(46.7%) competent, four (8.9%) partially proficient and one (2.2%) extremely limited. Satellite communications systems performance level responses included: six (13.3%) highly proficient, eight (17.8%) competent, five (11.1%) partially proficient and three (6.7%) extremely limited. In-flight entertainment systems performance level responses included: five (11.1%) highly proficient, 17 (37.8%) competent, seven (15.6%) partially proficient and two (4.4%) extremely limited.

Figure 8 provides a visual representation of responses on communications systems performance levels from the general and business aviation sector. The visual representation of this data depicts a high concentration of competent performance level responses across all of the communications systems. The next most prevalent response is the highly proficient performance level. This data is very similar to the commercial and regional airlines sector data in this area.

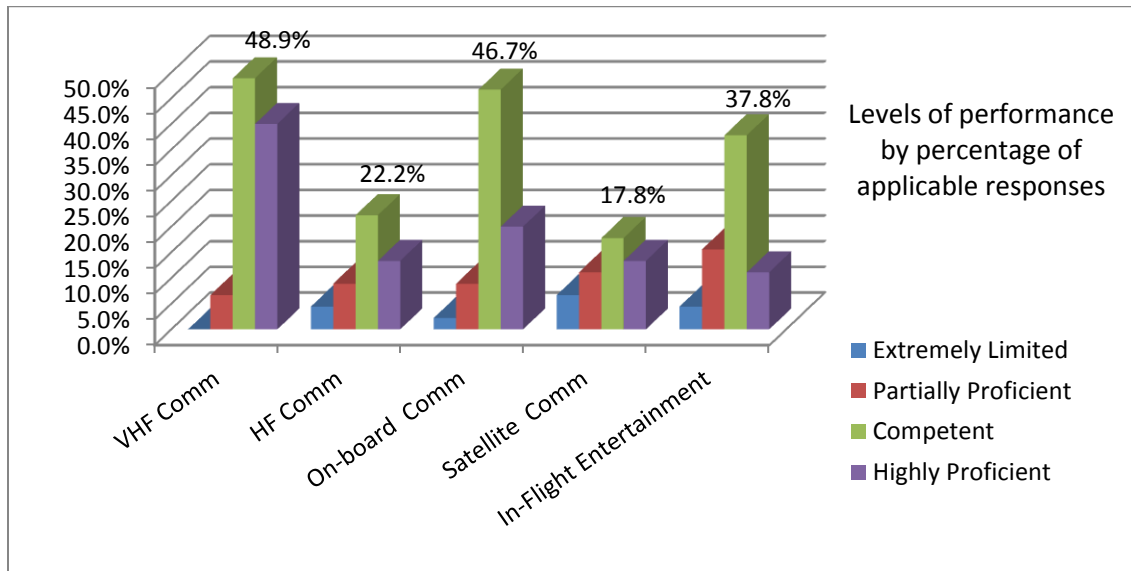


Figure 8. Communications systems performance levels from general and business aviation.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated communications systems work included VHF, HF, satellite communications, and in-flight entertainment systems. The knowledge level for HF systems was basic facts and terms, VHF systems and satellite communications had operation and some theory knowledge level selected. In-flight entertainment had theory and integration knowledge

level selected. The performance level, extremely limited was selected for HF systems. The VHF communications, satellite communications, and in-flight entertainment systems all had the competent performance level selected.

Dependent navigation systems. Participants were asked to select each of the dependent navigation systems that are applicable to their shops. The choices provided included; ADF, VOR, DME, Area Navigation, Localizer / glide slope, marker beacon, GPS, microwave landing systems, and not applicable. Participants were then asked to describe the knowledge and performance levels for technicians performing installation service or repair of each aircraft navigation systems selected. Knowledge level was distinguished by selecting one of four levels; basic facts and terms, basic theory and operation, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data indicated that of the 25 participant responses from the commercial and regional airlines sector, 11 (44%) participants' selected not applicable leaving 14 (56%) responses who work with dependent navigation systems. One (7.1%) of the 14 participants working with these systems selected all eight systems. ADF and VOR were selected by a total of 12 (85.7) participants, with DME and Localizer/glide slope being selected by 10 (71.4%) participants. Area navigation, marker beacon, and GPS systems were each selected by nine (36%) participants. A total of two (14.3%) participants selected microwave landing systems.

The data indicated that of the 45 participant responses from the general and business aviation sector, 100% worked with dependent navigation systems. Two (4.4%) participants selected all eight systems. ADF was selected by a total of 35 (87.5%) participants, and VOR was selected by 44 (97.8%) participants, with DME being selected by 40 (88.9%) and Localizer/glide slope being selected by 43 (95.6%) participants. Area navigation was selected by 31 (68.9%) participants, and marker beacon was selected by 39 (80%) participants, with GPS being selected by 42 (93.3%) participants. There were two (4.4%) selections for microwave landing systems.

Figure 9 is a visual representation of the dependent navigation systems comparing the commercial and regional airlines and general and business aviation sectors. This chart demonstrates little significant difference for these systems across each sector. A clear indication highlighted by the chart is the lack of involvement with microwave landing systems by either sector.

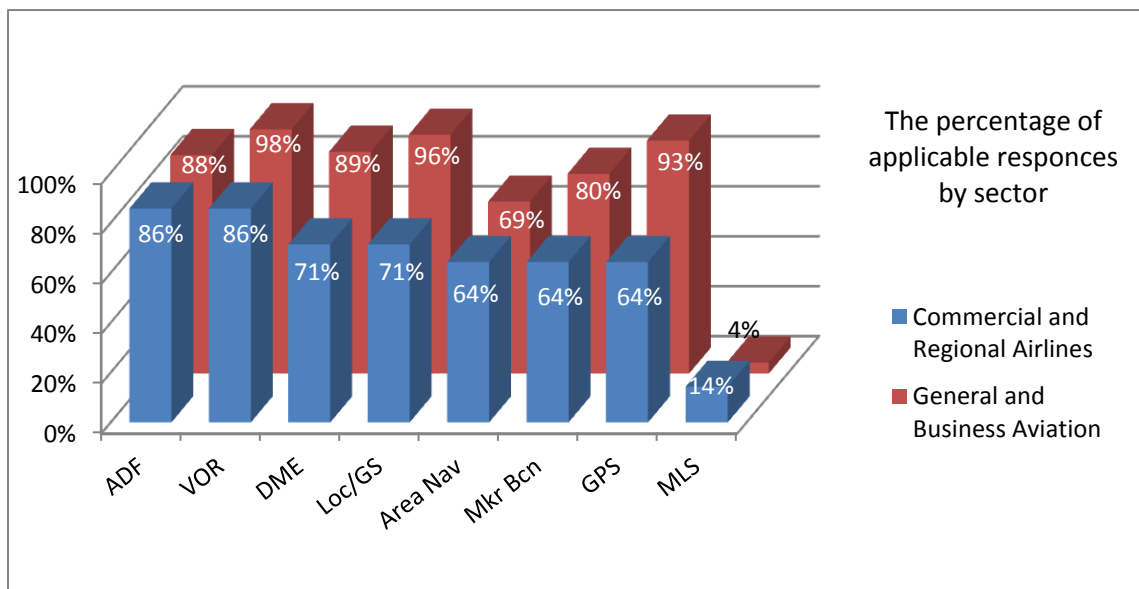


Figure 9. The dependent navigation systems installed, serviced, or repaired by sector.

Knowledge level commercial and regional airlines.

ADF systems knowledge level responses included: two (14.3%) with advanced theory and troubleshooting knowledge, five (35.7%) having theory and integration knowledge level, four (28.6%) with knowledge of operation and some theory, and one (7.1%) with only knowledge of basic facts and terms. VOR systems knowledge level responses included: three (21.4%) advanced theory and troubleshooting, four (28.6%) theory and integration, four (28.6%) operation and some theory, one (7.1%) basic facts and terms. DME systems knowledge level responses included: two (14.3%) advanced theory and troubleshooting, five (35.7%) theory and integration, three (21.4%) operation and some theory, no participants selected basic facts and terms. Area navigation systems knowledge level responses included: one (7.1%) advanced theory and troubleshooting, four (28.6%) theory and integration, two (14.3%) operation and some theory, two (14.3%) basic facts and terms. Localizer/glide slope systems knowledge level responses included: three (21.4%) advanced theory and troubleshooting, two (14.3%) theory and integration, four (28.6%) operation and some theory, one (7.1%) basic facts and terms. Marker beacon systems knowledge level responses included: two (14.3%) advanced theory and troubleshooting, four (28.6%) theory and integration, three (21.4%) operation and some theory, no participants selected basic facts and terms. GPS systems knowledge level responses included: three (21.4%) advanced theory and troubleshooting, two (14.3%) theory and integration, four (28.6%) selected operation and some theory, no participants selected basic facts and terms. Microwave landing systems knowledge level responses included: no one selected advanced theory and troubleshooting, one (7.1%)

selection for theory and integration, one (7.1%) for operation and some theory, and no participants selected basic facts and terms.

Figure 10 is a visual representation of the knowledge levels required by shops working on these navigation systems. The chart shows a theory and integration level of knowledge is most prevalent. The base knowledge level of basic facts and terms is the least chosen by the participants.

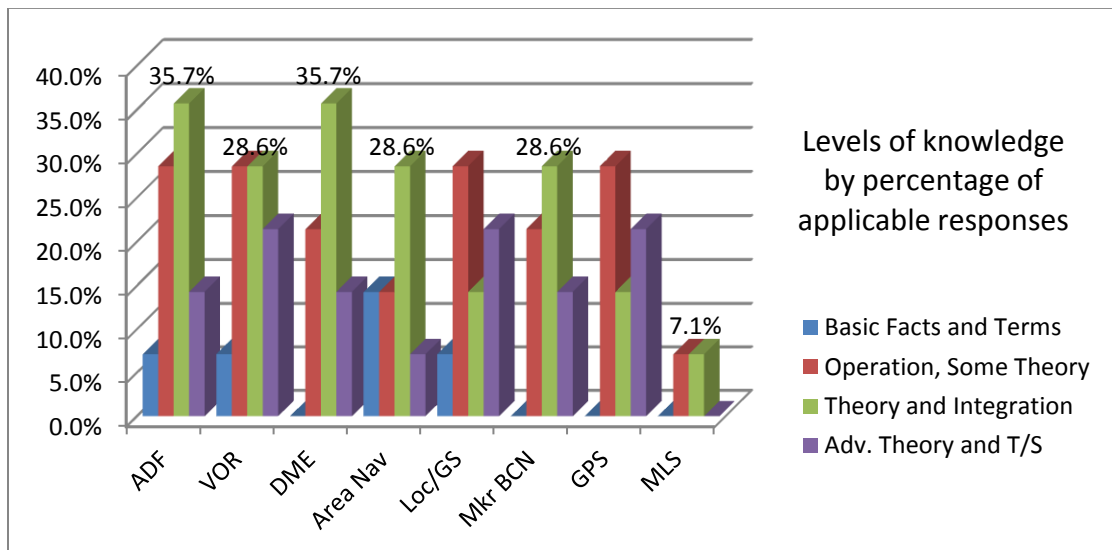


Figure 10. Dependent navigation systems knowledge levels from commercial and regional airlines.

Performance level commercial and regional airlines.

ADF systems performance level responses included: one (7.1%) highly proficient, seven (50%) competent, four (28.6%) partially proficient. VOR systems performance level responses included: three (21.4%) highly proficient, seven (50%) competent, two (14.3%) partially proficient and no one selected extremely limited. DME systems performance level responses included: two (14.3%) highly proficient, six (42.9%)

competent, two (14.3%) partially proficient and no one selected extremely limited. Area Navigation systems performance level responses included: one (7.1%) highly proficient, six (42.9%) competent, one (7.1%) partially proficient and one (7.1%) extremely limited. Localizer/Glide slope systems performance level responses included: three (21.4%) highly proficient, four (28.6%) competent, three (21.4%) partially proficient and no one selected extremely limited. Marker Beacon systems performance level responses included: two (14.3%) highly proficient, five (35.7%) competent, two (14.3%) partially proficient and no one selected extremely limited. GPS systems performance level responses included: one (7.1%) highly proficient, seven (50%) competent, one (7.1%) partially proficient and no participants selected extremely limited. Microwave landing systems performance level responses included: no one selecting highly proficient, one (7.1%) competent, one (7.1%) partially proficient and no participants selected extremely limited.

Figure 11 is a visual representation of the performance levels needed by shops working with these navigation systems. The chart indicates a significantly higher percentage of competent performance levels across the systems. Almost no selections for extremely limited performance levels were selected by participants.

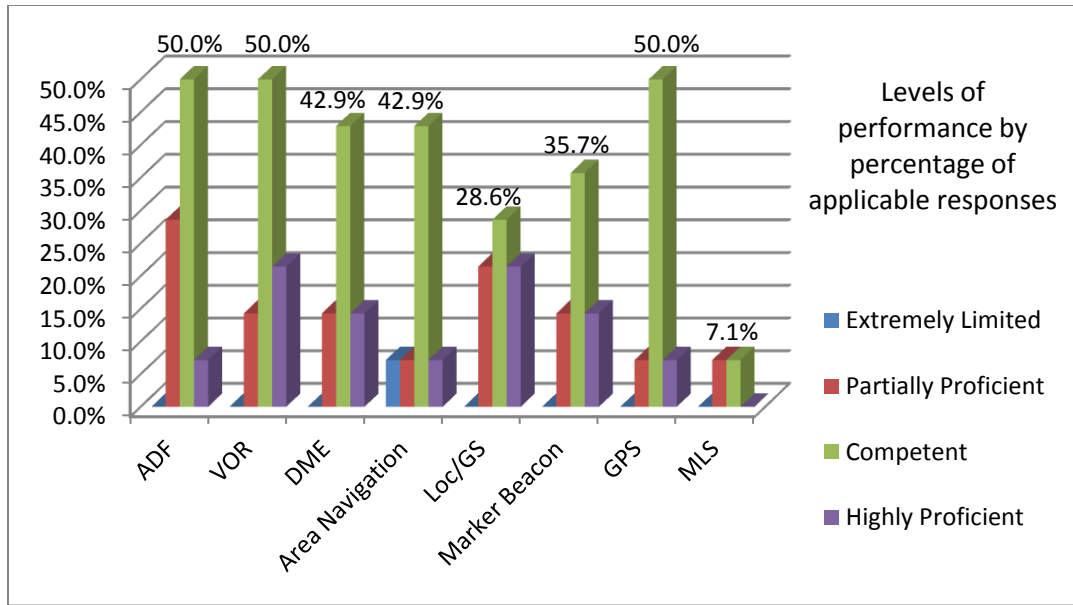


Figure 11. Dependent navigation systems performance levels from commercial and regional airlines.

Knowledge level general and business aviation.

ADF systems knowledge level responses included: 11 (24.4%) with advanced theory and troubleshooting knowledge, seven (15.6%) having theory and integration knowledge level, 11 (24.4%) with knowledge of operation and some theory, and three (6.7%) with only knowledge of basic facts and terms. VOR systems knowledge level responses included: 20 (44.4%) advanced theory and troubleshooting, nine (20%) theory and integration, nine (20%) operation and some theory, three (6.7%) basic facts and terms. DME systems knowledge level responses included: 14 (31.1%) advanced theory and troubleshooting, 13 (28.9%) theory and integration, eight (17.8%) operation and some theory, two (4.4%) basic facts and terms. Area navigation systems knowledge level responses included: 11 (24.4%) advanced theory and troubleshooting, eight (17.8%) theory and integration, five (11.1%) operation and some theory, five (11.1%) basic facts

and terms. Localizer/glide slope systems knowledge level responses included: 20 advanced theory and troubleshooting, nine (20%) theory and integration, 10 (22.2%) operation and some theory, one (2.2%) basic facts and terms. Marker beacon systems knowledge level responses included: 15 (33.3%) advanced theory and troubleshooting, eight (17.8%) theory and integration, 12 (26.7) operation and some theory, two (4.4%) basic facts and terms. GPS systems knowledge level responses included: 23 (51.1%) advanced theory and troubleshooting, 10 (22.2%) theory and integration, six (13.3) operation and some theory, one (2.2%) basic facts and terms. Microwave landing systems knowledge level responses included: no one selected advanced theory and troubleshooting, theory and integration, or operation and some theory, and one (2.2%) participant selected basic facts and terms.

Figure 12 is a visual representation of the knowledge levels required by shops working on these navigation systems. The chart shows a advanced theory and troubleshooting level of knowledge is most prevalent. The basic knowledge level of basic facts and terms is the least chosen by the participants.

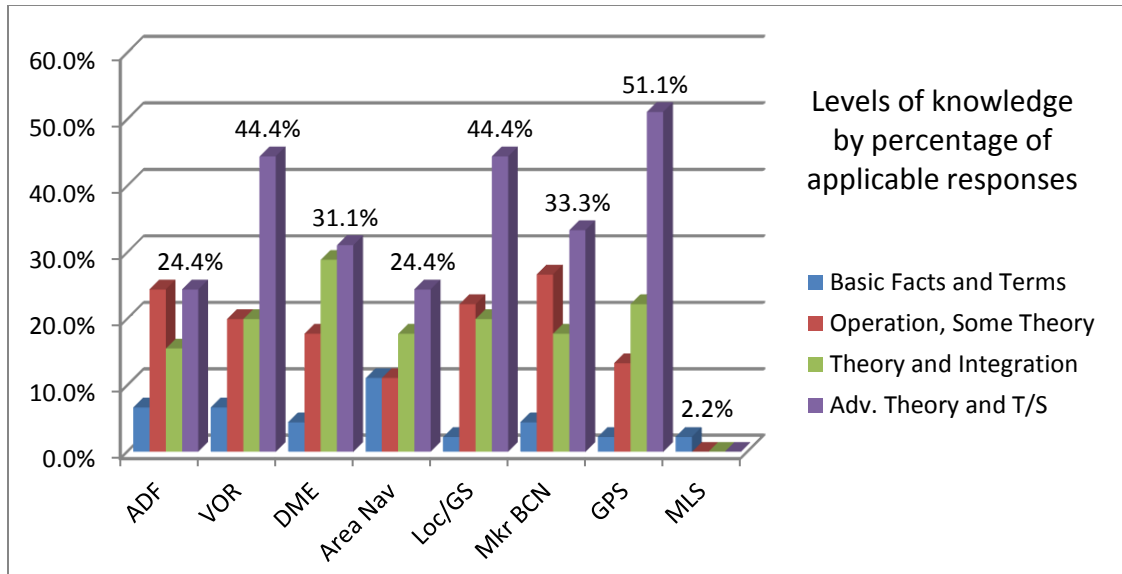


Figure 12. Dependent navigation systems knowledge levels from general and business aviation.

Performance level general and business aviation.

ADF systems performance level responses included: nine highly proficient, 16 (35.6%) competent, five (11.1%) partially proficient and two (4.4%) extremely limited. VOR systems performance level responses included: 14 (31.1%) highly proficient, 21 (46.7%) competent, five (11.1%) partially proficient and one (2.2%) extremely limited. DME systems performance level responses included: 12 (26.7%) highly proficient, 22 (48.9%) competent, three (6.7%) partially proficient and no one selected extremely limited. Area Navigation systems performance level responses included: nine (20%) highly proficient, 13 (28.9%) competent, five (11.1%) partially proficient and two (4.4%) extremely limited. Localizer/Glide slope systems performance level responses included: 16 (35.6%) highly proficient, 20 (44.4%) competent, four (8.9%) partially proficient and no one selected extremely limited. Marker Beacon systems performance level responses

included: 13 (28.9%) highly proficient, 19 (42.2%) competent, four (8.9%) partially proficient and one (2.2%) extremely limited. GPS systems performance level responses included: 17 (37.8%) highly proficient, 21 (46.7%) competent, two (4.4%) partially proficient and no one selected extremely limited. Microwave landing systems performance level responses included: no one selected highly proficient, competent, or partially proficient and one (2.2%) selected extremely limited.

Figure 13 is a visual representation of the performance levels needed by shops working with these navigation systems. The chart indicates a significantly higher percentage of competent and highly proficient performance levels across the systems. Almost no selections for extremely limited performance levels were selected by participants.

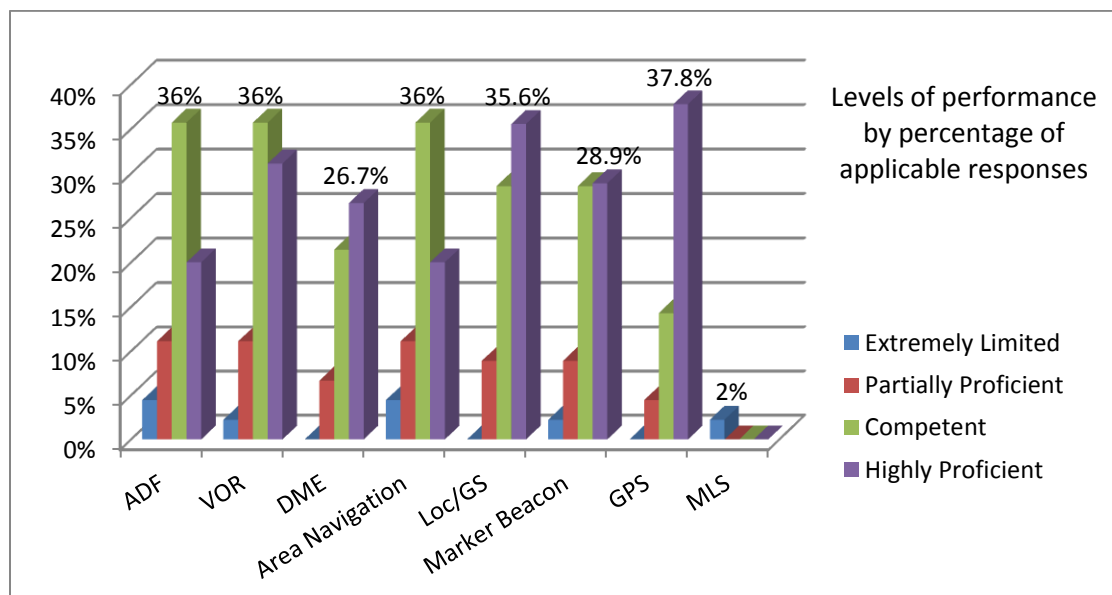


Figure 13. Dependent navigation systems performance levels from general and business aviation.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated dependent navigation systems work included ADF, VOR, DME, Area Navigation, Localizer/Glide slope, Marker Beacon, and GPS systems. The knowledge level for ADF systems was basic facts and terms, VOR and Area Navigation systems had a knowledge level of operation and some theory selected. DME, Localizer/Glide slope, Marker Beacon, and GPS systems had theory and integration knowledge level selected. The performance level for ADF systems was extremely limited, and for Area Navigation systems partially proficient was the performance level selected. VOR, DME, Localizer/Glide slope, Marker Beacon, and GPS systems had the competent performance level selected.

Autonomous navigation systems.

Participants were asked to select each of the autonomous navigation systems that are applicable to their shops. The choices provided included; inertial navigation systems, flight management systems, inertial reference systems, ring laser gyros, automatic flight control systems, and not applicable. Participants were then asked to describe the knowledge and performance levels for technicians performing installation service or repair of each aircraft autonomous navigation systems selected. Knowledge level was distinguished by selecting one of four levels; basic facts and terms, basic theory and operation, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data indicated that of the 25 participant responses from the commercial and regional airlines sector, four (16%) participants' selected not applicable leaving 21 (84%) responses working with autonomous navigation systems. One (4.8%) participant selected all five systems and this was the only selection for ring laser gyro. One (4.8%) participant selected inertial reference systems alone and two (9.5%) participants selected flight management systems alone.

Flight management systems were selected by a total of 20 (95.2%) participants and inertial navigation systems were selected by five (23.8%) participants. Inertial reference systems were selected by six (28.6%) participants while one (4.8%) participant selected ring laser gyro. Automatic flight control systems were selected by 18 (85.7%) participants.

The data showed that of the 42 participant responses from the general and business aviation sector, five (11.9%) participants' selected not applicable leaving 37 (88.1%) responses who work with autonomous navigation systems. Eight (21.6%) of the 37 participants selected all five systems and these were the only selections for ring laser gyro. Participants selecting automatic flight control systems alone totaled seven (18.9%) and three (8.1%) participants selected flight management systems alone.

Flight management systems were selected by a total of 29 (78.4%) participants and inertial navigation systems were selected by 14 (37.8%) participants. Inertial reference systems were selected by 12 (32.4%) participants while ring laser gyro was selected by eight (21.6%) participants. Automatic flight control systems were selected by 35 (94.6%) participants.

Figure 14 is a visual representation of the autonomous navigation systems installed, repaired, or serviced by the commercial and regional airlines and general and business aviation sectors. This chart demonstrates more similarities than differences for these systems across the sectors. A clear indication highlighted by the chart is the low percentages of work with ring laser gyros by either sector.

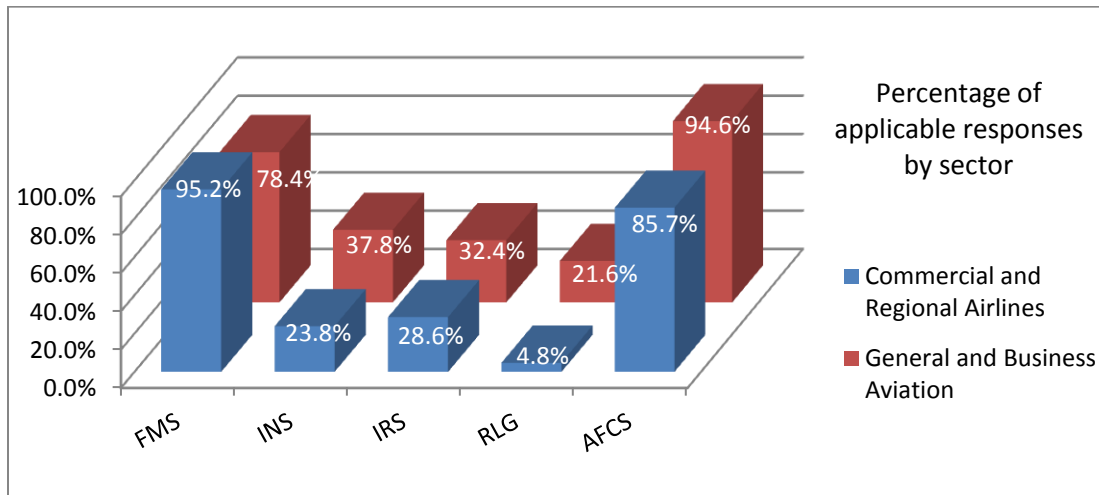


Figure 14. Autonomous navigation systems installed, repaired, or serviced by sector.

Knowledge level commercial and regional airlines.

Inertial navigation systems knowledge level responses included: four (19%) with advanced theory and troubleshooting knowledge, three (14.3%) having theory and integration knowledge level, six (28.6%) with knowledge of basic theory and operation, and eight (38.1%) selection of only knowledge of basic facts and terms. Flight management systems included: six (28.6%) advanced theory and troubleshooting, six (28.6%) theory and integration, five (23.8%) basic theory and operation, three (14.3%) basic facts and terms. Inertial reference systems included: three (14.3%) advanced theory and troubleshooting, one (4.8%) theory and integration, one (4.8%) basic theory and

operation, one (4.8%) basic facts and terms. Ring laser gyros included: no selections for advanced theory and troubleshooting, theory and integration, and one (4.8%) selection for basic theory and operation, with no one selecting basic facts and terms. Automatic flight control systems included: six (28.6%) advanced theory and troubleshooting, six (28.6%) theory and integration, six (28.6%) basic theory and operation, and no one selected basic facts and terms.

Figure 15 is a visual representation of the knowledge levels required by shops working on these autonomous navigation systems. The chart shows inertial navigation systems at varying levels of knowledge requirements with basic facts and terms selected most often. The clearest distinction is the knowledge levels for the inertial reference systems which has advanced theory and troubleshooting standing out above the rest.

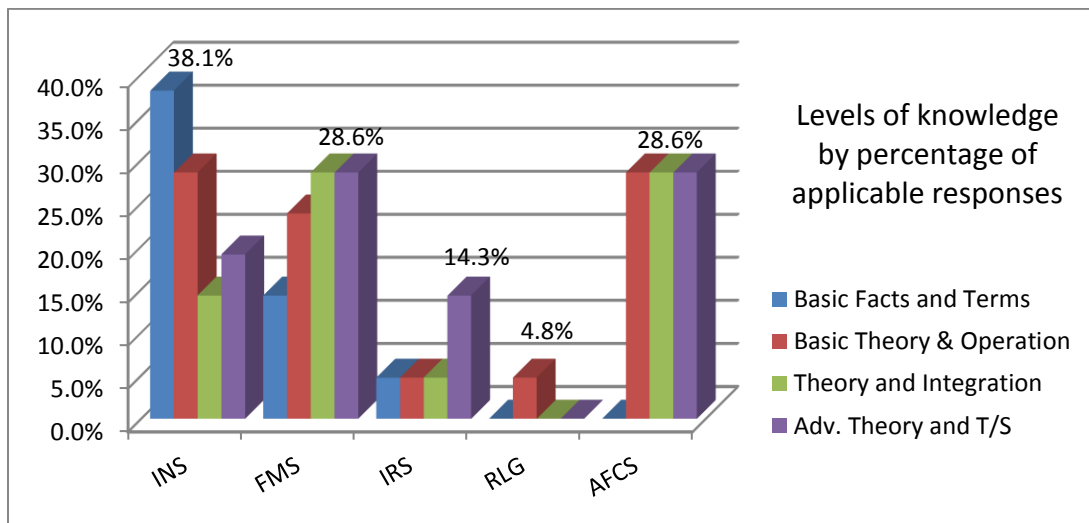


Figure 15. Autonomous navigation systems knowledge levels from commercial and regional airlines.

Performance level commercial and regional airlines.

Inertial navigation systems performance level responses included: three (14.3%) highly proficient, nine (42.9%) competent, one (4.8%) partially proficient and eight (38.1%) extremely limited. Flight management systems performance level responses included: five (23.8%) highly proficient, 13 (61.9%) competent, one (4.8%) partially proficient and one (4.8%) extremely limited. Inertial reference systems included: one (4.8%) highly proficient, four (19%) competent, one (4.8%) partially proficient and no one selected extremely limited. Ring laser gyro systems included: no one selected highly proficient, or competent, one (4.8%) partially proficient and no one selected extremely limited. Automatic flight control systems included: four (19%) highly proficient, 14 (66.7%) competent, no one selected partially proficient or extremely limited.

Figure 16 is a visual representation of the performance levels needed by shops working with these autonomous navigation systems. The chart indicates a significantly higher percentage of competent performance levels across most of the systems. The high number of selections for extremely limited performance level in the inertial navigation systems stands out as being in sharp contrast to the other systems results.

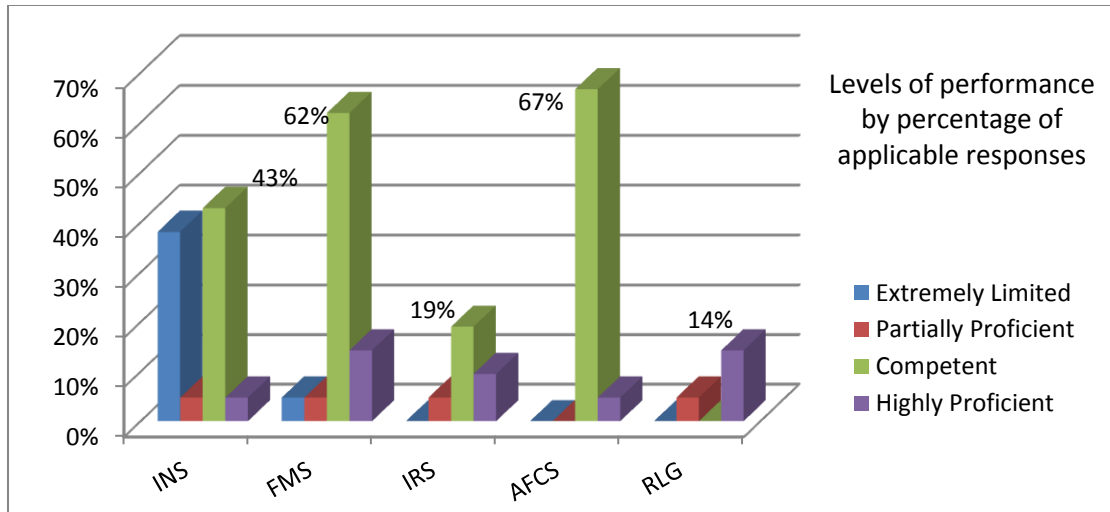


Figure 16. Autonomous navigation systems performance levels from commercial and regional airlines.

Knowledge level general and business aviation.

Inertial navigation systems knowledge level responses included: seven (18.9%) with advanced theory and troubleshooting knowledge, six (16.2%) having theory and integration knowledge level, 10 (27%) with knowledge of basic theory and operation, and 14 (37.8%) selections of basic facts and terms. Flight management systems knowledge level responses included: 10 (27%) advanced theory and troubleshooting, 12 (32.4%) theory and integration, five (13.5%) basic theory and operation, two (5.4%) basic facts and terms. Inertial reference systems knowledge level responses included: three (8.1%) advanced theory and troubleshooting, five (13.5%) theory and integration, three (8.1%) basic theory and operation, one (2.7%) basic facts and terms. Ring laser gyros knowledge level responses included: no one selected advanced theory and troubleshooting, three (8.1%) theory and integration, three (8.1%) basic theory and operation, two (5.4%) basic facts and terms. Automatic flight control systems knowledge level responses included: 18

(48.6%) advanced theory and troubleshooting, eight (21.6%) theory and integration, eight (21.6%) basic theory and operation, one (2.7%) basic facts and terms.

Figure 17 is a visual indication of the knowledge levels required by shops in the general and business aviation sector working on these autonomous navigation systems. Figure 17 indicates more participants require the advanced theory and troubleshooting knowledge level in the automatic flight control systems. Figure 17 also reflects more participants require at least the theory and integration levels of knowledge in each of these systems.

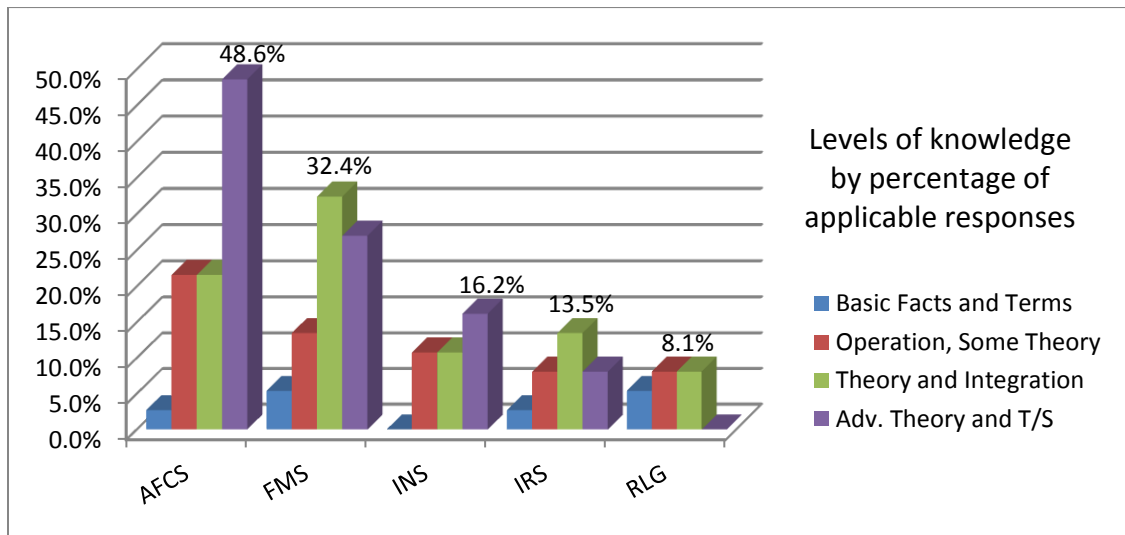


Figure 17. Autonomous navigation systems knowledge levels from general and business aviation sector.

Performance level general and business aviation.

Inertial navigation systems performance level responses included: five (13.5%) highly proficient, 11 (29.7%) competent, 11 (29.7%) partially proficient and 10 (27%) extremely limited. Flight management systems performance level responses included: 11

(29.7%) highly proficient, 15 (40.5%) competent, one (2.7%) partially proficient and two (5.4%) extremely limited. Inertial reference systems performance level responses included: four (10.8%) highly proficient, five (13.5%) competent, two (5.4%) partially proficient and one (2.7%) extremely limited. Ring laser gyro systems performance level responses included: one (2.7%) highly proficient, three (8.1%) competent, three (8.1%) partially proficient and one (2.7%) extremely limited. Automatic flight control systems performance level responses included: 13 (35.1%) highly proficient, 16 (43.2%) competent, five (13.5%) partially proficient and one (2.7%) extremely limited.

Figure 18 is a visual representation of the performance levels requirements for these autonomous navigation systems in the general and business aviation sector. The chart indicated most participants selected competent or highly proficient for the flight management and automatic flight control systems. Inertial navigation and ring laser gyro systems had highly proficient as the least selected performance level.

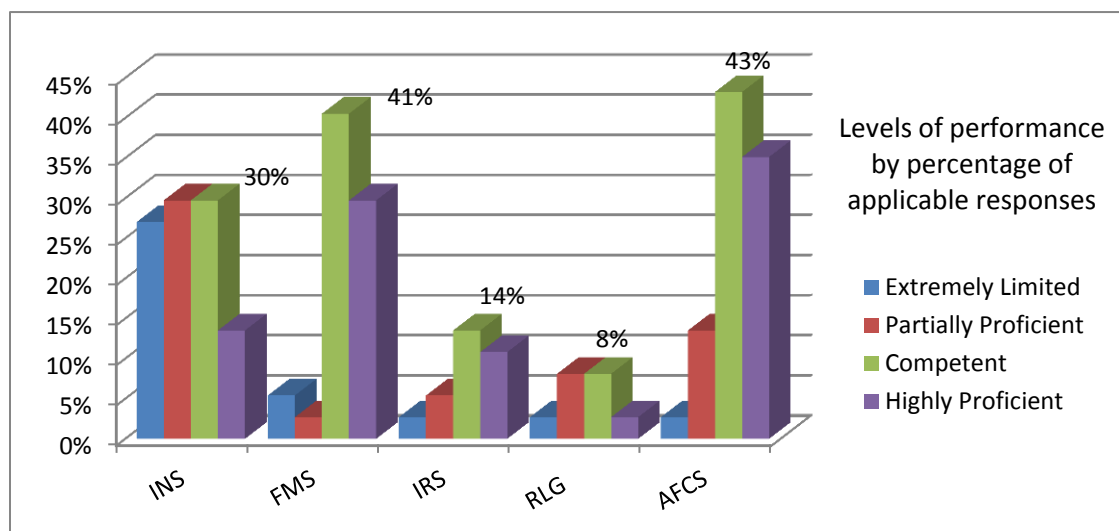


Figure 18. Autonomous navigation systems performance levels from general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated autonomous navigation systems work included flight management systems and automatic flight control systems. The knowledge level selected for both systems was theory and integration. The flight management systems performance level was partially proficient and for automatic flight control systems competent was the performance level selected.

Basic aircraft systems.

Participants were asked to select each of the basic aircraft systems that are applicable to their shops. The choices provided included; pitot/static and air-data systems, power distribution systems, generators / voltage regulators, aircraft batteries lead acid and ni-cad, lithium aircraft batteries, and not applicable. Participants were then asked to describe the knowledge and performance levels for technicians performing installation service or repair of each basic aircraft systems selected. Knowledge level was distinguished by selecting one of four levels; basic facts and terms, basic theory and operation, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector, three participants' selected not applicable leaving 22 responses who work with basic aircraft systems. Four (18.2%) participants selected all five systems. Two (9.1%) participants' selected aircraft batteries: lead acid and ni-cad as the only

system they work with out of the basic aircraft systems block and one (4.5%) participant selected lithium aircraft batteries as the only system of this set they work with. Pitot/static and air-data systems were selected by 14 (63.6%) participants and power distribution systems were selected by 15 (68.2%) participants. generators / voltage regulators were selected by 12 (54.5%) participants while aircraft batteries lead acid and ni-cad were selected by 15 (68.2%) participants. Lithium aircraft batteries were selected by 14 (63.6%) participants.

The data showed that of the 42 participant responses from the general and business sector, one participant selected not applicable leaving 41 responses who work with these basic aircraft systems. Twelve (29.3%) participants selected all five systems. Five (12.2%) participants' selected pitot/static and air-data systems as the only systems they work with out of the basic aircraft systems block. Pitot/static and air-data systems were selected by 41 (100%) participants and power distribution systems were selected by 33 (80.5%) participants. Generators / voltage regulators were selected by 27 (65.9%) participants while aircraft batteries lead acid and ni-cad was selected by 22 (53.7%) participants. Lithium aircraft batteries were selected by 13 (31.7%) participants.

Figure 19 indicates the installation, repair, or service of these basic aircraft systems is a larger part of the participants in the general and business aviation sector with the exception of battery services. The commercial and regional aviation sector has greater percentages of participants in the installation, repair, or service of both categories of batteries. The lithium batteries percentage was substantially lower in general and business aviation participant responses.

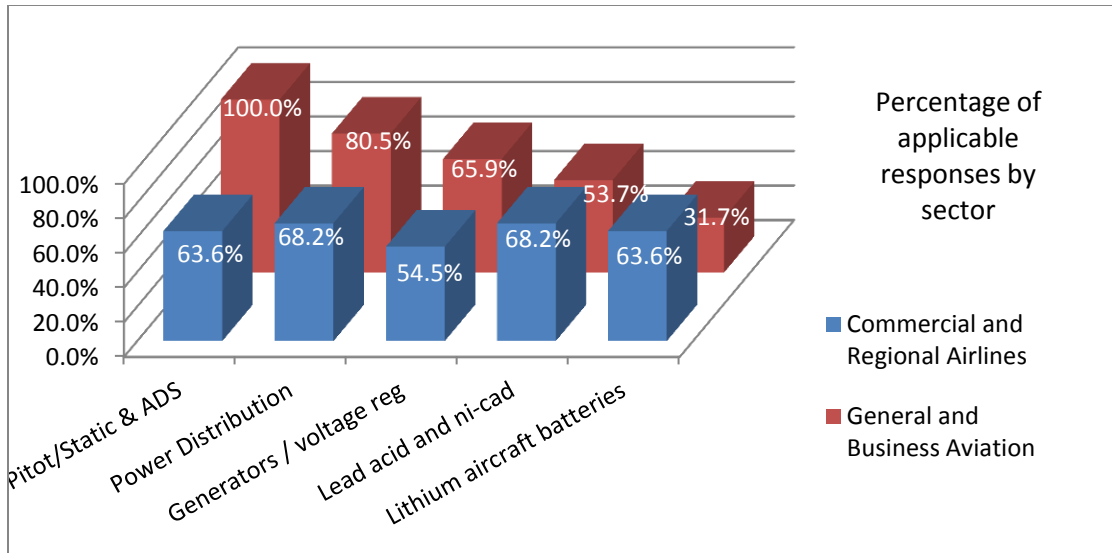


Figure 19. Basic aircraft systems installed, repaired, or serviced by sector.

Knowledge level commercial and regional airlines.

Pitot/static and air-data systems knowledge level responses included: six (27.3%) with advanced theory and troubleshooting knowledge, four (18.2%) having theory and integration knowledge level, three (13.6%) with knowledge of basic theory and operation, and one (4.5%) selection of only knowledge of basic facts and terms. Power distribution systems knowledge level responses included: four (18.2%) advanced theory and troubleshooting, six (27.3%) theory and integration, four (18.2%) basic theory and operation, one (4.5%) basic facts and terms. Generators / voltage regulator systems knowledge level responses included: five (22.7%) advanced theory and troubleshooting, four (18.2%) theory and integration, three (13.6%) basic theory and operation, no one selected basic facts and terms. Aircraft batteries lead acid and ni-cad systems knowledge level responses included: no one selected advanced theory and troubleshooting, five (22.7%) theory and integration, nine (40.9%) basic theory and operation, one (4.5%)

basic facts and terms. Lithium aircraft battery systems knowledge level responses included: two (9.1%) advanced theory and troubleshooting, four (18.2%) theory and integration, six (27.3%) basic theory and operation, two (9.1%) basic facts and terms.

Figure 20 indicates the highest knowledge level in these basic aircraft systems is in the pitot/static and generator systems. Both battery systems indicated a lower basic theory and operation knowledge level. The power distribution systems were most often selected at a theory and integration level of knowledge.

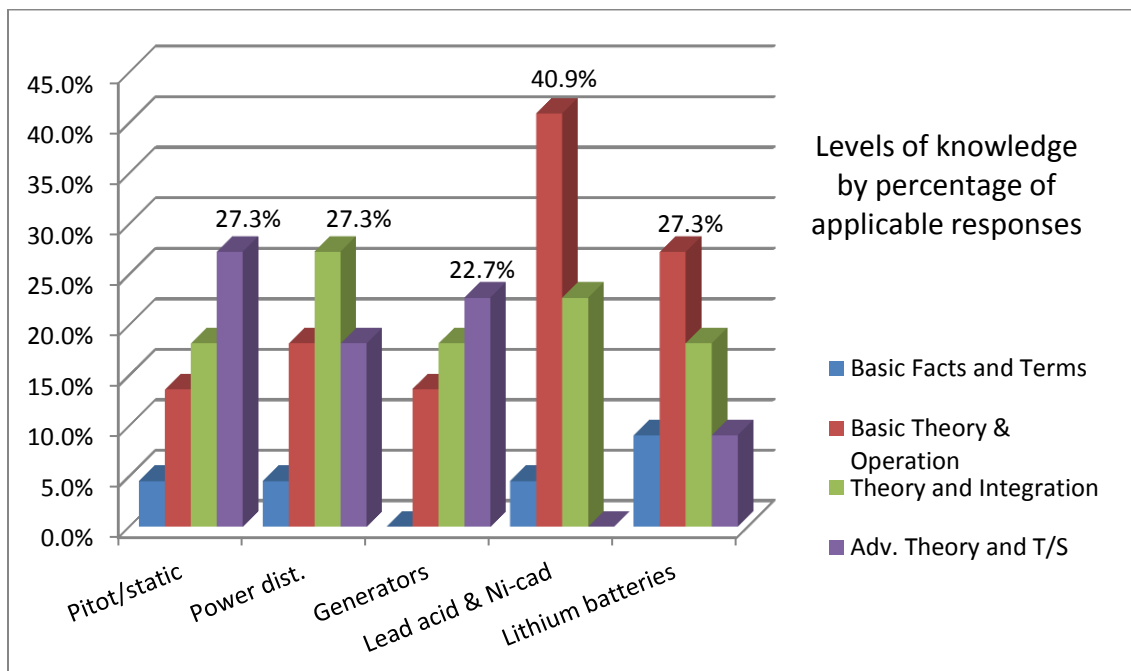


Figure 20. Basic aircraft systems knowledge levels from commercial and regional airlines.

Performance level commercial and regional airlines.

Pitot/static and air-data systems performance level responses included: four (18.2%) highly proficient, eight (36.4%) competent, one (4.5%) partially proficient and

one (4.5%) extremely limited. Power distribution systems performance level responses included: four (18.2%) highly proficient, eight (36.4%) competent, two (9.1%) partially proficient and one (4.5%) extremely limited. Generators / voltage regulator systems performance level responses included: four (18.2%) highly proficient, six (27.3%) competent, one (4.5%) partially proficient and one (4.5%) extremely limited. Aircraft batteries systems lead acid and ni-cad performance level responses included: no one selected highly proficient, 10 (45.5%) competent, four (18.2%) partially proficient and one (4.5%) extremely limited. Lithium aircraft batteries systems performance level responses included: no one selected highly proficient, 11 (50.0%) competent, two (9.1%) partially proficient and one (4.5%) extremely limited.

Figure 21 indicates the competent performance level has a higher percentage of responses for all the systems. The battery systems had a step down in performance to partially proficient as a second highest percentage. The pitot/static, power distribution, and generators systems have a step up to highly proficient performance levels as the second highest percentages.

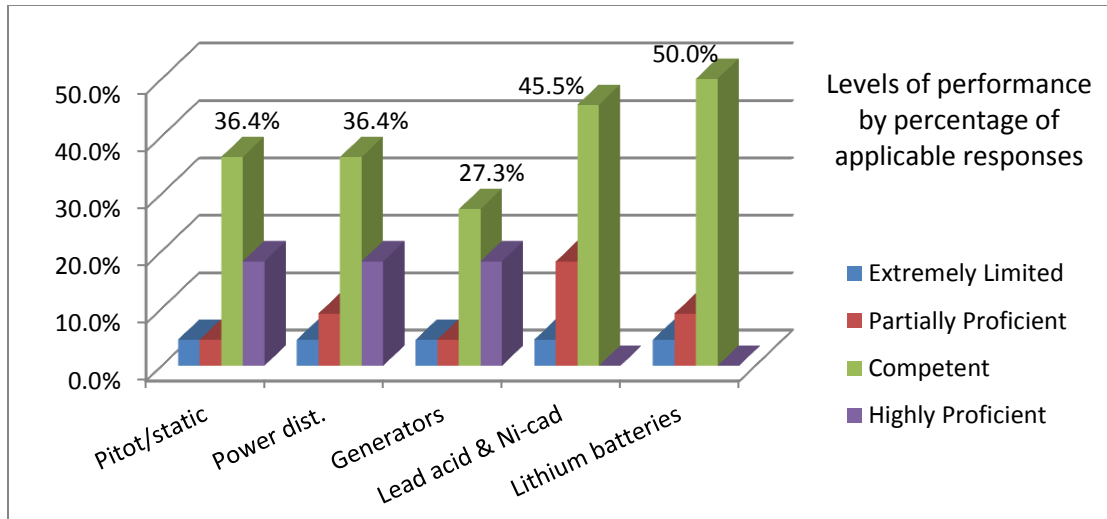


Figure 21. Basic aircraft systems performance levels from commercial and regional airlines.

Knowledge level general and business aviation.

Pitot/static and air-data systems knowledge level responses included: 31 (75.6%) with advanced theory and troubleshooting knowledge, five (12.2%) having theory and integration knowledge level, four (9.8%) with knowledge of basic theory and operation, and one (2.4%) selection of knowledge of basic facts and terms. Power distribution systems knowledge level responses included: 15 (36.6%) advanced theory and troubleshooting, 11 (26.8%) theory and integration, seven (17.1%) basic theory and operation, and no one selected basic facts and terms. Generators /voltage regulator systems knowledge level responses included: 12 (29.3%) advanced theory and troubleshooting, eight (19.5%) theory and integration, seven (17.1%) basic theory and operation, and no one selected basic facts and terms. Aircraft batteries lead acid and Ni-cad systems knowledge level responses included: seven (17.1%) advanced theory and troubleshooting, six (14.6%) theory and integration, eight (19.5%) basic theory and

operation, and one (2.4%) basic facts and terms. Lithium aircraft battery systems knowledge level responses included: two (4.9%) advanced theory and troubleshooting, three (7.3%) theory and integration, six (14.6%) basic theory and operation, and two (4.9%) basic facts and terms.

Figure 22 indicates three fourths of the general and business aviation sector participants chose the highest knowledge level of advanced theory and troubleshooting in pitot/static systems. The knowledge level of advanced theory and troubleshooting was selected most often in the pitot/static, power distribution, and generators basic aircraft systems. Both battery systems indicated a lower knowledge level of basic theory and operation was selected most often.

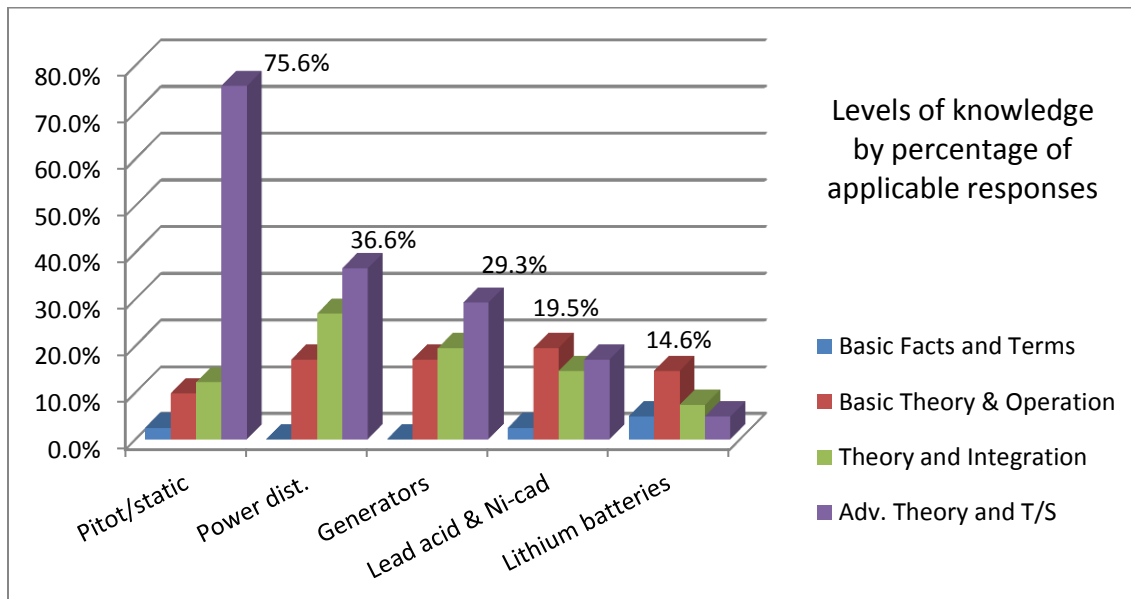


Figure 22. Basic aircraft systems knowledge levels from general and business aviation sector.

Performance level general and business aviation.

Pitot/static and air-data systems performance level responses included: 24 (58.5%) highly proficient, 14 (34.1%) competent, three (7.3%) partially proficient and no one selected extremely limited. Power distribution systems performance level responses included: nine (22.0%) highly proficient, 20 (48.8%) competent, four (9.8%) partially proficient and no one selected extremely limited. Generators / voltage regulator systems performance level responses included: eight (19.5%) highly proficient, 16 (39.0%) competent, three (7.3%) partially proficient and no one selected extremely limited. Aircraft batteries systems lead acid and Ni-cad performance level responses included: four (9.8%) highly proficient, 14 (34.1%) competent, four (9.8%) partially proficient and no one selected extremely limited. Lithium aircraft batteries systems performance level responses included: two (4.9%) highly proficient, five (12.2%) competent, five (12.2%) partially proficient and one (2.4%) extremely limited.

Figure 23 indicates highly proficient was selected most often in the pitot/static system for the general and business aviation sector. The competent performance level has a higher percentage of responses for all the other systems. Partially proficient was given the same number selections as competent for the lithium battery systems.

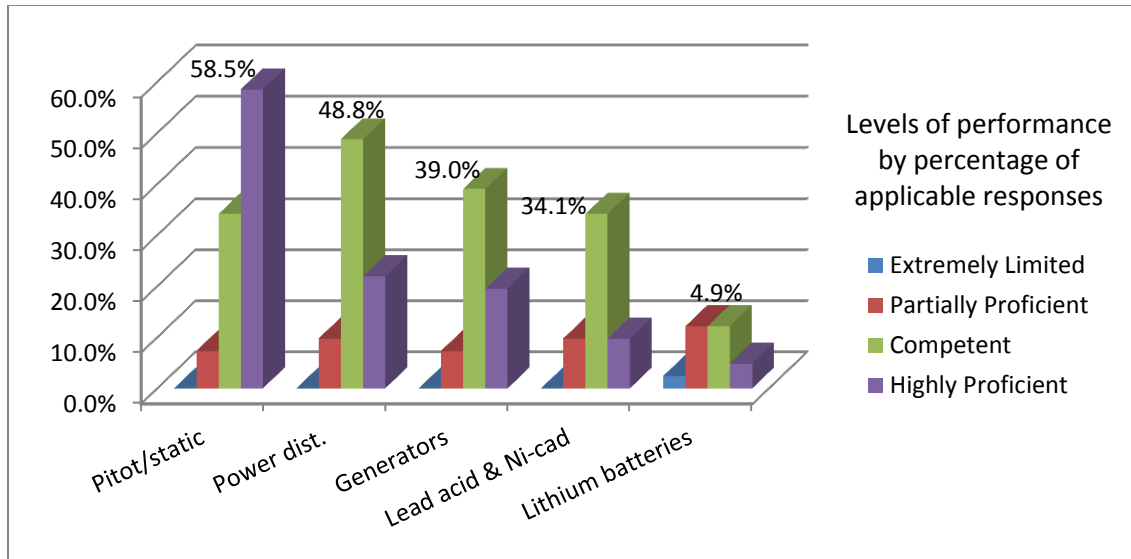


Figure 23. Basic aircraft systems performance levels from general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the basic aircraft systems work included pitot / static systems and power distribution systems. The knowledge level selected for both systems was advanced theory and troubleshooting. The power distribution systems performance level was competent and for pitot / static systems highly proficient was the performance level selected.

Pulse systems.

Participants were asked to select each of the pulse systems that are applicable to their shops. The choices provided included; weather radar systems, mode A, C, and S transponders, TCAS / TIS, ADS-B, ground proximity warning systems, and not applicable. Participants were then asked to describe the knowledge and performance

levels for technicians performing installation service or repair of each pulse systems selected. Knowledge level was distinguished by selecting one of four levels; basic facts and terms, basic theory and operation, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector, 15 participants' selected not applicable leaving 10 (40%) responses who work with pulse systems. Five (50%) participants selected all five systems. All 10 (100%) participants selected ground proximity warning systems, while one (10%) participant selected it as the only system of this set they work with. Weather radar systems were selected by nine (90%) participants and mode A, C, and S transponders were selected by eight (80%) participants. TCAS / TIS were selected by eight (80%) participants while ADS-B was selected by five (50%) participants. Ground proximity warning systems were selected by 10 (100%) participants.

The data showed that of the 42 participant responses from the general and business sector, one participant selected not applicable leaving 41 (97.6%) responses who work with these pulse systems. Twenty seven (65.9%) participants selected all five systems. One (2.4%) participant selected ground proximity warning systems as the only system they work with out of the pulse systems block. Weather radar systems were selected by 33 (80.4%) participants and mode A, C, and S transponders were selected by 40 (97.6) participants. TCAS / TIS were selected by 35 (85.4%) participants while ADS-B was selected by 40 (97.6%) participants. Ground proximity warning systems were selected by 29 (70.7%) participants.

Figure 24 shows 97 percent of the respondents in the general and business aviation sector are working with transponders and ADS-B systems. Fifty percent of the commercial and regional airlines sector participants are working with the ADS-B systems. All the commercial and regional airlines sector participants are working with ground proximity warning systems. Seventy percent of the general and business aviation sector participants are working with ground proximity warning systems.

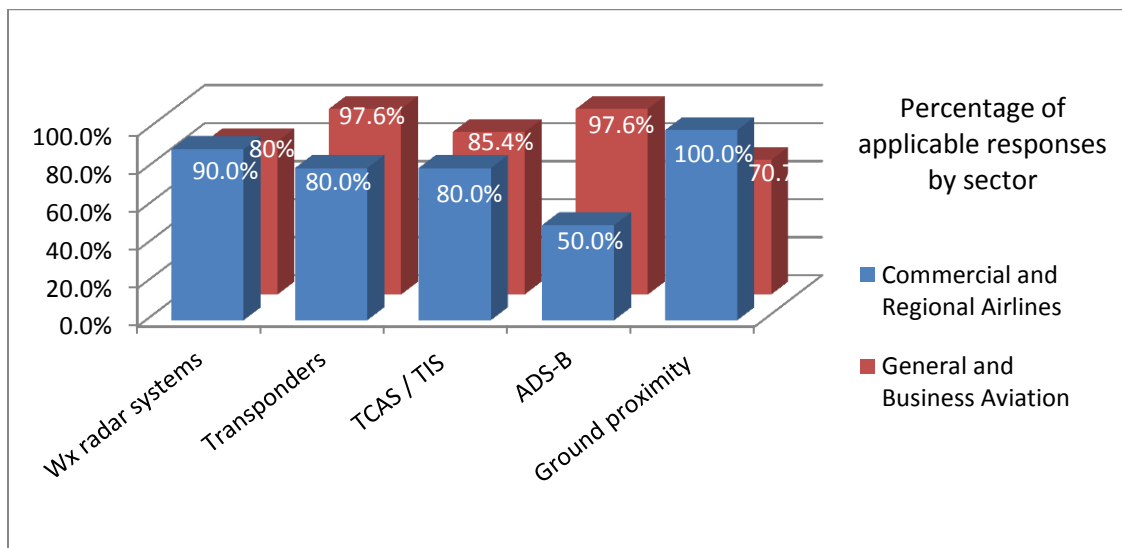


Figure 24. Aircraft pulse systems installed, repaired, or serviced by sector.

Knowledge level commercial and regional airlines.

Weather radar systems knowledge level responses included: two (20%) with advanced theory and troubleshooting knowledge, three (30%) having theory and integration knowledge level, two (20%) with knowledge basic theory and operation, and two (20%) selection of knowledge of basic facts and terms. Mode A, C, and S Transponders knowledge level responses included: three (30%) advanced theory and troubleshooting, one (10%) theory and integration, three (30%) basic theory and

operation, and one (10%) basic facts and terms. TCAS / TIS systems knowledge level responses included: three (30%) advanced theory and troubleshooting, two (20%) theory and integration, two (20%) basic theory and operation, and one (10%) basic facts and terms. ADS-B systems knowledge level responses included: one (10%) advanced theory and troubleshooting, two (20%) theory and integration, one (10%) basic theory and operation, and one (10%) selected basic facts and terms. Ground proximity warning systems knowledge level responses included: three (30%) advanced theory and troubleshooting, four (40%) theory and integration, two (20%) basic theory and operation, and one (10%) basic facts and terms.

Figure 25 indicates that most participant selections were for theory and integration in the weather radar, ground proximity warning, and ADS-B systems. The traffic systems; TCAS and TIS, saw most participants select the advanced theory and troubleshooting level of knowledge. Transponder systems had an equal number of participants select basic theory and operation along with advanced theory and troubleshooting knowledge levels.

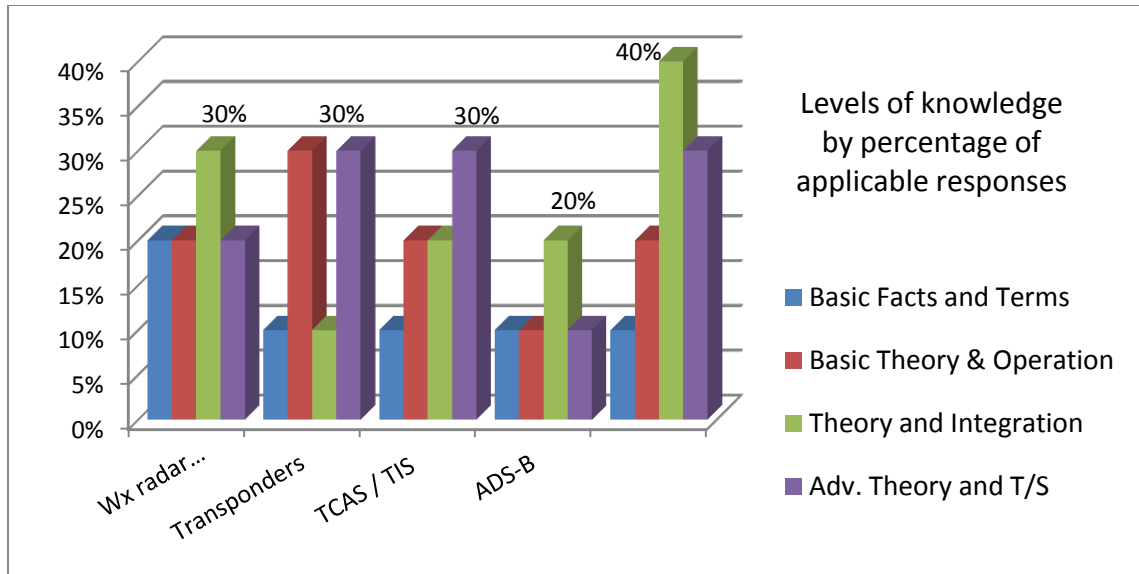


Figure 25. Aircraft pulse system knowledge levels from the commercial and regional airlines sector.

Performance level commercial and regional airlines.

Weather radar Systems performance level responses included: two (20%) highly proficient, four (40%) competent, one (10%) partially proficient and two (20%) extremely limited. Mode A, C, and S Transponders performance level responses included: three (30%) highly proficient, three (30%) competent, two (20%) partially proficient and no one selected extremely limited. TCAS / TIS systems performance level responses included: two (20%) highly proficient, five (50%) competent, one (10%) partially proficient and no one selected extremely limited. ADS-B systems performance level responses included: one (10%) highly proficient, three (30%) competent, no one selected partially proficient and one (10%) selected extremely limited. Ground proximity systems performance level responses included: one (10%) highly proficient, eight (80%) competent, one (10%) partially proficient and no one selected extremely limited.

Figure 26 indicates in four of the five systems that a competent level of performance was selected by most of the participants. Ground proximity warning systems stands out with 80 percent of the participants selecting competent as the level of performance needed. The transponder systems had an equal number of selections for competent and highly proficient levels of performance.

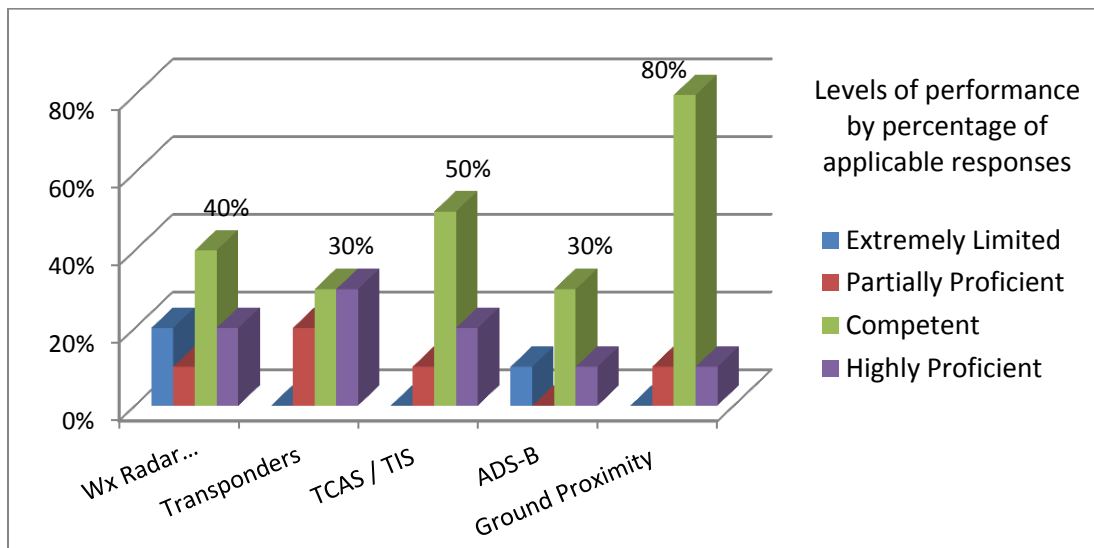


Figure 26. Aircraft pulse systems performance levels from commercial and regional airlines.

Knowledge level general and business aviation.

Weather radar systems knowledge level responses included: 14 (34.1%) with advanced theory and troubleshooting knowledge, six (14.6%) having theory and integration knowledge level, 13 (31.7%) with knowledge of basic theory and operation, and no one selected only knowledge of basic facts and terms. Mode A, C, and S Transponders knowledge level responses included: four (9.8%) advanced theory and troubleshooting, six (14.6%) theory and integration, four (9.8%) basic theory and

operation, and one (2.4%) basic facts and terms. TCAS / TIS systems knowledge level responses included: five (12.2%) advanced theory and troubleshooting, four (9.8%) theory and integration, three (7.3%) basic theory and operation, and no one selected basic facts and terms. ADS-B systems knowledge level responses included: no one selecting advanced theory and troubleshooting, five (12.2%) theory and integration, nine (21.6%) basic theory and operation, and one (2.4%) basic facts and terms. Ground proximity warning systems knowledge level responses included: two (4.9%) advanced theory and troubleshooting, four (9.8%) theory and integration, six (14.6%) basic theory and operation, and two (4.9%) basic facts and terms.

Figure 27 indicates advanced theory and troubleshooting was selected most often in weather radar systems, transponder systems and in ground proximity warning systems. Theory and integration was selected most often in the traffic and ADS-B systems. Two participants selected the knowledge level basic facts and terms in ground proximity warning systems with no selections for this level in the other systems.

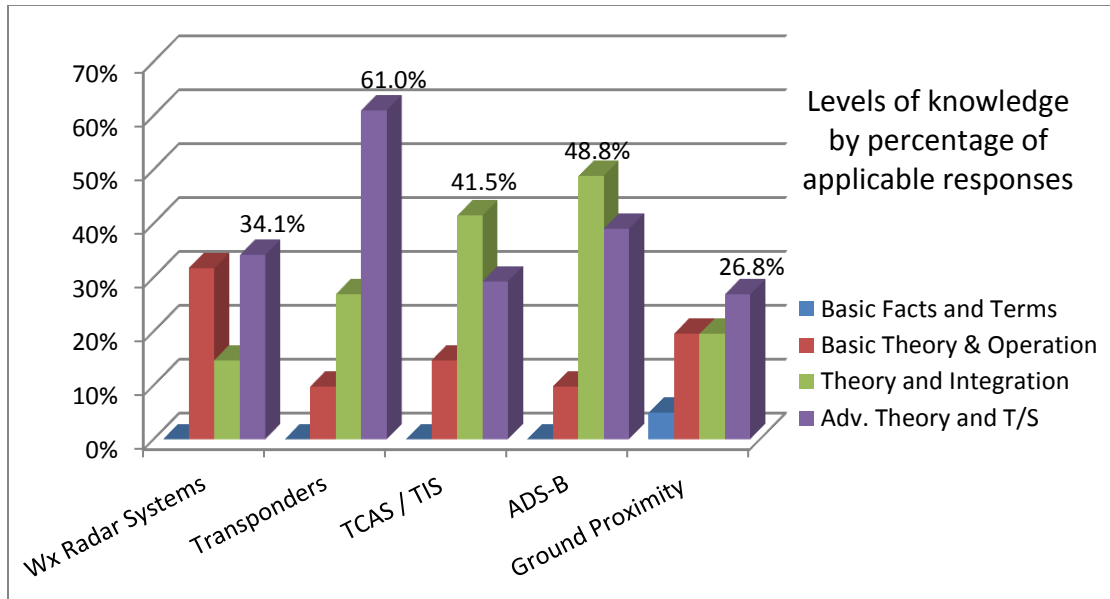


Figure 27. Aircraft pulse systems knowledge level from the general and business aviation sector.

Performance level general and business aviation.

Weather radar Systems performance level responses included: four (9.8%) highly proficient, eight (19.5%) competent, one (2.4%) partially proficient and one (2.4%) extremely limited. Mode A, C, and S Transponders performance level responses included: four (9.8%) highly proficient, eight (19.5%) competent, two (4.9%) partially proficient and one (2.4%) extremely limited. TCAS / TIS systems performance level responses included: four (9.8%) highly proficient, six (14.6%) competent, one (2.4%) partially proficient and one (2.4%) extremely limited. ADS-B systems performance level responses included: no one selecting highly proficient, ten (24.4%) competent, four (9.8%) partially proficient and one (2.4%) extremely limited. Ground proximity systems performance level responses included: no one selecting highly proficient, 11 (26.8%) competent, two (4.9%) partially proficient and one (2.4%) extremely limited.

Figure 28 indicates participants in the general and business aviation sector selected the competent performance level most often for these aircraft pulse systems. The highly proficient performance level was the second most selected choice. Ground proximity warning systems had equal selections for competent and highly proficient performance levels.

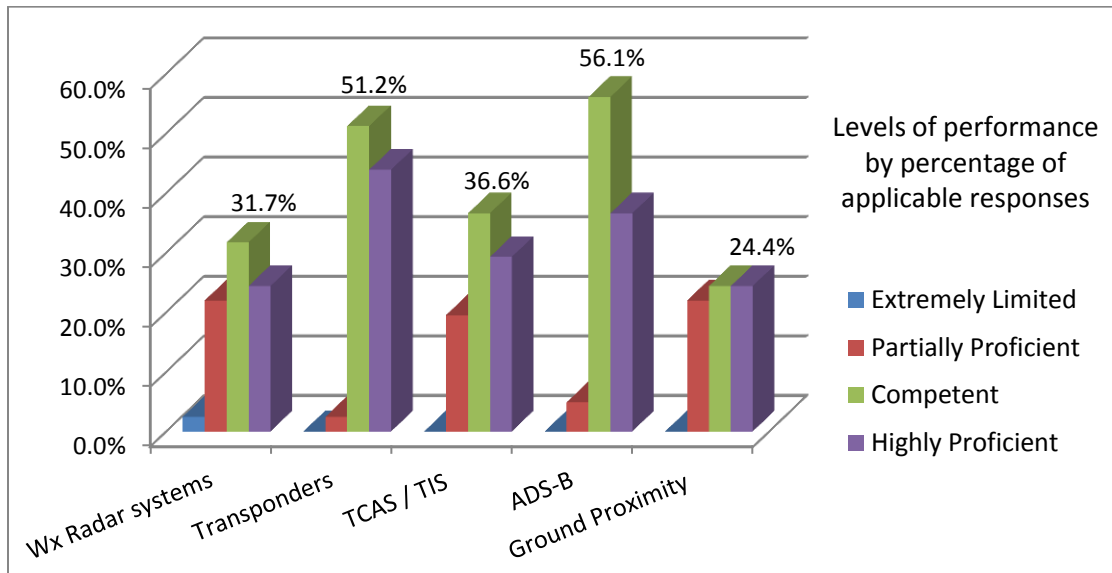


Figure 28. Aircraft pulse systems performance levels for general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated pulse systems work included weather radar, transponders, TCAS / TIS, ADS-B, and ground proximity warning systems. The knowledge level selected for weather radar, TCAS / TIS, and ground proximity warning systems was theory and integration. Transponders and ADS-B systems had the knowledge level advanced theory and troubleshooting. The TCAS / TIS systems performance level was partially proficient and

for weather radar, transponders, ADS-B, and ground proximity warning systems competent was the performance level selected.

Advanced avionics systems

Participants were asked to select each of the advanced avionics systems that are applicable to their shops. The choices provided included; basic two and three screen EFIS, advanced multi-screen EFIS, 429 and other data bus formats, fiber optics, micro-electro-mechanical-sensors (MEMS), airborne internet connectivity, engine performance analyzers, fly-by-wire systems, and not applicable. Participants were then asked to describe the knowledge and performance levels for technicians performing installation, service, or repair of each advanced avionics system selected. Knowledge level was distinguished by selecting one of four levels; basic facts and terms, basic theory and operation, theory and integration, advanced theory and troubleshooting. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector, three participants' selected not applicable leaving 22 (88%) responses that work with at least one of these advanced avionics systems. Twenty one (95.5%) of 22 participants selected 429 and other data bus formats. While five (22.7%) participants selected 429 and other data bus formats as the only system of this set they work with. Basic two and three screen EFIS was selected by 12 (54.5%) participants and advanced multi-screen EFIS was selected by 13 (59.1%) participants. Fiber optics was selected by two (9.1%) participants while MEMS were selected by five (22.7%)

participants. Airborne internet connectivity was selected by three (13.6%) participants. Engine performance analyzers were selected by six (27.3%) participants and fly-by-wire systems were selected by seven (31.8%) participants.

The data showed that of the 42 participant responses from the general and business sector, four participants selected not applicable leaving 38 (90.5%) responses who work with at least one of these advanced avionics systems. Thirty six (94.7%) of 38 participants selected basic two and three screen EFIS as an advanced avionics system they work with. While a single (2.6%) participant selected basic two and three screen EFIS as the only system of this set they work with. Two (5.3%) participants selected 429 and other data bus formats as the only one of these advanced avionics systems they work with. Basic two and three screen EFIS was selected by 36 (94.7%) participants and advanced multi-screen EFIS was selected by 28 (73.7%) participants. ARINC 429 and other data bus formats were selected by 34 (89.5%) participants while fiber optics was selected by seven (18.4%) participants. MEMS were selected by four (10.5%) participants and airborne internet connectivity was selected by 16 (42.1%) participants. Engine performance analyzers were selected by 25 (65.8) participants and fly-by-wire systems were selected by four (10.5%) participants.

Figure 29 highlights the low numbers associated with fiber optics by both sectors; 18 % and 9 % respectively. The low value of 11% for general and business aviation in both MEMS and fly-by-wire systems also stands out. The large differences of 14% of commercial and regional airlines sector compared to the 42% of the general and business aviation sector in internet connectivity systems represents a noteworthy difference. The 66% of general and business aviation sector compared with the 27% of the commercial

and regional airlines sector in engine performance analyzers also represents substantial differences.

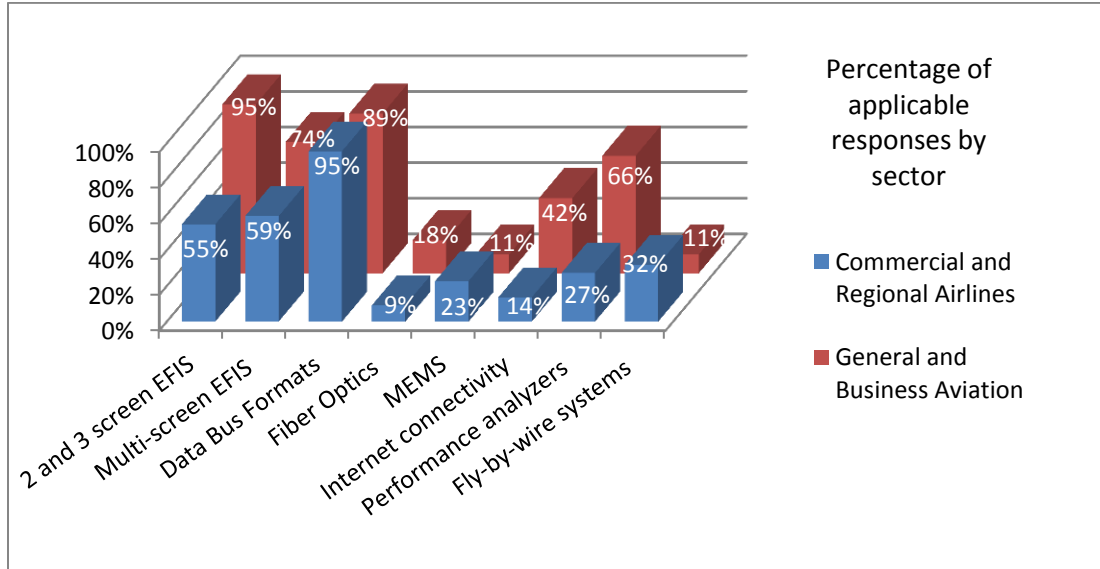


Figure 29. Advanced avionics systems installed, repaired, or serviced by sector.

Knowledge levels for commercial and regional airlines.

Basic two and three screen EFIS knowledge level responses included: four (18.2%) advanced theory and troubleshooting, three (13.6%) theory and integration, five (22.7%) basic theory and operation, and no one selected basic facts and terms. Multi-screen EFIS knowledge level responses included: five (22.7%) advanced theory and troubleshooting, four (18.2%) theory and integration, three (13.6%) basic theory and operation, and one (4.5%) basic facts and terms. ARINC 429 and other Data Bus Formats knowledge level responses included: six (27.3%) advanced theory and troubleshooting, seven (31.8%) theory and integration, five (22.7%) basic theory and operation, and three (13.6%) basic facts and terms. Fiber optics knowledge level responses included: one (4.5%) advanced theory and troubleshooting, one (4.5%) theory and integration, and no

one selected basic theory and operation, or basic facts and terms. MEMS knowledge level responses included: three (13.6%) advanced theory and troubleshooting one (4.5%) theory and integration, no one selected basic theory and operation, and one (4.5%) selection for basic facts and terms. Airborne internet connectivity knowledge level responses included: two (9.1%) advanced theory and troubleshooting, no one selected theory and integration, one (4.5%) basic theory and operation, and no one selected basic facts and terms. Engine performance analyzers knowledge level responses included: three (13.6%) advanced theory and troubleshooting, one (4.5%) theory and integration, two (9.1%) basic theory and operation, and no one selected basic facts and terms. Fly-by-wire systems knowledge level responses included: one (4.5%) advanced theory and troubleshooting, three (13.6%) theory and integration, one (4.5%) basic theory and operation, and two (9.1%) basic facts and terms.

Figure 30 indicates the higher levels of knowledge were selected for most of these advanced avionics systems. Advanced theory and troubleshooting was selected by more participants working with multi screen EFIS, MEMS, internet connectivity, and performance analyzers. Theory and integration was selected most often by those working with data bus formats and fly-by-wire systems. The two and three screen EFIS systems were the only system where basic theory and operation was selected more often than the higher knowledge levels.

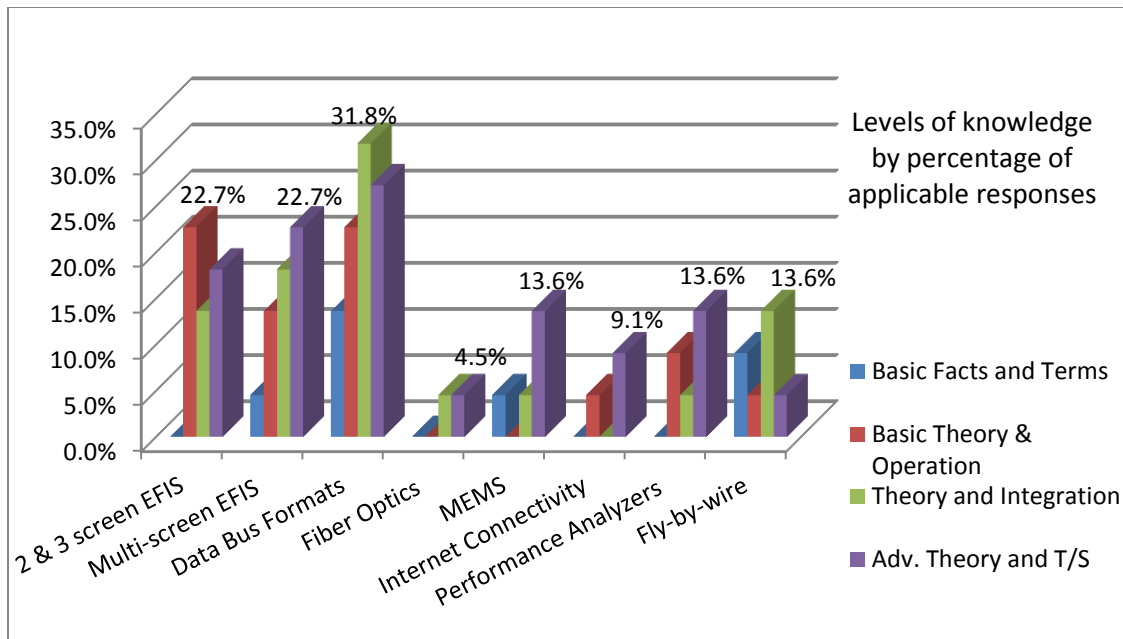


Figure 30. Advanced avionics systems knowledge levels from commercial and regional airlines.

Performance levels commercial and regional airlines.

Performance level responses for basic two and three screen EFIS included: three (13.6%) highly proficient, eight (36.4%) selections for competent, one (4.5%) partially proficient, and no one selected extremely limited. Multi-screen EFIS performance level responses included: two (9.1%) highly proficient, eight (36.4%) competent, three (13.6%) partially proficient, and no one selected extremely limited. ARINC 429 and other data bus formats performance level responses included: five (22.7%) highly proficient, 11 (50%) competent, two (9.1%) partially proficient, and three (13.6%) extremely limited. Fiber optics performance level responses included: no one selection for highly proficient, two (9.1%) selections for competent, and no one selected partially proficient or extremely limited. MEMS performance level responses included: one (4.5%) highly proficient,

three (13.6%) competent, while no one selected partially proficient or extremely limited. Airborne internet connectivity performance level responses included: one (4.5%) highly proficient, one (4.5%) competent, one (4.5%) selection for partially proficient, and on one selected extremely limited. Engine performance analyzers performance level responses included: three (13.6%) highly proficient, one (4.5%) competent, two (9.1%) selections for partially proficient, and on one selection for extremely limited. Fly-by-wire systems performance level responses included: no one selected highly proficient, five (22.7%) selected competent, one (4.5%) partially proficient, and one (4.5%) selection for extremely limited.

Figure 31 indicates the performance level of competent was selected most often in all but two of these advanced systems. The chart shows performance levels for internet connectivity are evenly spread across highly proficient, competent, and partially proficient, with all at 4.5%. Performance analyzers were the only systems where highly proficient was selected more often than the other choices.

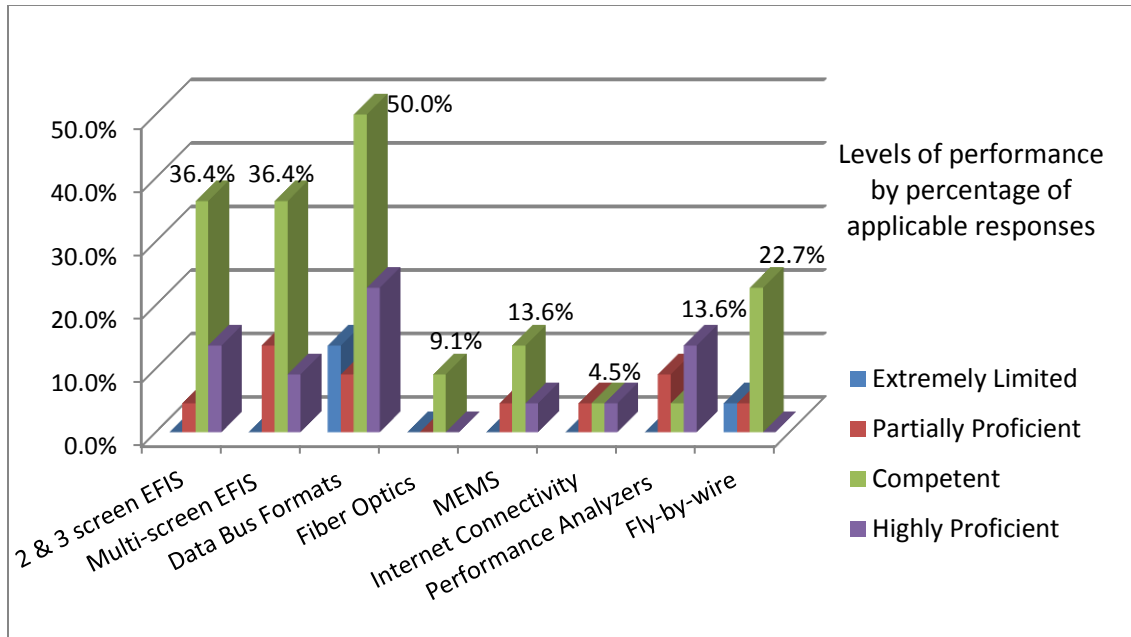


Figure 31. Advanced avionics systems performance levels from commercial and regional airlines sector.

Knowledge level general and business aviation.

Basic two and three screen EFIS knowledge level responses included: ten (26.3%) with advanced theory and troubleshooting knowledge, 17 (44.7%) having theory and integration knowledge level, seven (18.4%) with knowledge of basic theory and operation, and two (5.3%) selected knowledge of basic facts and terms. Multi-screen EFIS knowledge level responses included: nine (23.7%) advanced theory and troubleshooting, ten (26.3%) theory and integration, eight (21.1%) basic theory and operation, and one (2.6%) basic facts and terms. ARINC 429 and other data bus formats knowledge level responses included: 11(28.9%) advanced theory and troubleshooting, 17 (44.7%) theory and integration, six (15.8%) basic theory and operation, and no one selected basic facts and terms. Fiber Optics knowledge level responses included: no one

selected advanced theory and troubleshooting, two (5.3%) theory and integration, five (13.2%) basic theory and operation, and no one selected basic facts and terms. MEMS knowledge level responses included: no one selected advanced theory and troubleshooting, three (7.9%) theory and integration, one (2.6%) basic theory and operation, and no one selected basic facts and terms. Airborne internet connectivity knowledge level responses included: four (10.5%) advanced theory and troubleshooting, nine (23.7%) theory and integration, two (5.3%) basic theory and operation, and one (2.6%) basic facts and terms. Engine performance analyzers knowledge level responses included: four (10.5%) advanced theory and troubleshooting, 14 (36.8%) theory and integration, six (15.8%) basic theory and operation, and one (2.6%) basic facts and terms. Fly-by-wire systems knowledge level responses included: no one selected advanced theory and troubleshooting or theory and integration, four (10.5%) selected basic theory and operation, and no one selected basic facts and terms.

Figure 32 indicates a knowledge level of theory and integration was selected most often in all of these advanced systems except two. Basic theory and operation knowledge level was selected more often in both fiber optics and fly-by-wire systems by the participants in the general and business aviation sector. There were four participants in the general and business aviation sector that worked with fly-by-wire systems and all selected basic theory and operation as the knowledge level required when working with these systems.

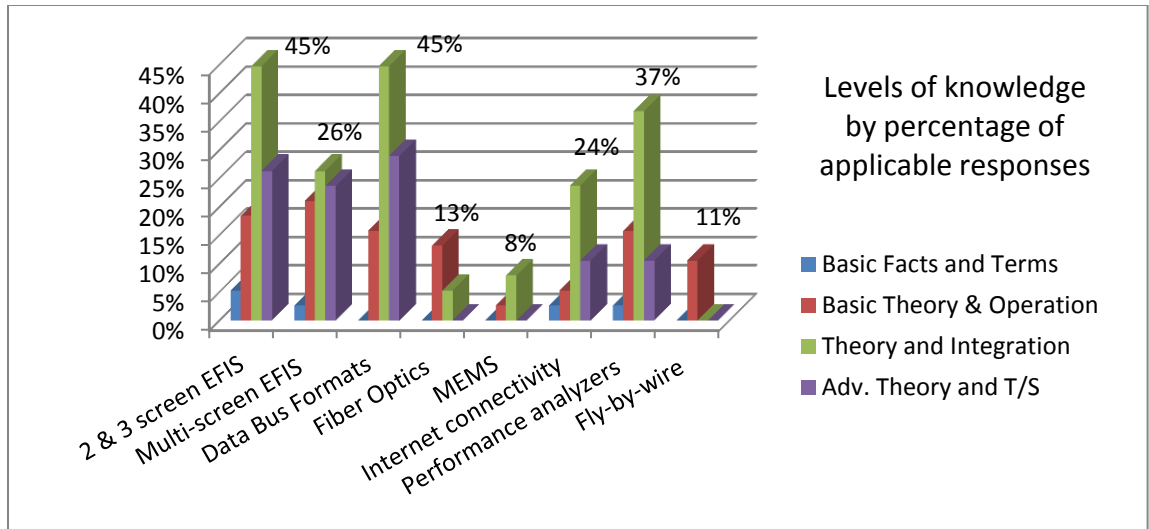


Figure 32. Advanced avionics systems knowledge levels for general and business aviation.

Performance level general and business aviation.

Performance level responses for basic two and three screen EFIS included eight (21.1%) highly proficient, 20 (52.6%) selections for competent, eight (21.1%) partially proficient, and no one selected extremely limited. Multi-screen EFIS performance level responses included: ten (26.3%) highly proficient, 11 (28.9%) competent, seven (18.4%) partially proficient, and no one selected extremely limited. ARINC 429 and other data bus formats performance level responses included: seven (18.4%) highly proficient, 21(55.3%) competent, six (15.8%) partially proficient, and no one selected extremely limited. Fiber optics performance level responses included: no selection for highly proficient, two (5.3%) selections for competent, and five (13.2%) selected partially proficient, and no one selected extremely limited. MEMS performance level responses included: no selections for highly proficient, one (2.6%) selection for competent, three selections for partially proficient, and no one selected extremely limited. Airborne internet connectivity

performance level responses included: five (13.2%) highly proficient, nine (23.7%) competent, one (2.6%) selection for partially proficient, and one (2.6%) selection for extremely limited. Engine performance analyzers performance level responses included: four (10.5%) highly proficient, 15 (39.5%) competent, six (15.8%) partially proficient, and on one selected extremely limited. Fly-by-wire systems performance level responses included: no selection for highly proficient, two (5.3%) selected competent, two (5.3%) partially proficient, and no one selected extremely limited.

Figure 33 indicates the competent level of performance was selected most often on five of these advanced avionics systems. Fiber optics and MEMS systems had more selections for partially proficient. Fly-by wire had equal selections for competent and partially proficient.

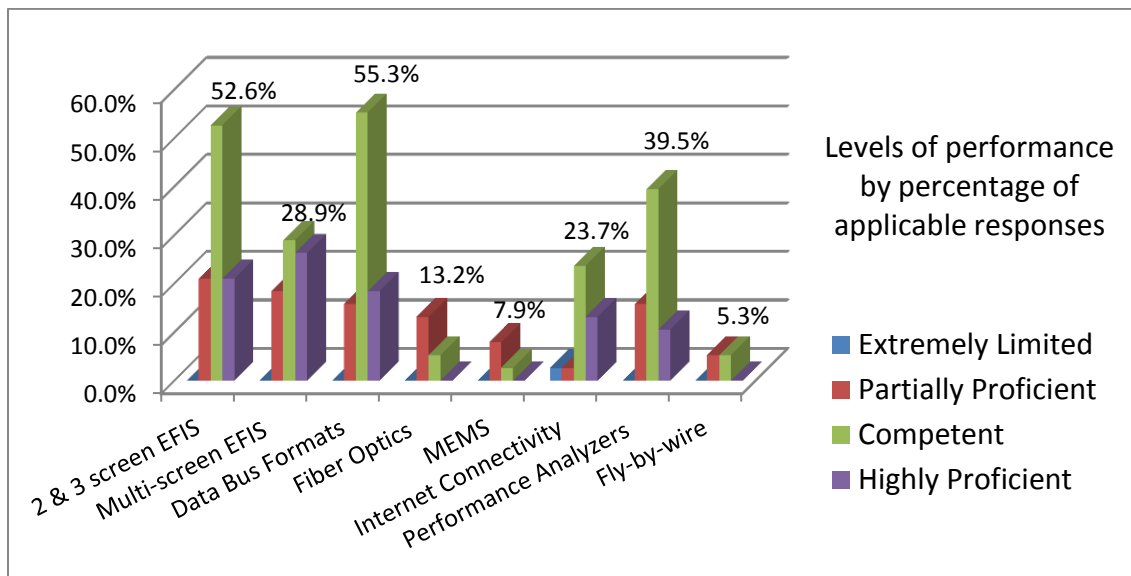


Figure 33. Advanced avionics systems performance levels from general and business aviation.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated advanced avionics systems work included basic two and three screen EFIS, multi-screen EFIS, ARINC 429 and other data bus formats. The knowledge level selected for ARINC 429 and other data bus formats was theory and integration. Basic two and three screen EFIS and multi-screen EFIS systems had the knowledge level advanced theory and troubleshooting. The basic two and three screen EFIS, multi-screen EFIS, ARINC 429 and other data bus formats all had the performance level competent selected.

Shop Tools, Equipment, and Processes

Determining the knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry requires knowing what tools, equipment, and processes the technicians are using. Advances occur in tooling and equipment which may require new or different training. Advances in tools, equipment, or materials may require new processes or changes to existing processes used in soldering and wiring aircraft electronics. This block of questions explores many of the common tools, equipment, and soldering and wiring processes associated with aircraft electronics maintenance.

Shop tools.

Participants were asked to select each of the shop tools that are applicable to their shops. The choices provided included; hot air soldering station, pneumatic powered hand tools, electric powered hand tools, grinders and sanders, sheet metal benders sheers and saws, bearing press, and not applicable. Participants were then asked to describe the knowledge and performance levels for understanding and usage of the shop tools

selected. Knowledge level was distinguished by selecting one of four levels; understands tool purpose, knows tool safety, knows operating procedures, knows care and maintenance. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector one (4%) participant selected not applicable leaving 24 responses that work with at least one of these shop tools. Eighteen (75%) of the participants selected hot air soldering stations as tools they work with while 13 (54.2%) participants selected pneumatic powered hand tools. Electric powered hand tools were selected by 19 (79.2%) of the 24 participants with grinders and sanders selected by 13 (54.2%) participants. Sheet metal benders, sheers and saws were selected by seven (29.2%) of the participants and bearing press was selected by four (16.7%) participants.

The data showed that of the 42 participant responses from the general and business sector, two (4.8%) of the participants selected not applicable leaving 40 (95.2%) of the responses who work with at least one of these shop tools. A total of 26 (65%) participants selected hot air soldering stations as tools they work with while 36 (90%) selected pneumatic powered hand tools. Electric powered hand tools were selected by 37 (92.5%) participants with grinders and sanders selected by 36 (90%) participants. Sheet metal benders, sheers and saws were selected by 35 (87.5%) participants and bearing press was selected by 12 (30%) participants.

The figure 34 is a visual representation of the data on shop tools applicable to avionics shops by business sectors. The figure clearly indicates greater usage of these

tools by the general aviation sector with the exception of the hot air soldering station. The figure also indicates extensive use of sheet metal working tools such as the benders sheers and saws in the general aviation sector as compared to the lack of use of these tools by the commercial sector.

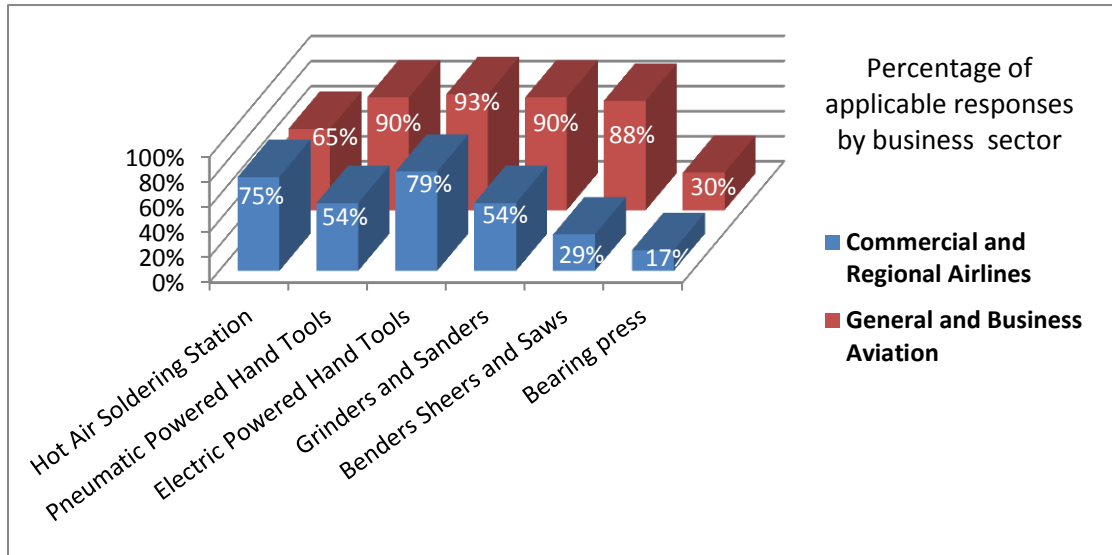


Figure 34. Shop tools applicable to avionics shops by sector.

Knowledge level commercial and regional airlines.

Hot air soldering station knowledge level responses included: nine (37.5%) participants selecting knows care and maintenance, eight (33.3%) participants selecting knows operating procedures, one (4.2%) selecting knows tool safety, and no one selected understands tool purpose. Pneumatic powered hand tools knowledge level responses included five (20.8%) selections for knows care and maintenance, five (20.8%) knows operating procedures, three (12.5%) knows tool safety, and no one selected understands tool purpose. Electric powered hand tools knowledge level responses included seven (29.2%) knows care and maintenance, nine (37.5%) knows operating procedures, two

(8.3%) knows tool safety, and one (4.2%) participant selected understands tool purpose. Grinders and sanders knowledge level responses included six (25%) knows care and maintenance, four (16.7%) knows operating procedures, three (12.5%) knows tool safety, and no one selected understands tool purpose. Sheet metal benders, sheers, and saws knowledge level responses included two (8.3%) knows care and maintenance, five (20.8%) knows operating procedures, and no selections for knows tool safety or understands tool purpose. Bering press knowledge level responses included three (12.5%) knows care and maintenance, one (4.2%) knows operating procedures, and no selections for knows tool safety or understands tool purpose.

Figure 35 indicates the percentage of participants selecting each knowledge level for shop tools applicable to avionics shops. The chart shows the highest level of knowledge, knows care and maintenance was selected more often for hot air soldering stations, grinders and sanders, and bearing presses. Knows operating procedures was selected most often for electric hand tools and benders sheers and saws.

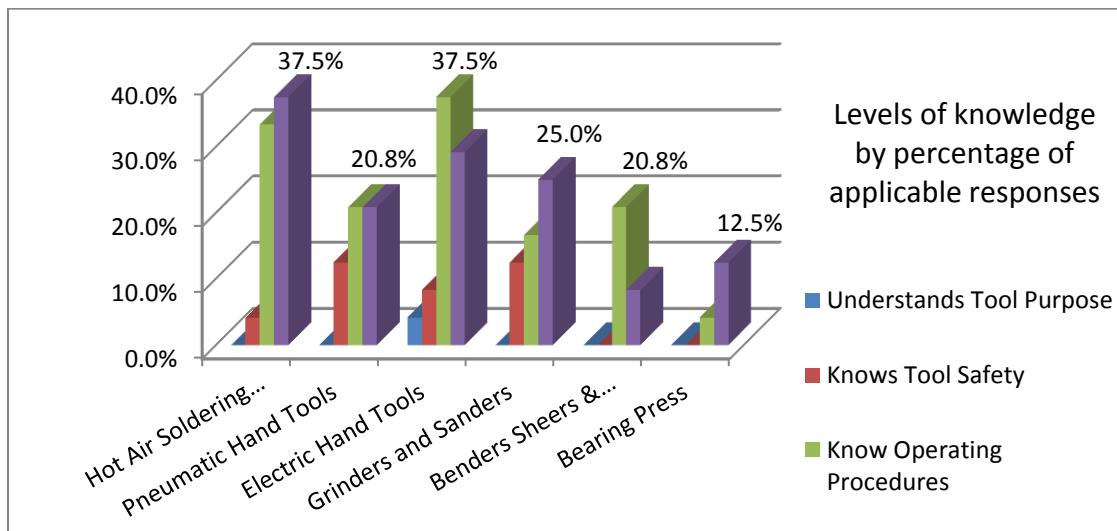


Figure 35. Shop tools knowledge level from the commercial and regional airlines sector.

Performance level commercial and regional airlines.

Hot air soldering station performance level responses included: 13 (54.2%) highly proficient, four (16.7%) competent, one (4.2%) partially proficient and no selections for extremely limited. Pneumatic powered hand tools performance level responses included: four (16.7%) highly proficient, seven (29.2%) competent, two (8.3%) partially proficient and no one selected extremely limited. Electric powered hand tools performance level responses included: six (25%) highly proficient, 11 (45.8%) competent, two (8.3%) partially proficient and no one selected extremely limited. Grinders and sanders performance level responses included: four (16.7%) highly proficient, seven (29.2%) competent, two (8.3%) selected partially proficient and no one selected extremely limited. Sheet metal benders, sheers, and saws performance level responses included: one (4.2%) highly proficient, five (20.8%) competent, no selections for partially proficient and one (4.2%) selection for extremely limited. Bering press performance level responses included: two (8.3%) highly proficient, one (4.2%) competent, one (4.2%) partially proficient and no one selected extremely limited.

Figure 36 indicates the percentage of participants selecting each performance level for shop tools applicable to avionics shops. The chart shows the performance level of competent was selected most often in both pneumatic and electric powered hand tools, grinders and sanders, and benders, sheers, and saws. Hot air soldering stations and bearing presses had highly proficient level of performance selected most often.

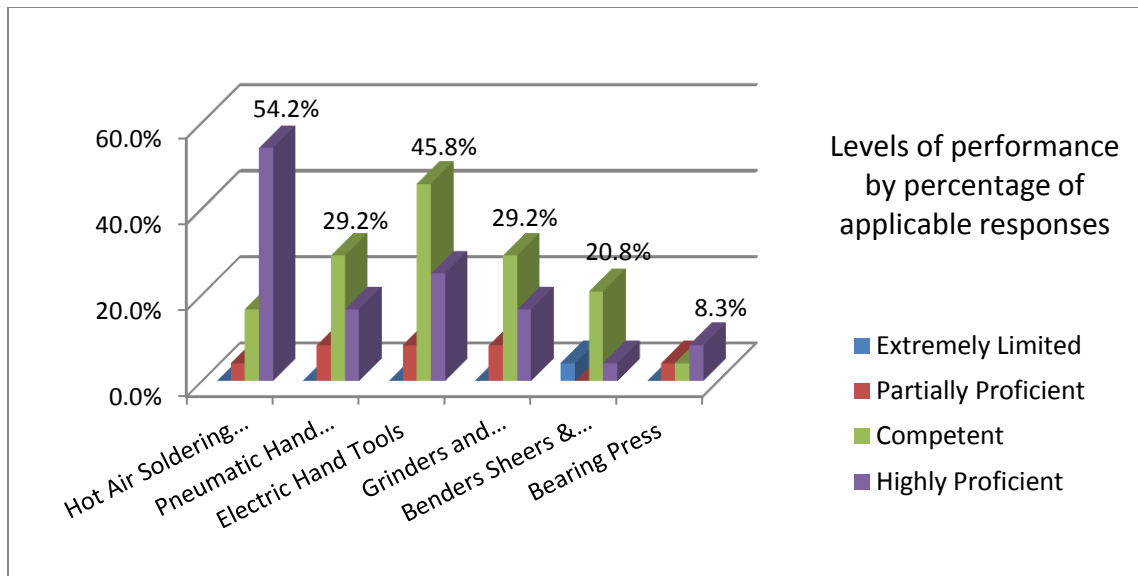


Figure 36. Shop tools performance levels from the commercial and regional airlines sector.

Knowledge level general and business aviation.

Hot air soldering station knowledge level responses included: ten (23.8%) participants selecting knows care and maintenance, 12 (28.6%) participants selecting knows operating procedures, no selections for knows tool safety, and two (4.8%) understands tool purpose.-Pneumatic powered hand tools knowledge level responses included 16 (38.1%) participants selecting knows care and maintenance, 17 (40.5%) participants selecting knows operating procedures, two (04.8%) selecting knows tool safety, and no selections for understands tool purpose. Electric powered hand tools knowledge level responses included 17 (40.5%) participants selecting knows care and maintenance, 15 (35.7%) participants selecting knows operating procedures, two (4.8%) selecting knows tool safety, and one (2.4%) selecting understands tool purpose.

Figure 37 indicates the percentage of participants selecting each knowledge level for shop tools applicable to avionics shops. The chart shows the highest level of knowledge, knows care and maintenance was selected more often for electric powered hand tools. Knows operating procedures was selected most often for all other tool groups with the highest level of knowledge, knows care and maintenance as a close second.

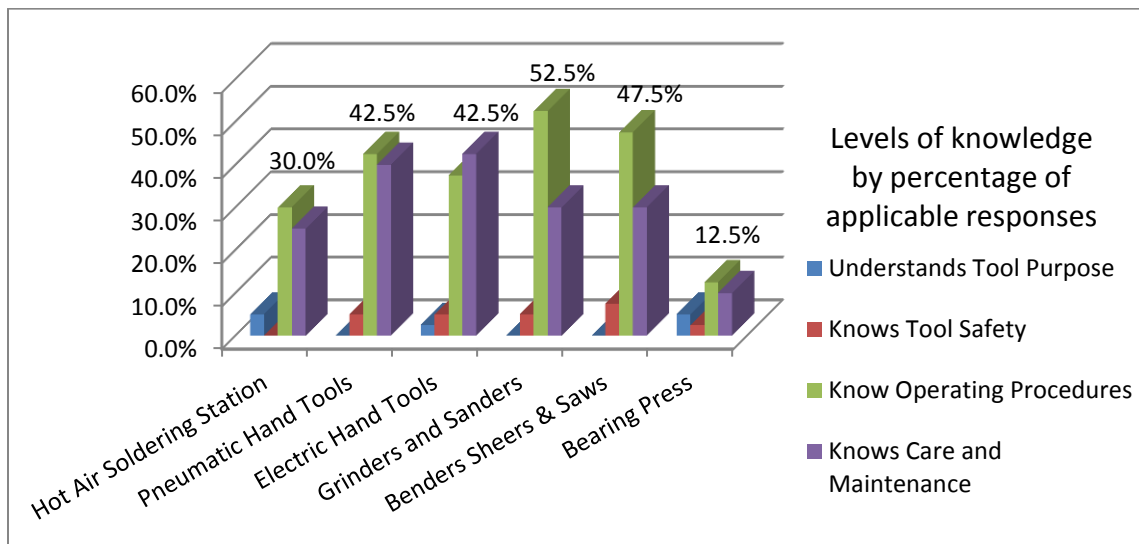


Figure 37. Shop tools knowledge levels from the general and business aviation sector.

Performance level general and business aviation.

Hot air soldering station performance level responses included: seven (17.5%) highly proficient, 14 (35%) competent, three (7.5%) partially proficient and no selections for extremely limited. Pneumatic powered hand tools performance level responses included: 15 (37.5%) highly proficient, 18 (45%) competent, two (5%) partially proficient and no one selected extremely limited. Electric powered hand tools performance level responses included: 17 (42.5%) highly proficient, 16 (40%) competent, two (5%) partially proficient and no one selected extremely limited. Grinders and sanders

performance level responses included: 14 (35%) highly proficient, 18 (45%) competent, three (7.5%) selected partially proficient and no one selected extremely limited. Sheet metal benders, sheers, and saws performance level responses included: 13 (32.5%) highly proficient, 18 (45%) competent, no selections for partially proficient or extremely limited. Bering press performance level responses included: four (10%) highly proficient, six (15%) competent, two (5%) partially proficient and no one selected extremely limited.

Figure 38 indicates the percentage of participants selecting each performance level for shop tools applicable to avionics shops. The chart shows the performance level of competent was selected most often in all tool groups with highly proficient as a close second. Electric powered hand tools had highly proficient level of performance selected most often with competent as a close second.

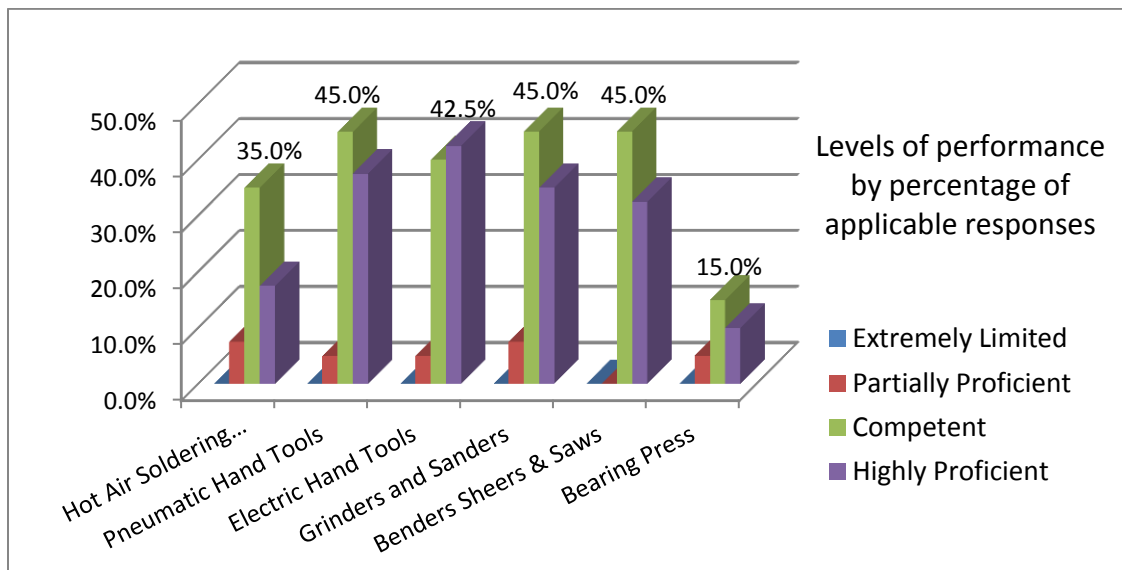


Figure 38. Shop tools performance levels from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated shop tools worked with included hot air soldering station, electric powered hand tools, and sheet metal benders sheers and saws. The knowledge level selected for electric powered hand tools was knows operating procedures. Hot air soldering station and sheet metal benders sheers and saws had the knowledge level knows care and maintenance selected. The electric powered hand tools performance level was competent and for hot air soldering station and sheet metal benders sheers and saws highly proficient was the performance level selected.

Shop equipment.

Participants were asked to select each of the shop equipment units that are applicable to technicians working in their shop. The choices provided included; volt meter, O-scope, battery chargers, pitot/static and air data testers, IFR 4000 ramp tester or equivalent, IFR 6000 ramp tester or equivalent, S-1403DL mode-S test set or equivalent, ATC1400A DME TXP test set or equivalent, and RD-300 radar test set or equivalent. Participants were then asked to describe the knowledge and performance levels for understanding and usage of the shop equipment selected. Knowledge level was distinguished by selecting one of four levels; identify parts and controls, knows basic procedures, knows principles of operation, and advanced understanding. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector all 25 (100%) work with volt meters. Twenty-two (88%) of the

participants selected O-scope as equipment they work with while 19 (76%) participants selected battery chargers. Pitot/static and air data testers were selected by 10 (40%) participants with IFR 4000 ramp tester or equivalent selected by six (24%) participants. IFR 6000 ramp tester or equivalent was selected by seven (28%) participants and S-1403DL mode-S test set or equivalent was selected by two (8%) participants. ATC1400A DME TXP test set was selected by five (20%) participants and the RD-300 radar test set or equivalent was selected by three (12%) participants.

The data showed that of the 40 participant responses from the general and business sector all 40 (100%) work with volt meters. Thirty (75%) of the participants selected O-scope as equipment they work with while 31 (77.5%) participants selected battery chargers. Pitot/static and air data testers were selected by 39 (97.5%) participants with IFR 4000 ramp tester or equivalent selected by 30 (75%) participants. IFR 6000 ramp tester or equivalent was selected by 32 (80%) participants and S-1403DL mode-S test set or equivalent was selected by 19 (47.5%) participants. ATC1400A DME TXP test set was selected by 20 (50%) participants and the RD-300 radar test set or equivalent was selected by 10 (25%) participants.

Figure 39 is a visual representation of the data on shop equipment applicable to avionics shops by business sectors. The figure clearly indicates greater usage of the IFR 4000 and 6000 ramp testers and pitot/static testers by the general aviation sector. The figure also indicates more extensive use of the mode-S and DME TXP test equipment in the general aviation sector. The volt meter is a basic piece of test equipment used by all electronics technicians as indicated by the 100% in both sectors.

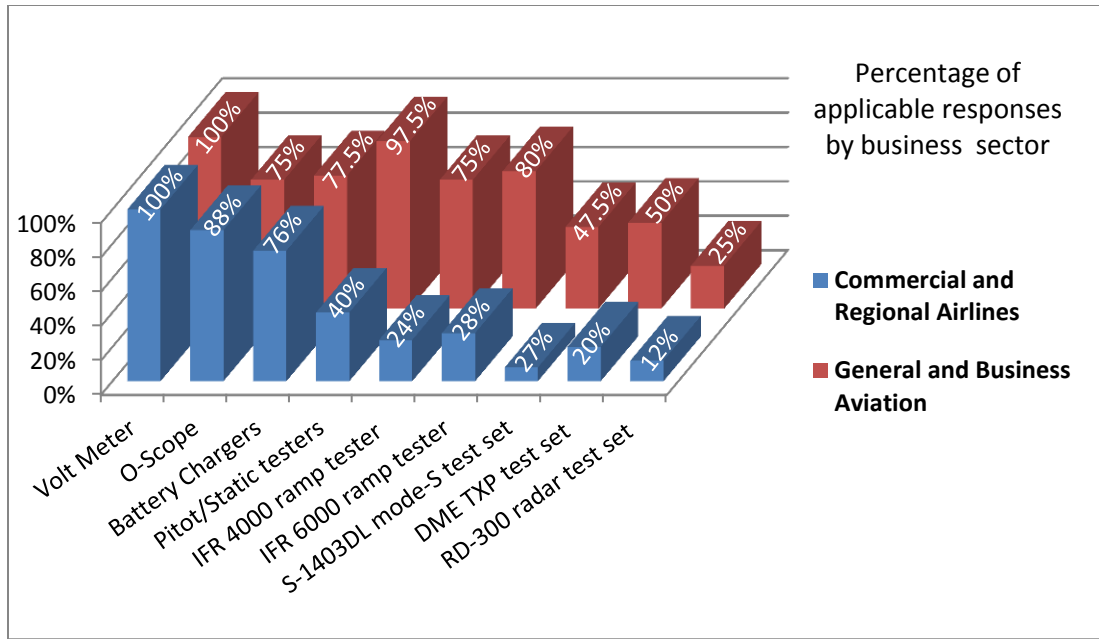


Figure 39. Shop equipment applicable to avionics shops by sector.

Knowledge level commercial and regional airlines.

Volt meter knowledge level responses included: 14 (56%) participants selecting advanced understanding, eight (32%) participants selecting knows principles of operation, three (12%) selecting knows basic procedures, and no one selected identify parts and controls. O-scope knowledge level responses included 11 (44%) selections for advanced understanding, nine (36%) knows principles of operation, two (8%) knows basic procedures, and no one selected identify parts and controls. Battery chargers knowledge level responses included five (20%) advanced understanding, 11 (44%) knows principles of operation, two (8%) knows basic procedures, and one (4%) participant selected identify parts and controls. Pitot/static and air data testers knowledge level responses included five (20%) advanced understanding, five (20%) knows principles of operation, and no one selected knows basic procedures or identify parts and

controls. IFR 4000 ramp tester or equivalent knowledge level responses included two (8%) advanced understanding, two (8%) knows principles of operation, two (8%) knows basic procedures and no selections identify parts and controls. IFR 6000 ramp tester or equivalent knowledge level responses included two (8%) advanced understanding, three (12%) knows principles of operation, two (8%) knows basic procedures, and no selections for identify parts and controls. S-1403DL mode-S test set or equivalent knowledge level responses included one (4%) advanced understanding, one (4%) knows principles of operation, and no one selected knows basic procedures or identify parts and controls. ATC1400A DME TXP test set or equivalent knowledge level responses included three (12%) advanced understanding, one (4%) knows principles of operation, one (4%) knows basic procedures and no selections identify parts and controls. RD-300 radar test set or equivalent knowledge level responses included two (8%) selections for advanced understanding, one (4%) knows principles of operation, and no selections for knows basic procedures or identify parts and controls.

Figure 40 indicates the percentage of participants selecting each knowledge level for shop equipment applicable to their avionics shop. The chart shows the highest level of knowledge, advanced understanding was selected most often for volt meter, O-scope and RD-300 radar test set or equivalent. The second highest level knows principle of operation was selected most often for battery chargers and IFR 6000 ramp tester or equivalent. Pitot/static and air data testers, IFR 4000 ramp tester or equivalent and S-1403DL mode-S test set or equivalent, all had the same percentage for advanced understanding and knows principles of operation.

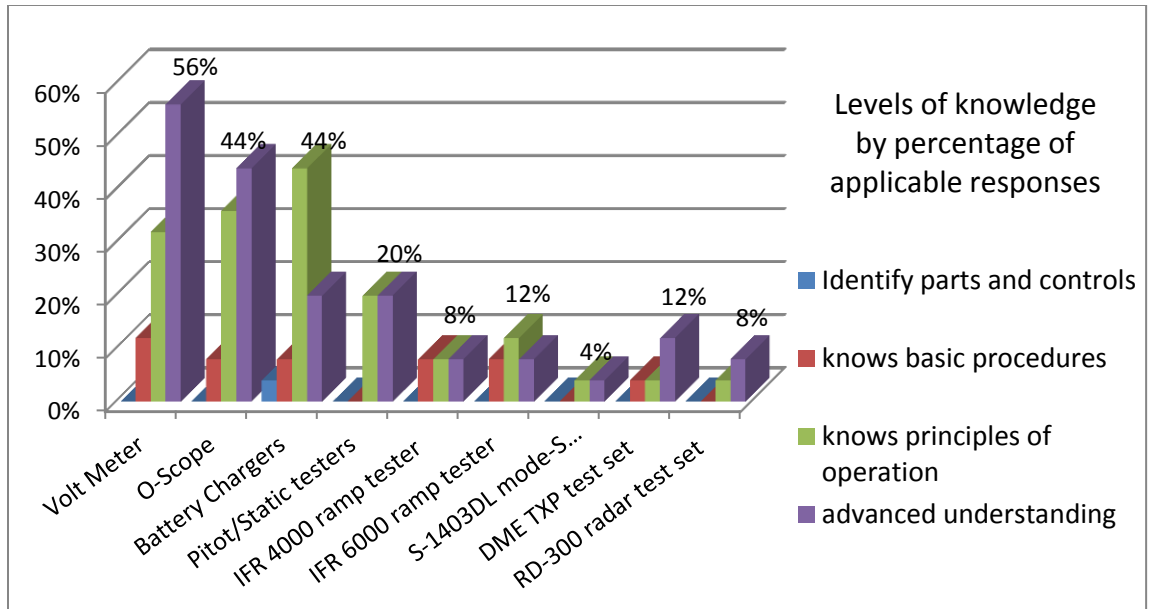


Figure 40. Shop equipment knowledge levels from the commercial and regional airlines sector.

Performance level commercial and regional airlines.

Volt meter performance level responses included: 14 (56%) highly proficient, seven (28%) competent, four (16%) partially proficient and no selections for extremely limited. O-scope performance level responses included: 12 (48%) highly proficient, six (24%) competent, four (16%) partially proficient and no one selected extremely limited. Battery chargers performance level responses included: seven (28%) highly proficient, eight (32%) competent, three (12%) partially proficient and one (4%) selected extremely limited. Pitot/static and air data testers performance level responses included: five (20%) highly proficient, four (16%) competent, one (4%) selected partially proficient and no one selected extremely limited. IFR 4000 ramp tester or equivalent performance level responses included: two (8%) highly proficient, three (12%) competent, one (4%)

selection for partially proficient and no one selected extremely limited. IFR 6000 ramp tester or equivalent performance level responses included: two (8%) highly proficient, four (16%) competent, one (4%) partially proficient and no one selected extremely limited. S-1403DL mode-S test set or equivalent performance level responses included: one (4%) highly proficient, one (4%) competent, and no one selected partially proficient or extremely limited. ATC1400A DME TXP test set or equivalent performance level responses included: four (16%) highly proficient, one (4%) competent, and no one selected partially proficient or extremely limited. RD-300 radar test set or equivalent performance level responses included: two (8%) highly proficient, one (4%) competent, and no one selected partially proficient or extremely limited.

Figure 41 indicates the percentage of participants selecting each performance level for shop tools applicable to avionics shops. The chart shows the performance level of competent was selected most often in both pneumatic and electric powered hand tools, grinders and sanders, and benders, sheers, and saws. Hot air soldering stations and bearing presses had highly proficient level of performance selected most often.

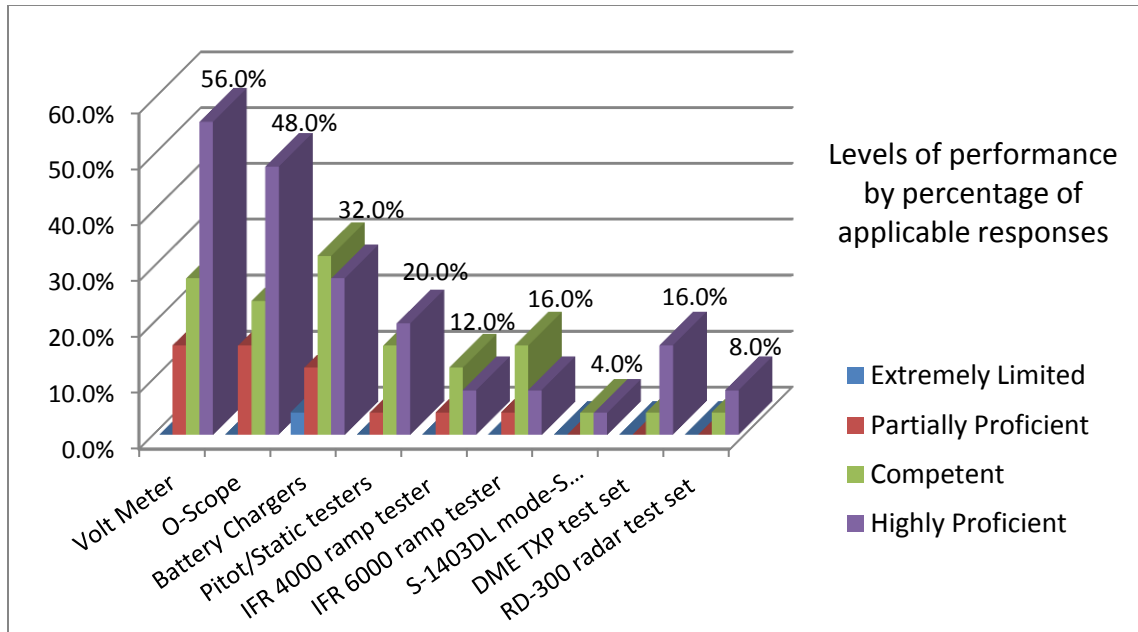


Figure 41. Shop equipment performance levels from the commercial and regional airlines sector.

Knowledge level general and business aviation.

Volt meter knowledge level responses included: 19 (47.5%) participants selecting advanced understanding, 18 (45%) participants selecting knows principles of operation, one (2.5%) selecting knows basic procedures, and one (2.5%) selection for identify parts and controls. O-scope knowledge level responses included 13 (32.5%) selections for advanced understanding, 10 (25%) knows principles of operation, five (10%) knows basic procedures, and one selection for identify parts and controls. Battery chargers knowledge level responses included 11 (27.5%) advanced understanding, 15 (37.5%) knows principles of operation, four (10%) knows basic procedures, and no one selected identify parts and controls. Pitot/static and air data testers knowledge level responses included 24 (60%) advanced understanding, 13 (32.5%) knows principles of operation,

one (2.5%) knows basic procedures, and no one selected identify parts and controls. IFR 4000 ramp tester or equivalent knowledge level responses included 10 (25%) advanced understanding, 18 (45%) knows principles of operation, no one selected knows basic procedures and one (2.5%) selection for identify parts and controls. IFR 6000 ramp tester or equivalent knowledge level responses included 13 (32.5%) advanced understanding, 17 (42.5%) selecting knows principles of operation, one (2.5%) knows basic procedures, and no selections for identify parts and controls. S-1403DL mode-S test set or equivalent knowledge level responses included: seven (17.5%) advanced understanding, 11 (27.5%) knows principles of operation, and no one selected knows basic procedures or identify parts and controls. ATC1400A DME TXP test set or equivalent knowledge level responses included 10 (25%) advanced understanding, nine (22.5%) knows principles of operation, and no one selected knows basic procedures or identify parts and controls. RD-300 radar test set or equivalent knowledge level responses included five (12.5%) selections for advanced understanding, four (10%) knows principles of operation, and no selections for knows basic procedures or identify parts and controls.

Figure 42 indicates the percentage of participants selecting each knowledge level for shop equipment applicable to their avionics shop. The chart shows the highest level of knowledge, advanced understanding was selected most often for volt meter, O-scope, pitot/static and air data testers, ATC1400A DME TXP test set or equivalent and RD-300 radar test set or equivalent. The second highest level, knows principle of operation was selected most often for battery chargers IFR 4000 ramp tester or equivalent, IFR 6000 ramp tester or equivalent and S-1403DL mode-S test set or equivalent.

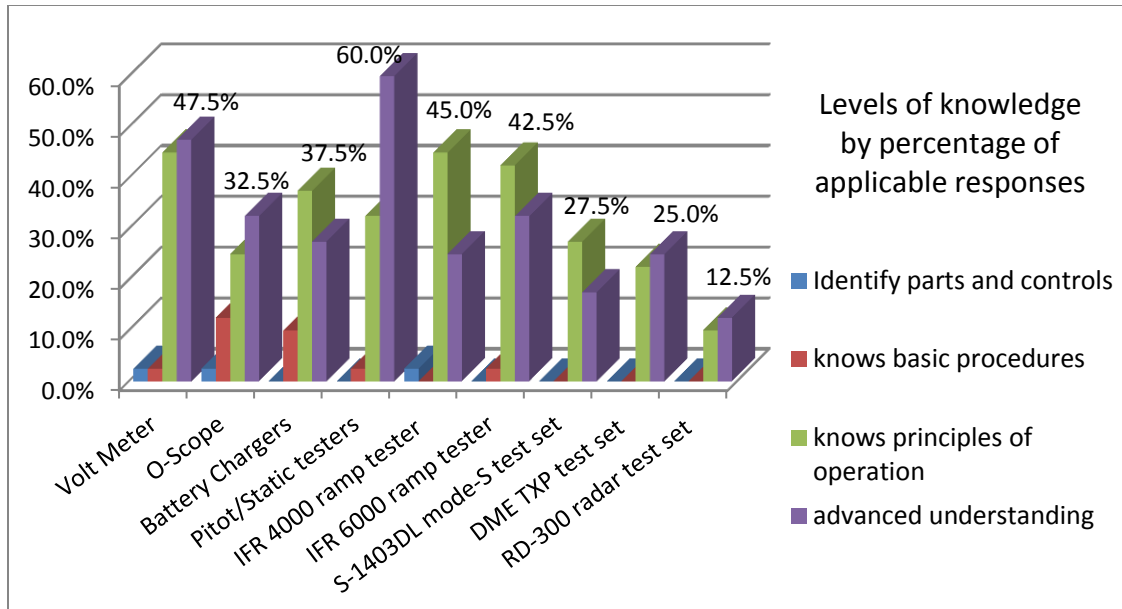


Figure 42. Shop equipment knowledge levels from the general and business aviation sector.

Performance level general and business aviation.

Volt meter performance level responses included: 19 (47.5%) highly proficient, 18 (45%) competent, one (2.5%) partially proficient and one (2.5%) selection for extremely limited. O-scope performance level responses included: 13 (32.5%) highly proficient, 10 (25%) competent, five (12.5%) partially proficient and one (2.5%) selection for extremely limited. Battery chargers performance level responses included: 11 (27.5%) highly proficient, 15 (37.5%) competent, four (10%) partially proficient, and no one selected extremely limited. Pitot/static and air data testers performance level responses included: 24 (60%) highly proficient, 13 (32.5%) competent, one (2.5%) selected partially proficient and no one selected extremely limited. IFR 4000 ramp tester or equivalent performance level responses included: 10 (25%) highly proficient, 18

(45%) competent, no one selected partially proficient and one (2.5%) selection extremely limited. IFR 6000 ramp tester or equivalent performance level responses included: 13 (32.5%) highly proficient, 17 (42.5%) competent, one (2.5%) partially proficient and no one selected extremely limited. S-1403DL mode-S test set or equivalent performance level responses included: seven (17.5%) highly proficient, 11 (27.5%) competent, and no one selected partially proficient or extremely limited. ATC1400A DME TXP test set or equivalent performance level responses included: 10 (25%) highly proficient, nine (22.5%) competent, and no one selected partially proficient or extremely limited. RD-300 radar test set or equivalent performance level responses included: five (12.5%) highly proficient, four (10%) competent, and no one selected partially proficient or extremely limited.

Figure 43 indicates the percentage of participants selecting each performance level for shop equipment applicable to their avionics shops. The chart shows the performance level of highly proficient was selected most often in volt meter, O-scope, pitot/static and air data testers, ATC1400A DME TXP test set or equivalent, and RD-300 radar test set or equivalent. Battery chargers, IFR 4000 ramp tester or equivalent, IFR 6000 ramp tester or equivalent and S-1403DL mode-S test set or equivalent had the competent level of performance selected most often.

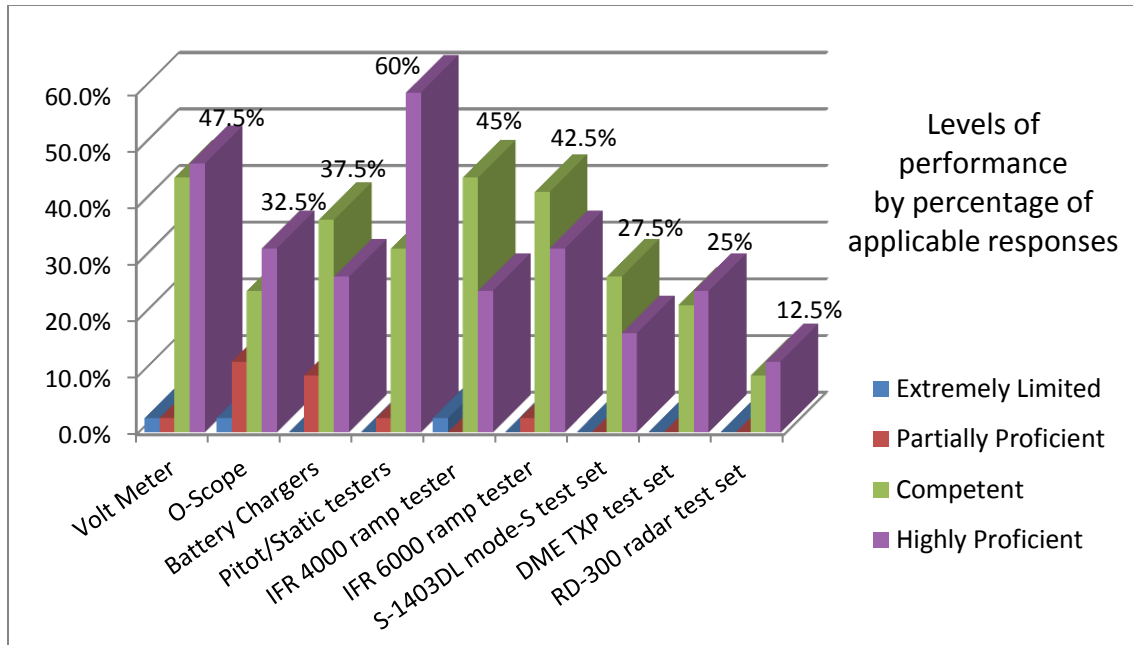


Figure 43. Shop equipment performance levels from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated shop equipment worked with included volt meter, O-scope, pitot/static, IFR 4000 ramp tester or equivalent, and IFR 6000 ramp tester or equivalent. The knowledge level selected for all the applicable shop equipment was advanced understanding. The O-scope and the IFR 6000 ramp tester or equivalent had the performance level competent selected. Volt meter, pitot/static, and IFR 4000 ramp tester or equivalent had highly proficient performance level selected.

Soldering and wiring processes.

Participants were asked to select each of these elements of soldering and wiring processes that are applicable to technicians working in their shop. The choices provided included; basic soldering through hole components, advanced soldering surface mount component, crimping tools and processes, coax routing and repair, and wire harness fabrication. Participants were then asked to describe the knowledge and performance levels for understanding and usage of the shop equipment selected. Knowledge level was distinguished by selecting one of four levels; understands terminology, knows procedures, knows theory principles, and resolves problems. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector 22 (88%) selected basic soldering through-hole components. Twenty (80%) participants selected advanced soldering surface mount component while 24 (96%) participants selected crimping tools and processes. Coax routing and repair was selected by 11(44%) participants with wire harness fabrication selected by 13 (52%) participants.

The data showed that of the 39 participant responses from the general and business sector 36 (92.3%) participants selected basic soldering through-hole components. Nineteen (48.7%) of the participants selected advanced soldering surface mount component while 39 (100%) participants selected crimping tools and processes.

Coax routing and repair was selected by 36 (92.3%) participants with wire harness fabrication selected by 36 (92.3%) participants.

The figure 44 is a visual representation of the data on soldering and wiring processes applicable to avionics shops by business sectors. The figure clearly indicates greater usage of the IFR 4000 and 6000 ramp testers and pitot/static testers by the general aviation sector. The figure also indicates more extensive use of the mode-S and DME TXP test equipment in the general aviation sector. The volt meter is a basic piece of test equipment used by all electronics technicians as indicated by the 100% in both sectors.

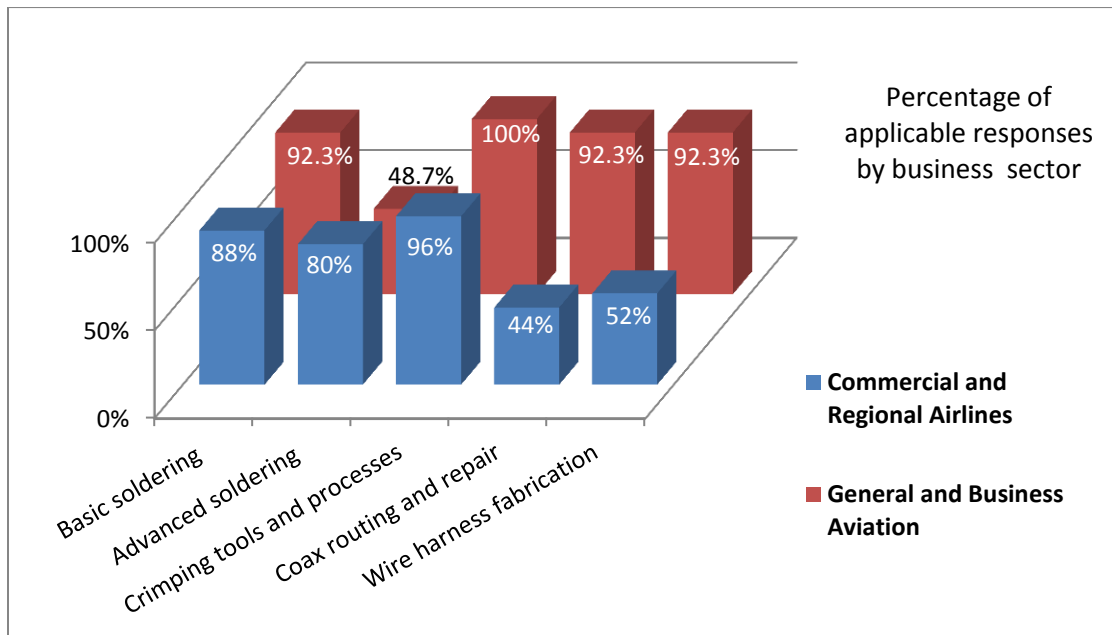


Figure 44. Soldering and wiring processes data applicable to avionics shops by sector.

Knowledge level commercial and regional airlines.

Basic soldering through-hole components knowledge level responses included: 18 (72%) participants selecting resolves problems, two (8%) participants selecting knows

theory principles, one (4%) selecting knows procedures, and one (4%) selection for understands terminology. Advanced soldering surface mount components knowledge level responses included 16 (64%) selections for resolves problems, two (8%) knows theory principles, two (8%) knows procedures, and no one selected understands terminology. Crimping tools and processes knowledge level responses included 14 (56%) resolves problems, three (12%) knows theory principles, seven (28%) knows procedures, and no one selected understands terminology. Coax routing and repair knowledge level responses included five (20%) resolves problems, three (12%) knows theory principles, three (12%) knows procedures, and no one selected understands terminology. Wire harness fabrication knowledge level responses included eight (32%) resolves problems, three (12%) knows theory principles, two (8%) knows procedures and no selections understands terminology.

Figure 45 indicates the percentage of participants selecting each knowledge level for the elements of soldering and wiring processes applicable to their avionics shop. The chart shows the highest level of knowledge, resolves problems was selected most often for all the elements of soldering and wiring processes. The lowest level understands terminology was selected by one participant in the basic soldering through-hole components element.

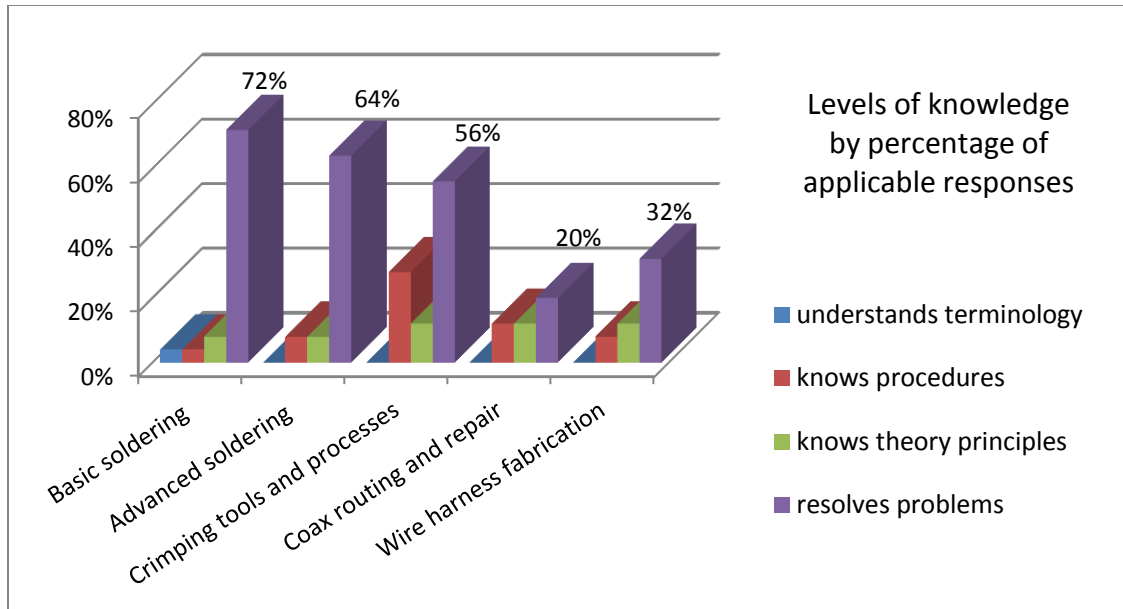


Figure 45. Soldering and wiring process elements knowledge level data from the commercial and regional airlines sector.

Performance level commercial and regional airlines.

Basic soldering through-hole components performance level responses included: 14 (56%) highly proficient, seven (28%) competent, one (4%) partially proficient and no one selected extremely limited. Advanced soldering surface mount components performance level responses included: 14 (56%) highly proficient, five (20%) competent, one (4%) partially proficient and no one selected extremely limited. Crimping tools and processes performance level responses included: 10 (40%) highly proficient, 13 (52%) competent, no selections for partially proficient, and one (4%) selection for extremely limited. Coax routing and repair performance level responses included: five (20%) highly proficient, four (16%) competent, one (4%) selected partially proficient and one (4%) selection for extremely limited. Wire harness fabrication performance level responses

included: seven (28%) highly proficient, six (24%) competent, no one selected partially proficient or extremely limited.

Figure 46 indicates percentage of participants selecting each performance level for the elements of soldering and wiring processes applicable to their avionics shop. The chart shows the highest level of performance, highly proficient was selected most often for all the elements of soldering and wiring processes except crimping tools and processes. Crimping tools and processes had the competent performance level selected most often. The lowest level of performance extremely limited was selected by two participants; one for the crimping tools and processes element and one for the coax routing and repair element.

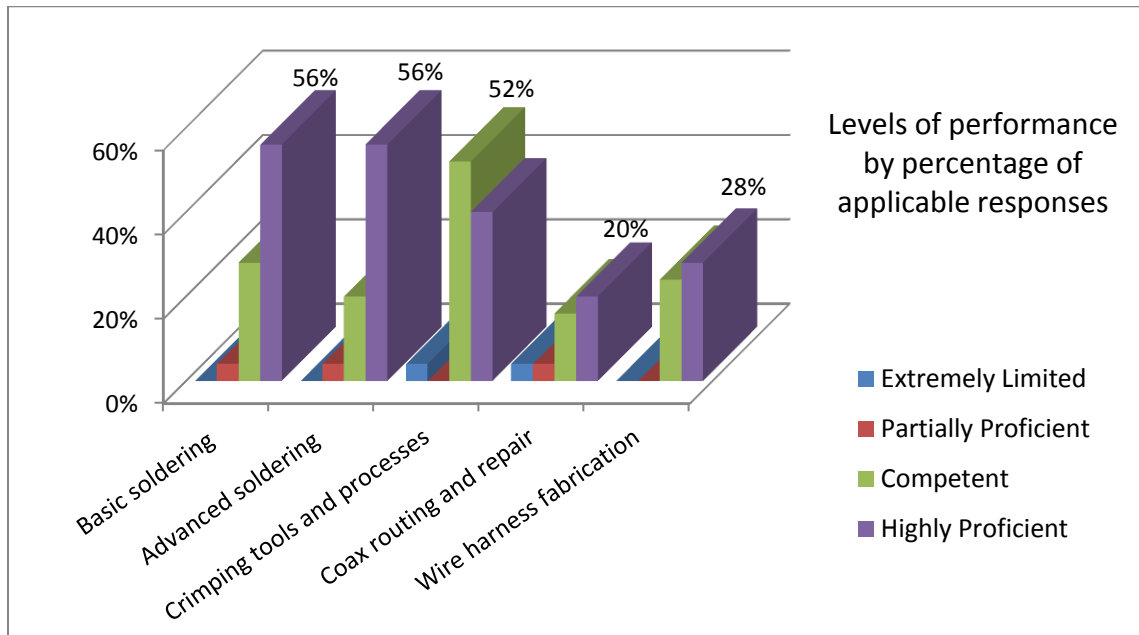


Figure 46. Soldering and wiring process elements performance level data from the commercial and regional airlines sector.

Knowledge level general and business aviation.

Basic soldering through-hole components knowledge level responses included: 21 (53.8%) participants selecting resolves problems, seven (17.9%) participants selecting knows theory principles, seven (17.9%) selecting knows procedures, and no one selected understands terminology. Advanced soldering surface mount components knowledge level responses included 11 (28.2%) selections for resolves problems, five (12.8%) knows theory principles, two (5.1%) knows procedures, and one (2.6%) selection for understands terminology. Crimping tools and processes knowledge level responses included 24 (61.5%) resolves problems, six (15.4%) knows theory principles, seven (17.9%) knows procedures, and one (2.6%) selection for understands terminology. Coax routing and repair knowledge level responses included 22 (56.4%) resolves problems, seven (17.9%) knows theory principles, six (15.4%) knows procedures, and no one selected understands terminology. Wire harness fabrication knowledge level responses included 26 (66.7%) resolves problems, five (12.8%) knows theory principles, four (10.3%) knows procedures and no selections understands terminology.

Figure 47 indicates the percentage of participants selecting each knowledge level for the elements of soldering and wiring processes applicable to their avionics shop. The chart shows the highest level of knowledge, resolves problems was selected most often for all the elements of soldering and wiring processes. The lowest level of knowledge, understands terminology was selected by two participants; one for the advanced soldering surface mount components element and one for the crimping tools and processes element.

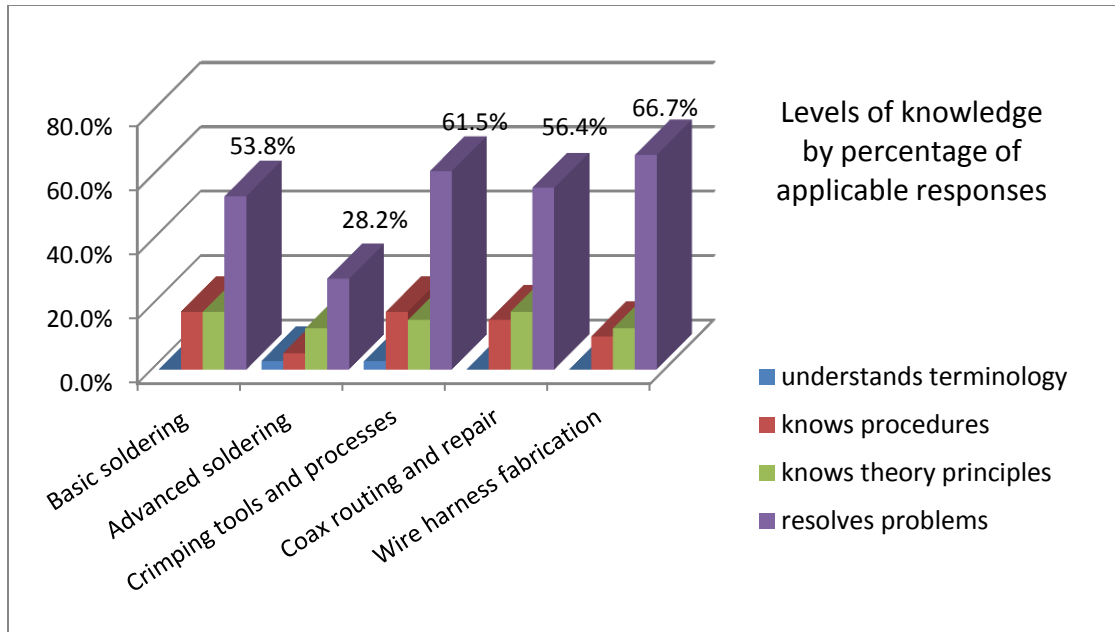


Figure 47. Soldering and wiring process elements knowledge level data from the general and business aviation sector.

Performance level general and business aviation.

Basic soldering through-hole components performance level responses included: 14 (35.9%) highly proficient, 19 (48.7%) competent, two (5.1%) partially proficient and no one selected extremely limited. Advanced soldering surface mount components performance level responses included: two (5.1%) highly proficient, 13 (33.3%) competent, three (7.7%) partially proficient and one (2.6%) selection for extremely limited. Crimping tools and processes performance level responses included: 22 (56.4%) highly proficient, 15 (38.5%) competent, no selections for partially proficient, and one (2.6%) selection for extremely limited. Coax routing and repair performance level responses included: 21 (53.8%) highly proficient, 14 (35.9%) competent, no one selected partially proficient or extremely limited. Wire harness fabrication performance level

responses included: 22 (56.4%) highly proficient, 13 (33.3%) competent, no one selected partially proficient or extremely limited.

Figure 48 indicates percentage of participants selecting each performance level for the elements of soldering and wiring processes applicable to their avionics shop. The chart shows the highest level of performance, highly proficient was selected most often for crimping tools and processes, coax routing and repair, and wire harness fabrication. Basic soldering through hole components and advanced soldering surface mount component had the competent performance level selected most often. The lowest level of performance extremely limited was selected by two participants; one for the advanced soldering surface mount component element and one for the crimping tools and processes element.

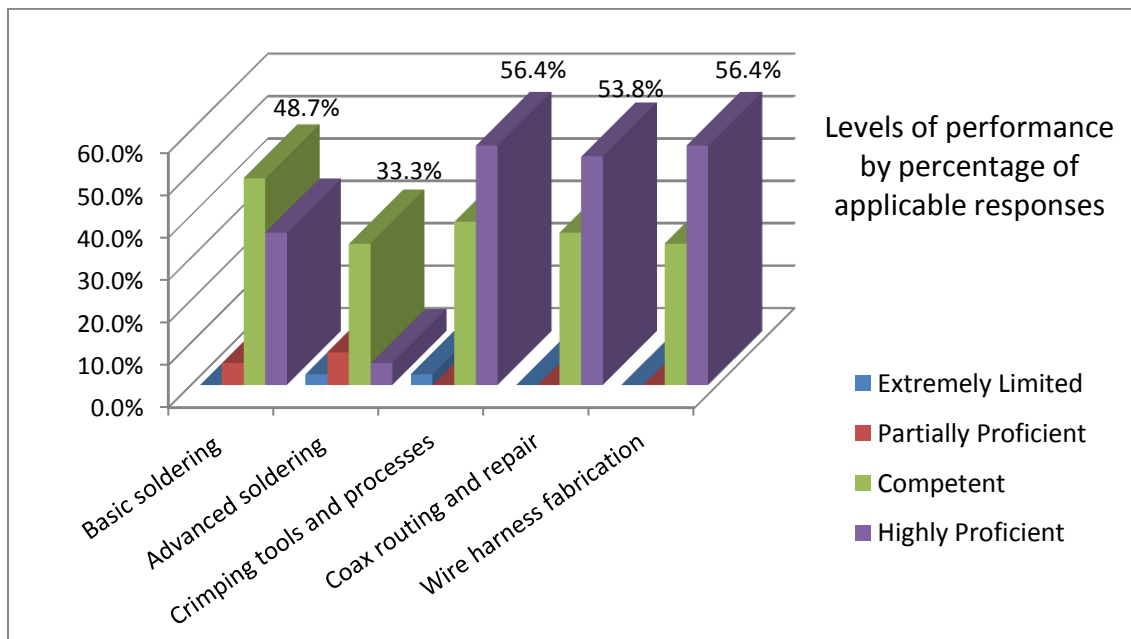


Figure 48. Soldering and wiring process elements performance level data from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the elements of soldering and wiring processes that are applicable to technicians working in their shop includes crimping tools and processes, coax routing and repair, and wire harness fabrication. The knowledge level selected for all the elements of soldering and wiring processes was resolves problems. The performance level selected for all these elements was highly proficient.

Generals Objectives

The FAA curriculum requirements for the training of airframe and powerplant technicians require that both programs must study material and pass tests relating to what are known as the generals. Many avionics training programs include some or all of these general knowledge elements. These general requirements typically include knowledge and skill elements in basic aviation maintenance, mathematics, basic physics, process and materials, and aircraft ground operations. Determining the knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry requires knowing what elements of these general requirements are applicable to technicians.

Basic aviation maintenance requirements.

Participants were asked to select each of these basic aviation maintenance requirements that are applicable to technicians working in their avionics shop. The choices provided included; aircraft drawings (blueprints, graphs, charts), weight and balance, maintenance forms and records, fluid lines and fittings, corrosion control and not

applicable. Participants were then asked to describe the knowledge and performance levels for each of these items associated with the A&P generals requirements. Knowledge level was distinguished by selecting one of four levels; knows basic facts, knows general principles, can analyze and draw conclusions, and has advanced understanding. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that of the 25 participant responses from the commercial and regional airlines sector five (20%) participants selected not applicable leaving 20 responses that have at least one of these elements that are applicable to their shop. The data showed that of the 20 participant responses 15 (75%) selected aircraft drawings (blueprints, graphs, charts). Two (10%) participants selected weight and balance while 19 (95%) participants selected maintenance, forms, and records. Fluid lines and fittings were selected by two (10%) participants with corrosion control selected by 13 (65%) participants.

The data showed that of the 38 participant responses from the general and business aviation sector one (2.6%) participant selected not applicable leaving 37 responses that have at least one of these elements that are applicable to their shop. The data showed that of the 37 participant responses 36 (97.3%) participants selected aircraft drawings (blueprints, graphs, charts). Thirty-one (83.8%) of the participants selected weight and balance while 37 (100%) participants selected maintenance, forms, and records. Fluid lines and fittings were selected by 17 (45.9%) participants with corrosion control selected by 18 (48.6%) participants.

Figure 49 is a visual representation of the data on these basic aviation maintenance requirements that are applicable to technicians working in their avionics shop. The figure clearly indicates greater usage of the IFR 4000 and 6000 ramp testers and pitot/static testers by the general aviation sector. The figure also indicates more extensive use of the mode-S and DME TXP test equipment in the general aviation sector. The volt meter is a basic piece of test equipment used by all electronics technicians as indicated by the 100% in both sectors.

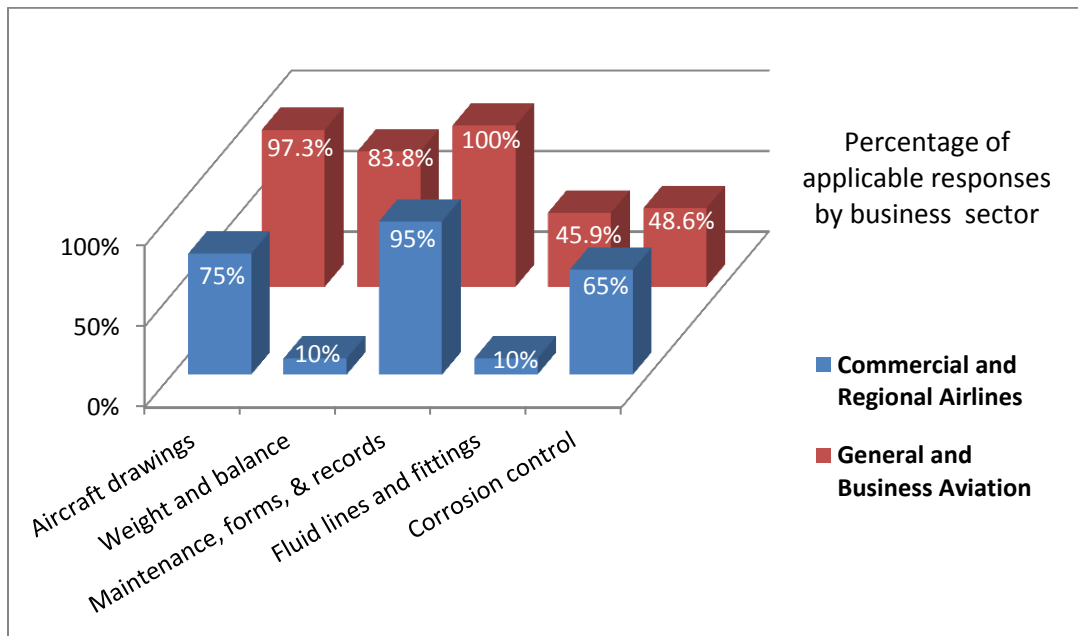


Figure 49. Basic aviation maintenance requirements applicable to avionics shops by sector.

Knowledge level commercial and regional airlines.

Aircraft drawings (blueprints, graphs, charts) knowledge level responses included: seven (35%) participants selecting has advanced understanding, six (30%) participants selecting can analyze and draw conclusions, one (5%) selecting knows general principles,

and no one selected knows basic facts. Weight and balance knowledge level responses included one (5%) selection for has advanced understanding, no selections for can analyze and draw conclusions, one (5%) selection for knows general principles, and no one selected knows basic facts. Maintenance, forms, and records knowledge level responses included nine (45%) has advanced understanding, eight (40%) can analyze and draw conclusions, two (10%) knows general principles, and no one selected knows basic facts. Fluid lines and fittings knowledge level responses included no selections for has advanced understanding, one (5%) can analyze and draw conclusions, one (5%) knows general principles, and no one selected knows basic facts. Corrosion control knowledge level responses included five (25%) has advanced understanding, four (20%) can analyze and draw conclusions, four (20%) knows general principles and no one selected knows basic facts.

Figure 50 indicates the percentage of participants selecting each knowledge level for the elements of basic aviation maintenance requirements applicable to their avionics shop. The chart illustrates the highest level of knowledge; advanced understanding was selected most often for the maintenance, forms, and records elements. The lowest level of knowledge; knows basic facts was not selected by any participants.

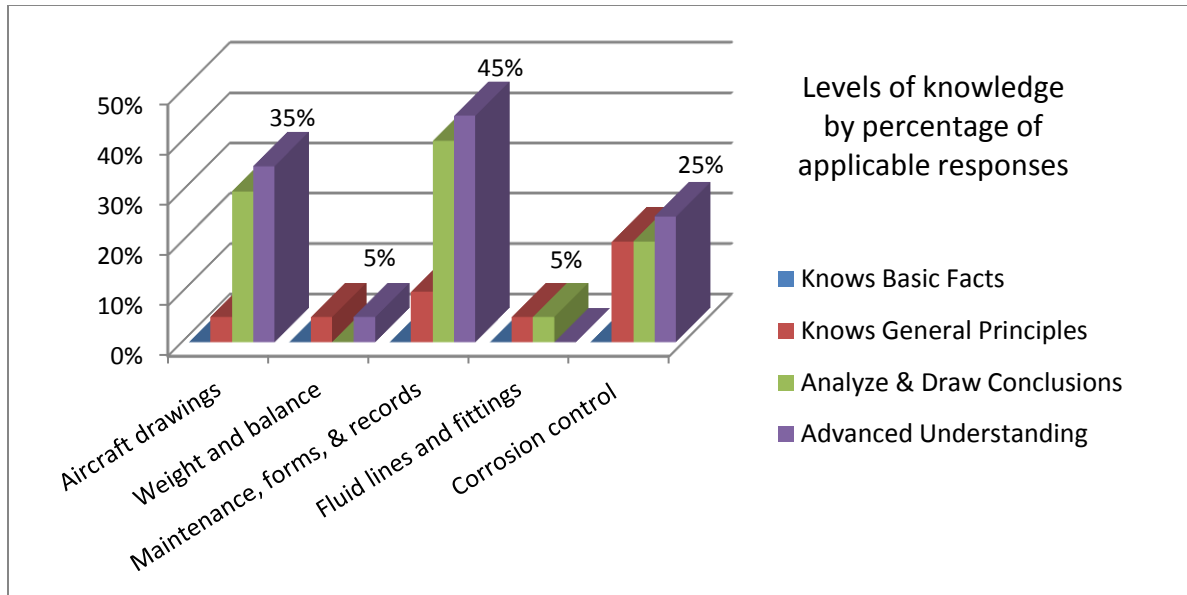


Figure 50. Basic aviation maintenance requirements knowledge level data from the commercial and regional airlines sector.

Performance level commercial and regional airlines.

Aircraft drawings (blueprints, graphs, charts) performance level responses included: seven (35%) highly proficient, six (30%) competent, one (5%) partially proficient and no one selected extremely limited. Weight and balance performance level responses included: one (5%) highly proficient, one (5%) competent, and no one selected partially proficient or extremely limited. Maintenance, forms, and records performance level responses included: 10 (50%) highly proficient, eight (40%) competent, one (5%) partially proficient, and no selections for extremely limited. Fluid lines and fittings performance level responses included: no selections for highly proficient, two (10%) selections for competent, and no selections for partially proficient or extremely limited. Corrosion control performance level responses included: four (20%) highly proficient,

eight (40%) competent, one (5%) partially proficient, and no one selected extremely limited.

Figure 51 indicates the percentage of participants selecting each performance level for the elements of basic aviation maintenance requirements applicable to their avionics shop. The chart shows the highest level of performance, highly proficient was selected most often aircraft drawings and maintenance, forms, and records. Fluid lines and fittings had the competent performance level selected most often. The lowest level of performance extremely limited was not selected by any participants.

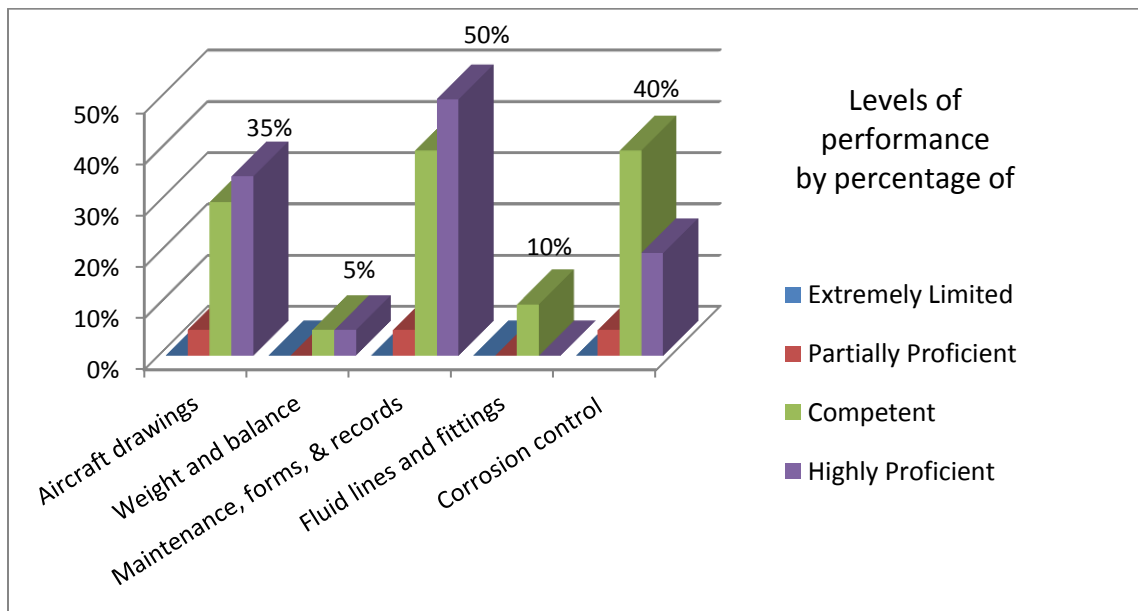


Figure 51. Basic aviation maintenance requirements performance level data from the commercial and regional airlines sector.

Knowledge level general and business aviation.

Aircraft drawings (blueprints, graphs, charts) knowledge level responses included: 11 (29.7%) participants selecting has advanced understanding, 20 (54.1%) participants selecting can analyze and draw conclusions, four (10.8%) selecting knows general principles, and one (2.7%) selection for knows basic facts. Weight and balance knowledge level responses included 12 (32.4%) has advanced understanding, five (13.5%) can analyze and draw conclusions, 13 (35.1%) knows general principles, and one (2.7%) selection for knows basic facts. Maintenance, forms, and records knowledge level responses included 15 (40.5%) has advanced understanding, 13 (35.1%) can analyze and draw conclusions, eight (21.6%) knows general principles, and one (2.7%) selection for knows basic facts. Fluid lines and fittings knowledge level responses included three (8.1%) has advanced understanding, eight (21.6%) can analyze and draw conclusions, five (13.5%) knows general principles, and one (2.7%) selection for knows basic facts. Corrosion control knowledge level responses included four (10.8%) has advanced understanding, five (13.5%) can analyze and draw conclusions, eight (21.6%) knows general principles and one (2.7%) selection for knows basic facts.

Figure 52 indicates the percentage of participants selecting each knowledge level for the elements of basic aviation maintenance requirements applicable to their avionics shop. The chart illustrates the highest level of knowledge; advanced understanding was selected most often for the maintenance, forms, and records element. The aircraft drawings and fluid lines and fittings had can analyze and draw conclusions level of knowledge selected most often. Weight and balance and corrosion control elements had the level of knowledge knows general principles selected most often.

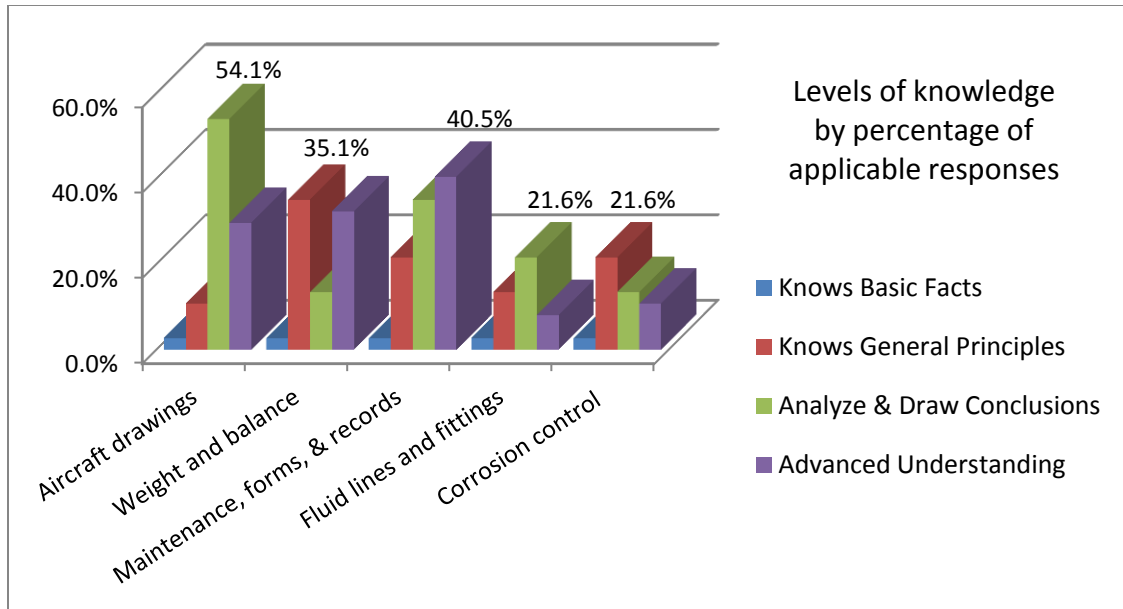


Figure 52. Basic aviation maintenance requirements knowledge level data from the general and business aviation sector.

Performance level general and business aviation.

Aircraft drawings (blueprints, graphs, charts) performance level responses included: 10 (27%) highly proficient, 21 (56.8%) competent, five (13.5%) partially proficient and no one selected extremely limited. Weight and balance performance level responses included: six (16.2%) highly proficient, 19 (51.4%) competent, six (16.2%) partially proficient, and no one selected extremely limited. Maintenance, forms, and records performance level responses included: 12 (32.4%) highly proficient, 22 (59.5%) competent, three (8.1%) partially proficient, and no one selected extremely limited. Fluid lines and fittings performance level responses included: one (2.7%) highly proficient, 15 (40.5%) competent, one (2.7%) partially proficient, and no one selected extremely limited. Corrosion control performance level responses included: three (8.1%) highly

proficient, 13 (35.1%) competent, two (5.4%) partially proficient, and no one selected extremely limited.

Figure 53 indicates the percentage of participants selecting each performance level for the elements of basic aviation maintenance requirements applicable to their avionics shop. The chart shows the second highest level of performance, competent was selected most often in all elements. The highest level of performance, highly proficient was next most often selected in all elements.

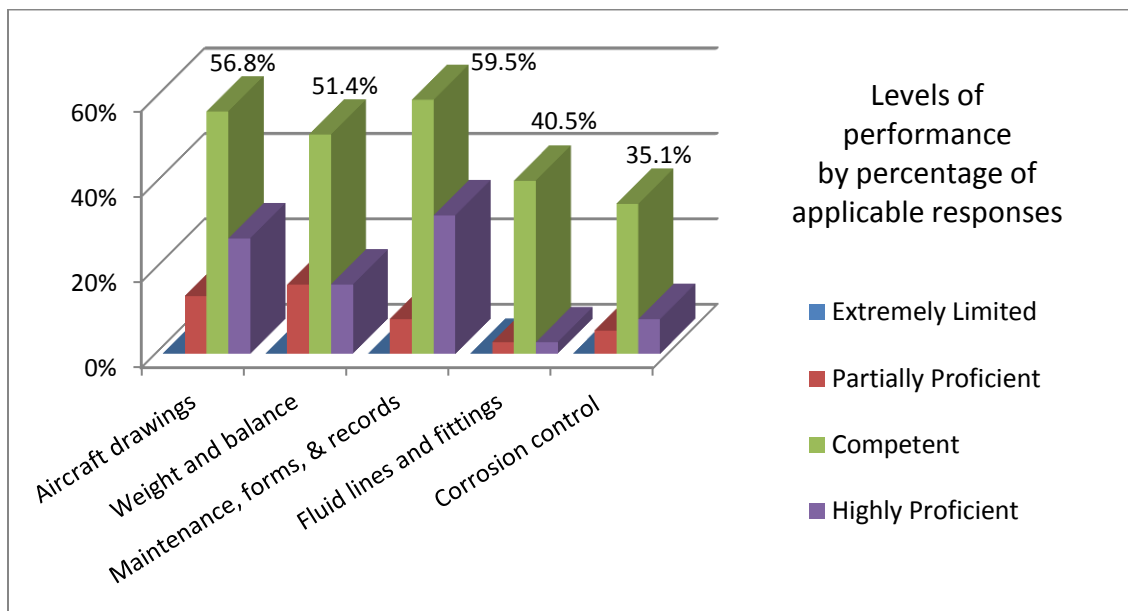


Figure 53. Basic aviation maintenance requirements performance level data from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the basic aviation maintenance requirements that are applicable to technicians working in their avionics shop included aircraft drawings (blueprints, graphs, charts) and

maintenance forms and records. The knowledge level selected for these basic aviation maintenance requirements was can analyze and draw conclusions. The performance level selected for these basic aviation maintenance requirements was competent.

Mathematics.

Participants were asked to describe the performance levels needed for each of these mathematic operations that are applicable to technicians working in their avionics shop. The operations included; extract roots and raise numbers to a given power, determine areas and volumes of various geometrical shapes, and solve ratios proportions and percentage problems and also preform algebraic operations. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

Performance level commercial and regional airlines.

The data showed that in the commercial and regional airlines sector, of the 24 participants responding to extract roots and raise numbers to a given power, one (4.2%) selected highly proficient, 11 (45%) competent, seven (29.2%) partially proficient, and five (20.8%) selected extremely limited. The mathematical operation of determine areas and volumes of various geometrical shapes had one (4.2%) selection for highly proficient, eight (33.3%) competent, seven (29.2%) partially proficient, and eight (33.3%) selected extremely limited. The mathematical operation of solve ratios, proportions, and percentage problems had one (4.2%) selection for highly proficient, 15 (62.5%) competent, two (8.3%) partially proficient, and six (25%) selections for extremely limited. The mathematical operation of preform algebraic operations had two (8.3%)

highly proficient, 11 (45.8%) competent, three (12.5%) partially proficient, and eight (33.3%) selections for extremely limited.

Figure 54 indicates the percentage of participants selecting each performance level for the elements of mathematical operation as it applies to technicians in their avionics shop. The chart shows the performance level of competent was selected most often for each of the mathematical operations. The performance level of highly proficient was selected the least often in each mathematical operation category.

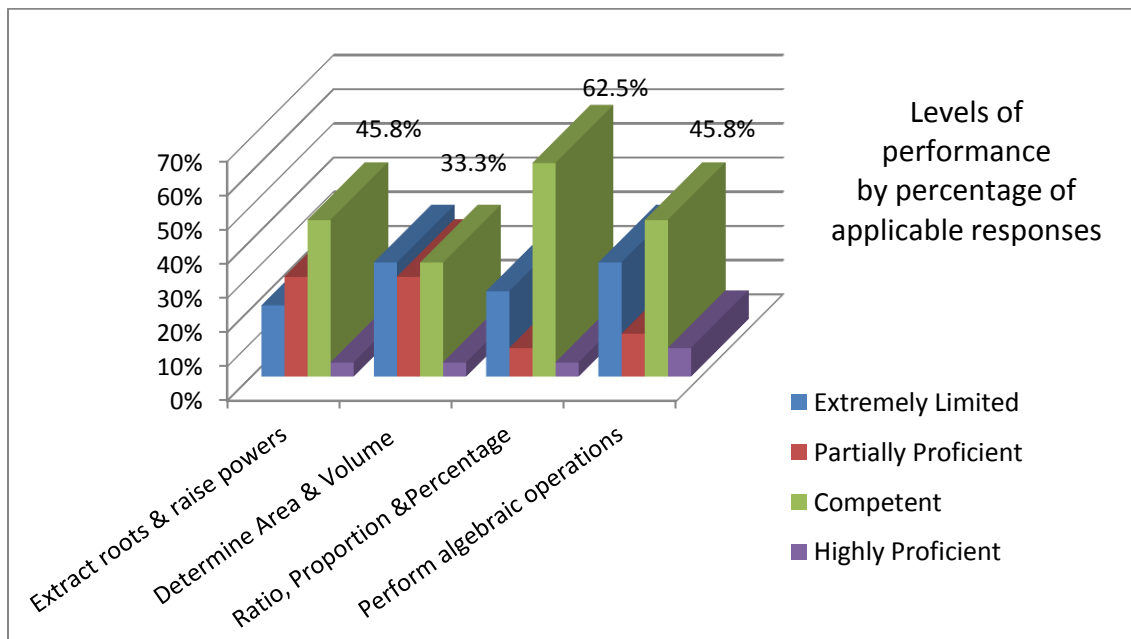


Figure 54. Mathematical operations performance level data from the commercial and regional airlines sector.

Performance level general and business aviation.

The data showed that in the general and business aviation sector, of the 38 participant responses responding to extract roots and raise numbers to a given power one (2.6%) selected highly proficient, 11 (28.9%) competent, 11 (28.9%) partially proficient, 15 (39.5%) selected extremely limited. The mathematical operation of determine areas and volumes of various geometrical shapes had no one select highly proficient, 14 (36.8%) competent, nine (23.7%) partially proficient, and 15 (39.5%) selected extremely limited. The mathematical operation of solve ratios, proportions, and percentage problems had two (5.3%) selection for highly proficient, 18 (47.4%) competent, 12 (31.6%) partially proficient, and six (15.8%) selections for extremely limited. The mathematical operation of preform algebraic operations had three (7.9%) highly proficient, 15 (39.5%) competent, 14 (36.8%) partially proficient, and nine (23.7%) selections for extremely limited.

Figure 55 indicates the percentage of participants selecting each performance level for the elements of mathematical operations as it applies to technicians in their avionics shop. The chart shows the performance level of competent was selected most often for the mathematical operations of solve ratios, proportions, and percentage problems and preform algebraic operations. The performance level of extremely limited was selected most often in the mathematical operations of extract roots and raises numbers to a given power and determines areas and volumes of various geometrical shapes. The performance level of highly proficient was selected the least in each mathematical operation category.

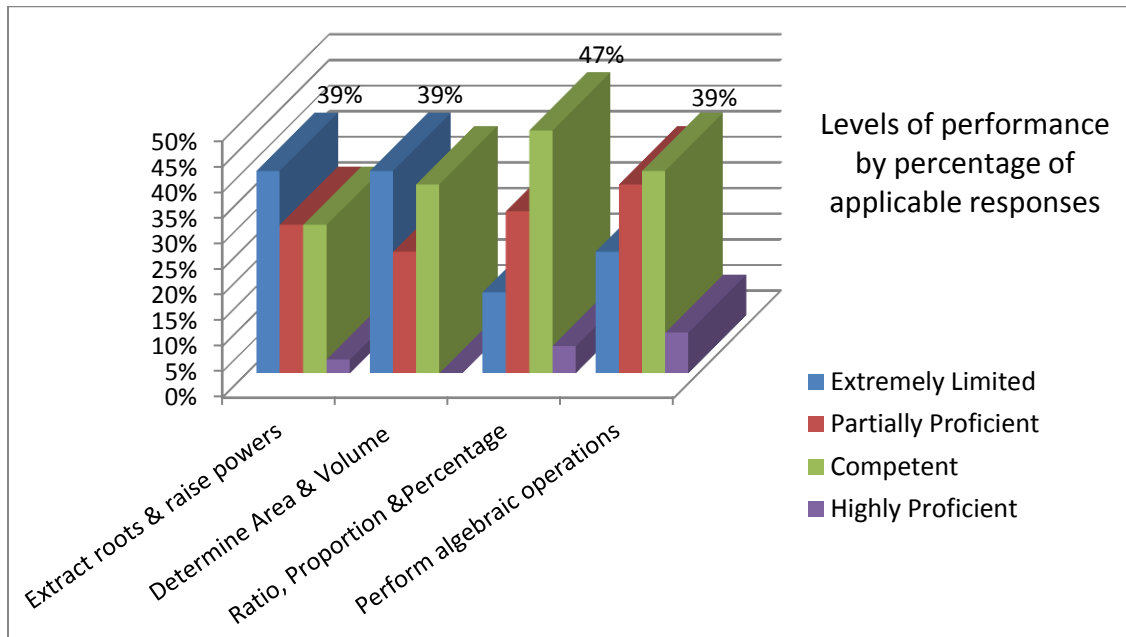


Figure 55. Mathematical operations performance level data from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the mathematic operations that are applicable to technicians working in their avionics shop by selecting the performance levels needed for each. The performance level for extract roots and raise numbers to a given power, determine areas and volumes of various geometrical shapes, and solve ratios proportions and percentage problems was partially proficient. The performance level selected for algebraic operations was competent.

Basic physics.

Participants were asked to describe the knowledge levels needed for each of these basic principles of physics that are applicable to technicians working in their avionics shop. The principles included; principles of simple machines, principles of sound fluid and heat dynamics, principles of basic aerodynamics; aircraft structures; and theory of flight. Knowledge levels were distinguished by selecting one of four levels; knows basic facts, knows general principles, can analyze and draw conclusions, and has advanced understanding.

Knowledge level commercial and regional airlines.

The data showed that in the commercial and regional airlines sector, of the 22 participants responding to principles of simple machines the knowledge level responses included three (13.6%) has advanced understanding, seven (31.8%) can analyze and draw conclusions, five (22.7%) knows general principles, and seven (31.8%) selections for knows basic facts. Principles of sound, fluid, and heat dynamics knowledge level responses included two (9.1%) have advanced understanding, five (22.7%) can analyze and draw conclusions, four (18.2%) knows general principles, and 10 (45.5%) selections for knows basic facts. Basic aerodynamics, aircraft structures, and theory of flight knowledge level responses included four (18.2%) have advanced understanding, five (22.7%) can analyze and draw conclusions, four (18.2%) knows general principles and eight (36.4%) selections for knows basic facts.

Figure 56 indicates the percentage of participants selecting each knowledge level for the elements of basic physics requirements applicable to their avionics shop. The

chart illustrates the lowest level of knowledge, knows basic facts was selected most often for all three elements. The highest level of knowledge advanced understanding was selected by the fewest participants in each element of basic physics.

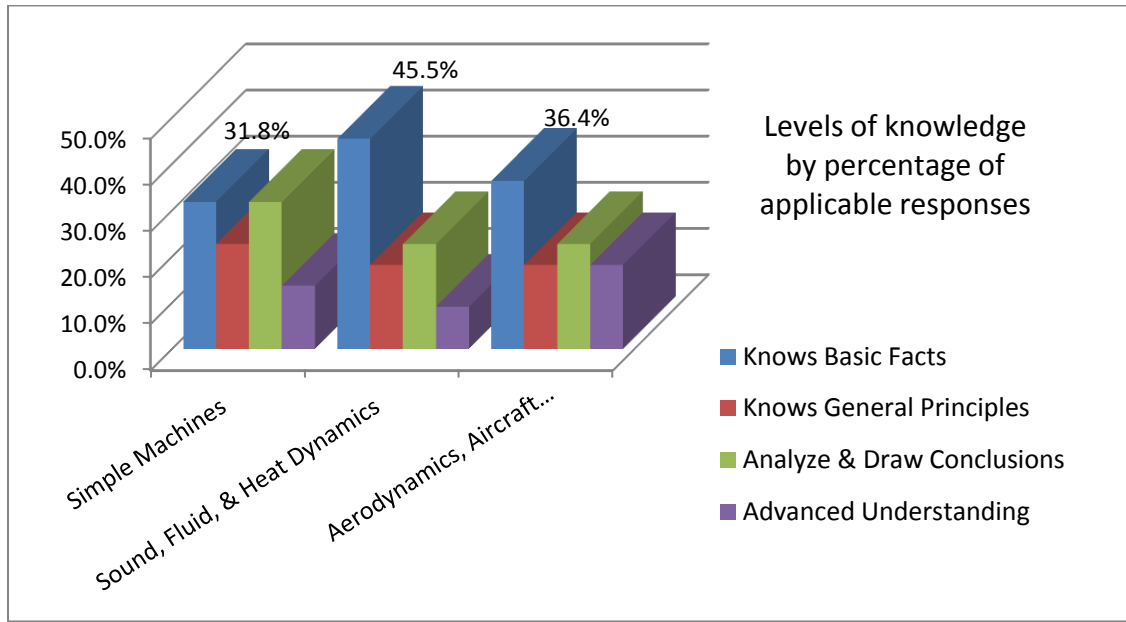


Figure 56. Physics knowledge level data from the commercial and regional airlines sector.

Knowledge level general and business aviation.

The data showed that in the general and business aviation sector, of the 37 participants responding to principles of simple machines the knowledge level responses included 13 (35.1%) has advanced understanding, 13 (35.1%) can analyze and draw conclusions, five (13.5%) knows general principles, and six (16.2%) selections for knows basic facts. Principles of sound, fluid, and heat dynamics knowledge level responses included two (5.4%) have advanced understanding, 12 (32.4%) can analyze and draw conclusions, 13 (35.1%) knows general principles, and 10 (27%) selections for knows

basic facts. Basic aerodynamics, aircraft structures, and theory of flight knowledge level responses included seven (18.9%) have advanced understanding, 15 (40.5%) can analyze and draw conclusions, 12 (32.4%) knows general principles and three (8.1%) selections for knows basic facts.

Figure 57 indicates the percentage of participants selecting each knowledge level for the elements of basic physics requirements applicable to their avionics shop. The chart illustrates the highest levels of knowledge advanced understanding and can analyze and draw conclusions were selected equally by the most participants in the simple machines element. The knowledge level of knows general principles was selected most often by the participants in the sound, fluid, and heat dynamics element. Can analyze and draw conclusions was selected most often in the aerodynamics, aircraft structures, and theory of flight element of basic physics.

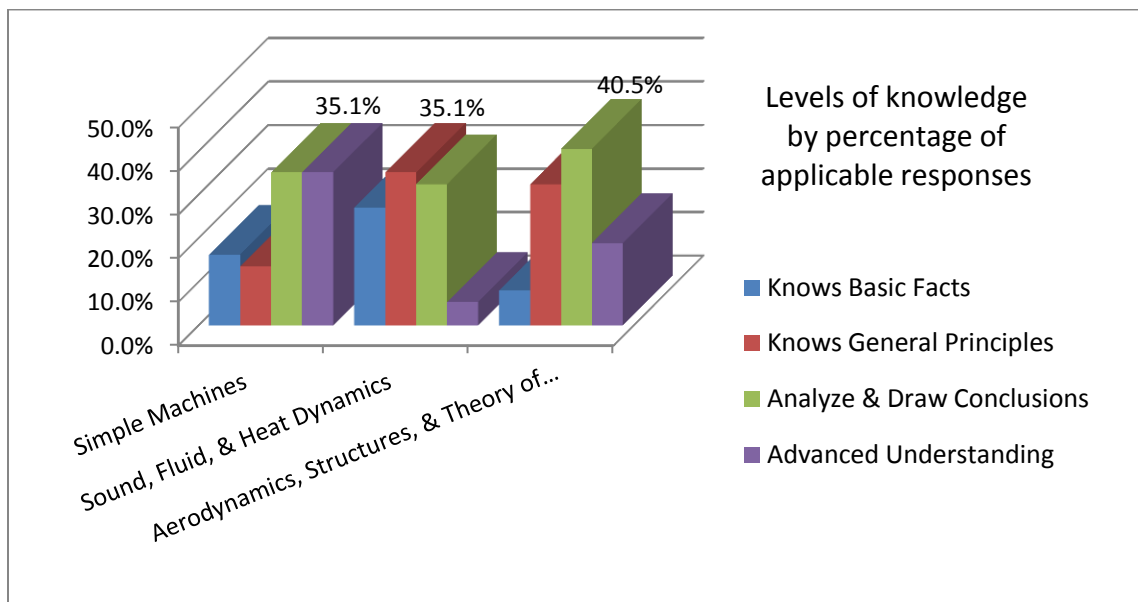


Figure 57. Physics knowledge level data from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated the basic principles of physics that are applicable to technicians working in their avionics shop by selecting the knowledge levels needed for each. The knowledge level; knows general principles was selected for principles of basic aerodynamics; aircraft structures; and theory of flight. The knowledge level selected for principles of simple machines and principles of sound, fluid, and heat dynamics was can analyze and draw conclusions.

Processes and materials.

Participants were asked to describe the performance levels needed for each of these items associated with processes and materials that are applicable to technicians working in their avionics shop. The processes and materials included; perform precision physical and mechanical measurements, perform precision electrical and electronic measurements, identify and select proper hardware, materials, and components. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

Performance level commercial and regional airlines.

The data showed that in the commercial and regional airlines sector, of the 24 participants responding to perform precision physical and mechanical measurements, one (4.2%) selected highly proficient, 18 (75%) competent, four (16.7%) partially proficient, and one (4.2%) participant selected extremely limited. The processes and materials requirement of perform precision electrical and electronic measurements had 11 (45.8%)

selection for highly proficient, nine (37.5%) competent, three (29.2%) partially proficient, and one (4.2%) selected extremely limited. The processes and materials requirement of identify and select proper hardware, materials, and components had 12 (50%) selection for highly proficient, eight (33.3%) competent, three (12.5%) partially proficient, and one (4.2%) participant selected extremely limited.

Figure 58 indicates the percentage of participants selecting each performance level for the elements of processes and materials requirements as it applies to technicians in their avionics shop. The chart shows the performance level of competent was selected most often for perform precision physical and mechanical measurements. The performance level of highly proficient was selected the most often in perform precision electrical and electronic measurements and identify and select proper hardware, materials, and components.

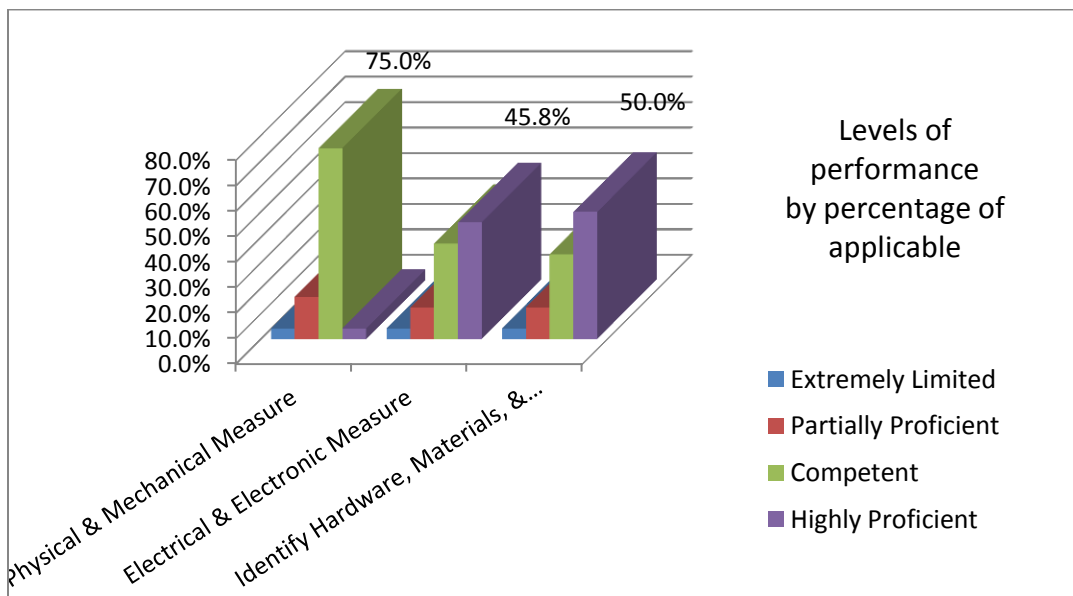


Figure 58. Processes and materials requirements performance level data from the commercial and regional airlines sector.

Performance level general and business aviation.

The data showed that in the general and business aviation sector, of the 38 participants responding to perform precision physical and mechanical measurements, three (7.9%) selected highly proficient, 25 (65.8%) competent, six (15.8%) partially proficient, and four (10.5%) participants selected extremely limited. The processes and materials requirement of perform precision electrical and electronic measurements had 11 (28.9%) selection for highly proficient, 23 (37.5%) competent, two (5.3%) partially proficient, and two (5.3%) participants selected extremely limited. The processes and materials requirement of identify and select proper hardware, materials, and components had 12 (31.6%) selection for highly proficient, 22 (57.9%) competent, three (7.9%) partially proficient, and one (2.6%) participant selected extremely limited.

Figure 59 indicates the percentage of participants selecting each performance level for the elements of processes and materials requirements as it applies to technicians in their avionics shop. The chart shows the performance level of competent was selected most often for all three elements. The performance level of highly proficient was selected the least often in perform precision physical and mechanical measurements. The performance level of extremely limited was selected least often for the elements of perform precision electrical and electronic measurements and identify and select proper hardware, materials, and components.

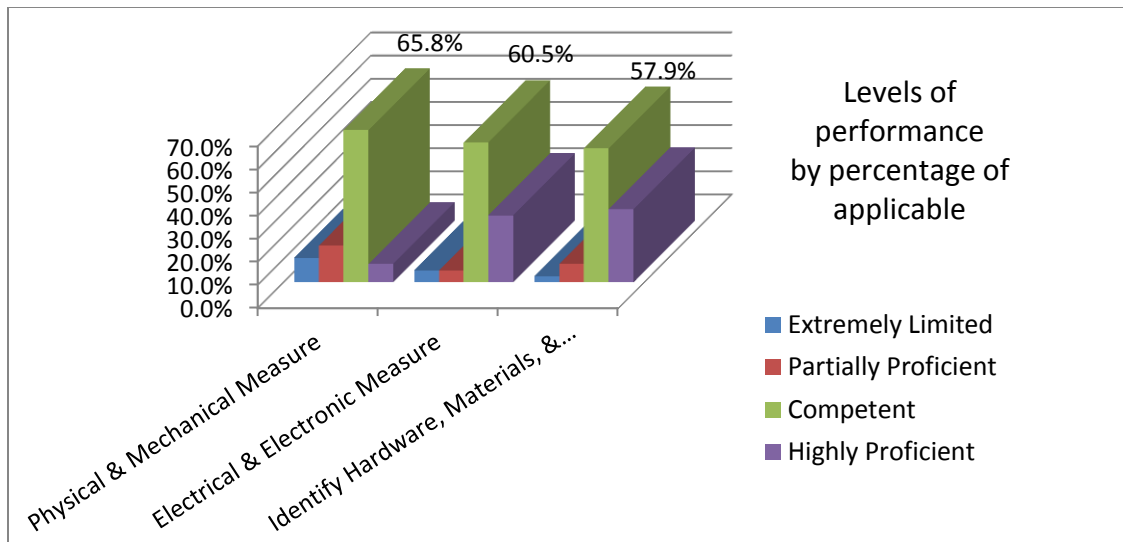


Figure 59. Processes and materials requirements performance level data from the general and business aviation sector.

Manufacturing.

The data from the single participant representing the manufacturing sector identified the items associated with processes and materials that are applicable to technicians working in their avionics shop. Identification was made by selecting the performance levels needed for each item. The performance level highly proficient was selected for the processes of performing precision physical and mechanical measurements, performing precision electrical and electronic measurements and for the identification and selection of proper hardware, materials, and components.

Aircraft ground operations.

Participants were asked to describe the performance levels needed for the basic aircraft ground operations associated with the A&P generals requirements that are applicable to technicians working in their avionics shop. The basic aircraft ground

operations included one element described as ground operation, aircraft servicing, and aircraft taxi. Performance levels were distinguished by selecting one of four levels; extremely limited, partially proficient, competent, and highly proficient.

The data showed that in the commercial and regional airlines sector, of the six participants responding to aircraft ground operations, one (16.7%) selected highly proficient. Three (50%) participants selected the performance level of competent. One (16.7%) participant selected partially proficient and one (16.7%) participant selected the lowest performance level of extremely limited.

The data showed that in the general and business aviation sector, of the 37 participants responding to aircraft ground operations, five (13.5%) selected highly proficient. Eighteen (48.6%) participants selected the performance level of competent, with six (16.2%) participants selecting partially proficient. Eight (21.6%) participants selected the lowest performance level of extremely limited.

Figure 60 indicates the percentage of participants selecting each performance level for the A&P requirement of aircraft ground operations as it applies to technicians in their avionics shop. The chart displays both the commercial and regional airlines sector and the general and business aviation sector because there is only one element to this question. The chart shows a performance level of competent was selected most often by participants in both sectors.

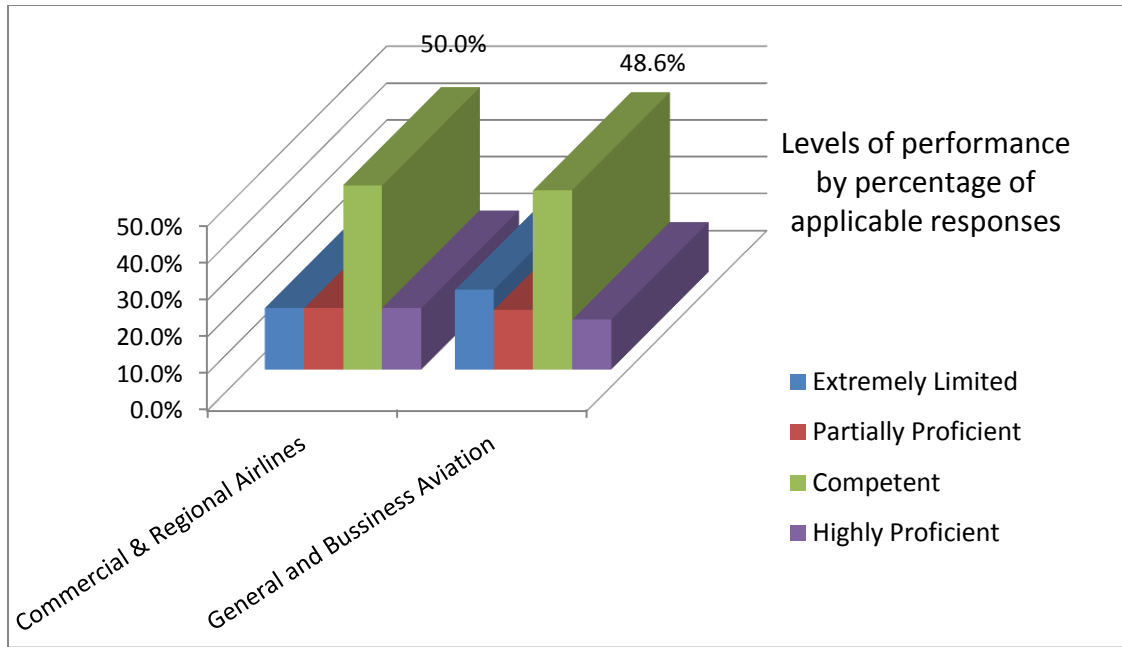


Figure 60. Aircraft ground operations performance level data by sector.

Manufacturing.

The data from the single participant representing the manufacturing sector indicated a requirement for basic aircraft ground operations. Basic aircraft ground operations were described as involving ground operation, aircraft servicing, and aircraft taxi. The performance level competent was selected.

CHAPTER V

SUMMARIES AND CONCLUSIONS

Summary of Research Method and Survey Design

Research in this study was conducted through the use of a single online survey utilizing the Qualtrics online survey system. The survey participants were aircraft technicians and supervisors of aircraft technicians currently working in the aviation industry. Participants were sought from all three business sectors through personal contacts and professional trade organizations, by means of mass emailing and personal solicitations. Participants were requested using business card size invitations that were distributed at the 2017 Aircraft Electronics Association 60th anniversary annual convention in New Orleans and through approximately 250 personal contacts. A mailing list of AEA members and a list of commercial and regional airline associates gained through personal and professional contacts were used to generate more than 500 email invitations. All of these efforts resulted in 74 participants providing information through the survey. The low response suggests caution should be used in generalizing some findings to larger populations.

The survey provided qualifier questions to ensure only technicians currently in the industry could participate. A block of demographic questions determined the industry

sector, training methods, types of services offered, and shop type of the participants.

Demographics also determined A&P certificate status, types of aircraft, and if on-aircraft work was done. The next block of questions determined the types of avionics systems worked on in the participant's shop. These questions further inquired as to the technician knowledge level and performance level required for each system. Systems were divided

into the following groups:

- Communications
- Dependent Navigation Systems
- Autonomous Navigation Systems
- Basic Aircraft Systems
- Pulse Systems
- Advanced Avionics Systems

Following the systems questions, another block of questions explored the required shop tools, shop equipment, and soldering and wiring processes used in the participant's environment. These questions addressed traditional and modern versions of common aircraft and electronics tools and equipment used by technicians. Each element was queried for knowledge or performance level as appropriate.

The last block of questions addressed topics in the objectives of the A&P program of study known as the generals. This grouping of questions examines elements contained in the learning objectives which cover general aviation knowledge and understanding. These elements are considered necessary for technicians when working on or around aircraft. The elements include:

- Basic aviation maintenance requirements
- Mathematics
- Basic Physics
- Process and Materials
- Aircraft Ground Operations

Each of these elements was also queried for knowledge or performance level as appropriate.

Summary of Participants

One of the major objectives of the study was to separate the responses by industry sector. Of the 74 responses which provided information only one was from the manufacturing sector. In areas where the total of all responses is stated, the data from the one manufacturing participant will be included. In areas where the differences between the industry sectors are analyzed, the data was not given for the single manufacturing sector participant.

Eleven of the participants did not complete the entire survey. In the analysis of each data set, all data given for that set is included. This explains why the total number of participants for a given data set may differ from set to set. It is the belief of this researcher that a problem occurred with the last question in the last block preventing many participants from accessing the question. The data will be given for that question; however the number of participants from the commercial and regional airlines sector was very low.

Summary of Demographic Data

There are 74 sets of responses, 35.1% represented the commercial and regional airlines and 63.5% represented the general and business aviation sector. The commercial sector had 31% of the technicians working on-aircraft and 63% of those were required to have A&P certificate. The general aviation sector had 94% of the technicians working on-aircraft and only 18% of those required the A&P certificate.

In the commercial and regional airlines sector, a single organization may have a large maintenance system with many levels. Most participants from the commercial and regional airlines sector, 73.1%, selected greater than 10 technicians working in their shop. This type of organization may have many technicians working in bench level shops and fewer technicians in the shops that perform on-aircraft tasks. Participants from this sector which included work on-aircraft equaled only 30.8% of the total. Those who work at the on-aircraft level of maintenance must be able to do all types of tasks often including airframe, powerplant, and avionics repair. These technicians may be required to work under individual A&P certificates. The FAA Airframe & Powerplant certificate was required by 62.5% of participants working on-aircraft in the commercial and regional airlines sector.

General aviation avionics shops tend to be smaller organizations with more technicians that are working directly on-aircraft. The general aviation sector represented 95% of the shops with one to three technicians and 68% of the shops with four to six technicians. Ninety three percent of the general and business aviation participants indicated they work on-aircraft. These technicians typically operate under a certified repair station license with individual repairman certificates and would have fewer technicians holding an A&P certificate. Only 18% of general and business aviation participants working on-aircraft were required to have an A&P certificate.

Summary of Services

Selections for On-aircraft services included avionics installation and avionics troubleshooting and repair. The commercial and regional airlines sector included only

26.9 % of the participants selecting avionics installation and 30.8% selecting avionics troubleshooting and repair. These numbers correspond very closely with the 30.8 % from this sector who selected working on-aircraft. The general and business aviation sector had 91.5 % select avionics installation and 93.6% selected avionics troubleshooting and repair. This again shows a very close correlation to the total number of 93.6% who selected working on-aircraft. It can be concluded that an avionics technician working on-aircraft will be performing avionics installations and troubleshooting and repair.

The data for the repair of LRUs showed in the commercial and regional airlines sector, 88.5% of participants selected LRU modular repair, 84.6% selected LRU component repair, and 69.2% selected LRU overhaul. This averaged 35.4% higher than the selections made by the general and business aviation sector. This would suggest that the general and business aviation sector do significantly less LRU repair and overhaul than the commercial and regional airlines sector. This supports the concept that commercial and regional airlines have larger networks of technicians working at different levels. These levels include LRU modular and component repair and LRU overhaul. General and Business aviation shops are generally smaller and support LRU repair on a much more limited basis.

The data for instrument inspections indicated relatively high percentages of shops in both sectors perform these tasks. The commercial and regional airlines had 65.4% of participants' select instrument inspections while the general and business aviation sector had 85.1% select instrument inspections. These periodic inspections can require some costly test equipment, however, not as costly as having a specialists show up on site each time an inspection is due. Many times, faults found in these types of inspections require

on-aircraft troubleshooting and repair, if the fault is found in the instrument it is usually removed for evaluation and repair by an instrument shop. In the case of commercial and regional airlines, this may be an instrument level shop in their system, where as the general and business aviation sector is more likely to use a specialized private instrument repair center or return the equipment to the manufacturer. The data for the instrument repairs supports this conclusion. The commercial and regional airlines sector had 53.8% of the participants select instrument repair while the general and business aviation sector had only 29.8% select this type of service as being offered in their shops.

The data for airframe inspection and repair and powerplant inspection and repair indicated low percentages in the commercial and regional airline sector at 23.1% and 19.2%. The general and business aviation sector showed 48.9% and 40.4% for these two services. The data on these services seems to be in contradiction to the data for requirements of A&P certificates. The discrepancy may be due to the isolation of the airframe and powerplant work from the avionics work. This type of work may be isolated to specialized shops that would not typically include avionics work. In the general and business aviation sector the shops tend to be less segmented and more of a mixed environment. These avionics technicians would be more likely to be in the same environment where airframe and powerplant inspections and repairs are carried out by the A&P certificated personnel.

Summary of Training Requirements

Initial Training

Nearly half (47.3%) of all participants received their initial training through technical colleges or training centers. The next largest source for initial training was the military with just over 32% receiving their initial training through the military. These numbers were consistent across the sectors.

Continuing Education

Overall, 71.6% of the participants utilized on-the-job training to receive the majority of their new technical training. An overwhelming majority (86.5%) of participants indicated that electronic advances in the last decade have generated the need for additional training. The general and business aviation sector had 93.6 % responding yes while commercial and regional airlines sector had 76.9% responding yes to this question. These responses indicate that avionics technicians in all sectors are seeing advanced electronics that require additional training with a larger majority of general and business aviation technicians facing these challenges. Generally, the participants indicated that learning new subjects, new tasks, and new skills were required for these new electronic advances and 69% indicated on-the-job training was used to achieve this.

Training and the FAA 2020 Mandate for ADS-B

The FAA 2020 mandate for ADS-B has had a wide impact on the aviation industry and has required additional training from the majority of avionics shops. Nearly 80% of the participants indicated an increase in workload due to the 2020 mandate and

76% of these indicated a need for additional technicians, while 75% also indicated a need for additional training. The ADS-B system is a new application of existing technologies. It combines GPS and transponder systems in a new configuration which generates new challenges for technicians. A clear majority (65%) of the training for this mandate was accomplished thru on-the-job training. The data indicated training encompassed mostly learning new subjects, but included some new tasks and some new skills as well.

Summary of Avionics Systems

Communications Systems

More than half (53.8%) of the commercial and regional airlines sector participants indicated none of the listed communications systems applied to their shop. This would point toward a layered structure of commercial and regional airlines sector maintenance systems. In this type of structure individual shops specializing in specific related systems would handle only those systems once the LRU is removed from the aircraft. The 30.8% of commercial and regional airlines sector participants selecting communications systems all selected multiple communications systems. One participant in this group did not complete any other questions in the survey. The remaining commercial and regional airlines sector participants working also selected multiple systems in each systems group supporting the conclusion on-aircraft that a limited number of technicians are assigned to work on the aircraft and would work with many different systems.

All the general and business aviation sector participants had some communications system applicable to their shop. General and business aviation sector participants indicated 96% worked with VHF communications systems. On-board

communications are also common in many general and business aviation sector aircraft. A fact supported by the 76% of participants working with on-board communications systems. In-flight entertainment systems, widely used in commercial aircraft for many years are now common in general and business aviation sector aircraft. Seventy percent of the general and business aviation participants indicated they now work with in-flight entertainment systems.

The lowest percentages of the communications group was 50% and associated with both HF and satellite communications systems. Satellite communication and HF communication systems are used for long range communications. These types of systems are required in aircraft when crossing large bodies of water. The HF systems have been common in many general aviation aircraft for years. Satellite communications systems are more expensive and more complex than HF and have typically been less common in the general and business aviation aircraft. The data in this section indicates technicians in the general and business aviation sector are working with more of these complex communications systems like satellite communications and in-flight entertainment which were formerly associated primarily with commercial aircraft.

The communications systems knowledge levels from the commercial and regional airlines sector clearly indicated advanced theory and troubleshooting are required in most cases. The communications systems performance levels were generally in the competent or highly proficient range. These numbers also support the tiered or layered maintenance system with highly knowledgeable and highly competent specialist working on a limited number of systems.

The communications systems knowledge levels from the general and business aviation sector were not as clear as the commercial sector. The VHF communications had the highest percentage of participants selecting the knowledge level operation, some theory at 35.6% with the higher level, advanced theory and troubleshooting close behind at 33.3%. HF communications had almost equal percentages in all knowledge levels as did satellite communications between 10% and 15%. On-board communications had the higher levels of knowledge selected more often. In-flight entertainment had equal selections for basic facts and terms and advanced theory and troubleshooting, however theory and integration was selected most often. The performance levels selected most often were for competent in each of the systems.

These numbers indicate modern shops where a variety of communications systems are serviced to a variety of depth. These shops have technicians that are highly knowledgeable and highly proficient at installation repair and troubleshooting on many communications systems and partially knowledgeable and less proficient on others. These shops depend on the shared expertise of the diverse group of technicians. This format promotes and supports on-the-job training and it benefits from individuals with specialties as well as more generalized skills.

Dependent Navigation Systems

The data from the dependent navigation systems indicated that most shops in both sectors work with all the dependent navigation systems with the exception of the microwave landing systems. The data showed an extremely low percentage of participants in both sectors selected microwave landing systems as a system they work

with. Microwave landing systems were slated to be the new precision approach system for adoption by the FAA when GPS was first introduced (Helfrick, 2015). GPS precision approach offered less ground equipment investment and less aircraft equipment investment and large scale plans to upgrade to microwave landing systems were scrapped as GPS quickly became the favorite (Helfrick, 2015).

The knowledge levels from the commercial and regional airlines sector indicated operation and some theory or theory and integration were required for these dependent navigation systems. The general and business aviation sector knowledge levels indicated advanced theory and troubleshooting was selected most often with theory and integration along with operation and some theory in second place. The performance level of competent was selected most often by the commercial and regional airlines sector and competent or highly proficient was selected most often by the general and business aviation sector. The data from this section indicates that most avionics shops work with dependent navigation systems and that most avionics technicians regardless of the business sector they are in, need to have a through knowledge and understand these systems.

Autonomous Navigation Systems

The largest system group in the autonomous navigation section selected by the commercial and regional airlines sector participants was flight management systems with 95.2% of applicable participants selecting it. Automatic flight control systems had similarly high results with 85.7% selecting it. Inertial navigation and inertial reference

systems both scored much lower with 23.8% and 28.6% respectively. Only one participant from this sector selected ring laser gyro as a system they work with.

The general and business aviation sector had very similar numbers with 78.4% in FMS and 94.6% in AFCS. Also similar, inertial navigation at 37.8% and inertial reference systems at 32.4%, both much lower than the other two systems. Less than 22% of general and business aviation sector participants selected all five systems and these were the only selections for ring laser gyros.

Autonomous navigation is critical to aircraft in both commercial and general aviation sectors. Flight management systems interface with various computer systems associated with different aspects of controlling or reporting flight parameters of the aircraft and is traditionally found on larger more sophisticated aircraft (Henderson, 1993). Automatic flight control systems traditionally found on smaller jets and turboprop aircraft, also interface with many different aircraft systems to control aircraft flight but in a less computerized format (Henderson, 1993). The numbers for these systems indicate a wide range of users for both of these system types. The lower numbers in the inertial navigation and reference systems may reflect less of these systems in use or it may be a reflection of their non-serviceable sealed case design.

Fifty eight participants found autonomous navigation systems applicable to their shops and 85% did not work with ring laser gyros. Eight participants from the general and business aviation sector and one participant from the commercial and regional airlines sector selected ring laser gyro as a system they work with. Each participant making this selection also selected all the systems in this group. These nine also selected

working on-aircraft and selected multiple systems in each of the system groups. These numbers indicate the participants working with ring laser gyros are general practitioners of avionics; troubleshooting on-aircraft systems to the LRU and not to the component level.

Basic Aircraft Systems

Four participants of the 67 responding to this section selected not applicable to the section on basic aircraft systems. One of those actually worked on-aircraft doing avionics installation work. This was the clear exception. Participants from the general and business aviation sector selecting these basic aircraft systems as applicable to their shop all selected pitot/static and air-data systems. Seventy five percent of those participants also selected advanced theory and troubleshooting as the knowledge level associated with pitot/static and air-data systems. More than 90% also selected competent or highly proficient as the performance level for pitot/static and air-data systems.

Commercial and regional airlines sector participants selected pitot/static and air-data systems much less. Only 63.6% of these participants selected pitot/static and air-data systems as a system they work with. Lithium aircraft battery was also selected by 63.6% of the commercial and regional airlines sector participants. This newer technology has been in the news in recent years as new designs from Boeing had problems with battery fires (Paur, 2013). The general and business aviation sector had 31.7% of participants select the lithium aircraft battery. This indicates a growing presence of new lithium battery technology in the general and business aviation environment.

Pulse Systems

The data from the pulse systems group indicated 53% of the total participants working with pulse systems also selected component level repair as a service offered by their shops. More than 66% of these shops offering component level repair were in shops with less than 10 technicians. This high percentage of small shops offering component level repair reflects the necessity to maintain these systems at a local level. Included in this pulse system group are the transponder and ADS-B systems. These critical systems provide location and identification information to air traffic controllers. This information is used when directing air traffic and these systems are required for all aircraft operating in controlled airspace.

The data from the commercial and regional airlines sector for pulse systems had 60% select not applicable to their shop. All of these had greater than 10 technicians in their shops. All of these participants also selected LRU troubleshooting and repair to a modular level and a component level. Most of these participants also selected FMS or AFCS or both under autonomous navigation systems. Most did not select any systems from communications or dependent navigation. These results would indicate most of this 60% of commercial and regional airlines sector participants were from mid level LRU repair centers with specialties in autopilot systems.

The 40% of the commercial and regional airlines sector participants that are working with pulse systems all selected multiple systems across several systems groups. Seventy percent worked on-aircraft and 90% included communications and dependent navigation systems. These all appear to be avionics technicians capable of work on many

types of avionics systems. Some of these are in smaller line level shops working on-aircraft, while others are working in large shops with many different systems and including on-aircraft and bench repair operations.

The general and business aviation sector had all but one participant (97.6%) working with pulse systems. All but one of these worked with transponders and ADS-B systems. These general and business aviation sector participants also all selected multiple systems across several systems groups indicating the high levels of integration associated with pulse systems.

The association of multiple systems selections by those who work with pulse systems leads to the conclusion that shops which include work on pulse systems tend to be work centers with many capabilities. This also indicates that work with pulse systems is work with systems integrated into the aircraft and to other systems requiring technicians highly trained in multiple systems on-aircraft. It may also be concluded that technicians trained for component level repair working in the on-aircraft environments are often working with pulse systems.

Summary of Advanced Avionics Systems

Fiber optics was selected by a low percentage (15%) of all participants working with any of these advanced systems, indicating it is rare, but still found in aircraft from both sectors. The high number of participants (91.7%) selecting AIRNC 429 and other data bus formats indicate this technology is found in most aircraft in either sector. The differences in the sectors were indicated by the selections in the two and three screen electronic flight instrument systems, and engine performance analyzers.

The general and business aviation selected two and three screen electronic flight instrument systems 40% more often than the commercial and regional airlines. Two and three screen EFIS is now found in many general and business aviation aircraft, either as original equipment or aftermarket upgrade. Commercial and regional airlines have been using EFIS screens for several years, mostly in a multi-screen format. Also commercial and regional aircraft are more likely to have the original equipment configuration. Upgrading a fleet of aircraft to new cockpit design is costly. Although EFIS systems can improve efficiencies, the cost savings would not likely pay for the cost of the upgrade. A better option is to incorporate the new design in the next generation of new aircraft purchased.

Engine performance analyzers are available for most models of general and business aviation aircraft and provide additional safety and reduced maintenance costs for relatively affordable equipment investment. Commercial and regional airlines use engine performance monitors and centralized monitoring systems and not aftermarket stand alone analyzers. The sensors of these systems may be in the realm of the mechanics with only the monitoring computers maintained by the avionics technicians.

Another area of difference is in internet connectivity. Forty-two percent of general and business aviation participants selected internet connectivity as systems they work with. Only 14% of commercial and regional airlines participants selected this. The reduced cost, increased number of service providers, and services available explain the large percentage of general and business aviation participants selecting this. However, the low number of commercial and regional airlines sector participants may be due to the

specialist nature of the airlines maintenance structure. Also, a lower number of regional airline aircraft would be equipped with these systems.

Summary of Shop Tools, Equipment, and Processes

Data from the shop tools section clearly reflected the installation and on-aircraft troubleshooting of the general and business aviation sector with high usage of hand tools and metal working tools. The most significant of these was the nearly 60% gap between sectors responses for the use of benders, sheers, and saws. The commercial and regional airlines sector lead only in the use of the hot air soldering equipment which is most often required in component level repair.

Data from the shop equipment section also reflected the installation element of the general and business aviation sector. Both sectors indicated near equal usage of O-scope and battery chargers. However, general and business aviation sector responses dominated in all types of ramp testers and some bench test equipment. In the general and business aviation sector bench repair shops, stand-alone test sets capable of testing units from different manufacturers are used. In commercial and regional airlines LRU repair centers special computerized test systems are often used. An LRU suspected of a fault is connected to the system and many preprogramed tests are executed to determine faults. These systems may be capable of testing an entire suite of LRU's from a specific manufacturer and isolating faults to different circuits or to specific components.

The data from soldering and wiring processes also illustrated the greater amount of installation and on-aircraft troubleshooting and repair done by avionics shops in the general and business aviation sector. Coax routing and repair and wire harness fabrication

were selected by 92.3% of general and business aviation participants. Commercial and regional airlines participants had 44% select coax routing and repair and 52% selected wire harness fabrication.

These numbers indicate most general and business aviation shops have installation and on-aircraft troubleshooting and require the knowledge of tools, equipment, and soldering and wiring processes that support that work. The data also indicates that commercial and regional airlines technicians may also require the same skills and knowledge of tools, equipment, and soldering and wiring processes for both on-aircraft and LRU applications.

Summary of General Objectives

The data for basic aviation maintenance requirements indicated a nearly balanced number of selections for aircraft drawings, maintenance forms & records, and corrosion control. The largest variance was in the selections for weight and balance. Commercial and regional airlines sector participants had only 10% select weight and balance while the general and business aviation sector participants had 83% select it. The extremely low percentage of the commercial and regional airlines sector would be consistent with removing and replacing identical equipment or working from engineering drawings where weight and balance is calculated at the engineering level and not done by the avionics technicians. The high percentage of selections for weight and balance by the general and business aviation sector is consistent with new installations of non original equipment components where technicians need to calculate weight and balance for the old equipment removed and the new equipment installed.

The data for the performance of mathematical operations required by the A & P general's objectives indicated a wide variance across shops in both sectors. There were many selections for extremely limited, partially proficient, and for competent from both sectors. The real consistency across sectors in this group of data was in the very low selections for highly proficient by both sectors. The varied data leads to the conclusion that avionics technicians in most environments need to be at least partially proficient to competent with the mathematical operations required by the A & P general's objectives. Technicians may find environments in both sectors where these skills are not required but are just as likely to find those environments where they are needed.

The data for the knowledge level of the basic principles of physics required by the A & P general's objectives also indicated a wide variance across shops in both sectors. Commercial and regional airlines sector participants had more selections for knowing only the basic facts, but also had many selections for competent and advanced understanding. The general and business aviation sector had similar variance with more selections for the competent knowledge level. Again, technicians may find environments in both sectors where this knowledge is required to a minimal degree or it may be required to a much greater depth of understanding.

The data for the performance of processes and materials including precision physical and mechanical measurements, precision electrical and electronic measurements, identification and selection of proper hardware, materials, and components indicated selections of competent and highly proficient led in both sectors. There were very few selections for the extremely limited performance level. Aviation electronic technicians in most environments will be required to take precision measurements and to properly

identify hardware, materials, and components. Technicians will need to do this to a competent or highly proficient level skill level.

Aircraft ground operations had only six participants from the commercial and regional airlines sector. The general and business aviation sector had 37 responses. The question had one element described as ground operation, aircraft servicing, and aircraft taxi. The overwhelming majority in both sectors was for a competent performance level with minimal selections for each of the other performance levels.

Conclusions and Discussions

Aircraft electronics have undergone many changes since the first radio was used to navigate the darkness. Electronics products are constantly evolving as capabilities of existing systems are improved and new systems are introduced. The invention of the microprocessor led to significant increases in electronics capability and transformed how we use the technology. More recent improvements in display technology coupled with dramatic increases in computing power and reductions in electronics costs have led to significant increases in advanced electronic systems available in large and small modern aircraft. These new systems introduce new challenges for the technicians in installation, testing, and repair of avionics systems.

1. Research Question I

What are the knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry?

The knowledge, skills, and abilities used by aircraft electronics technicians in the modern aviation maintenance industry vary widely depending on what business sector of

the industry and the segment of maintenance process involved. All of the elements listed in the survey of this study, with a few exceptions and probably a few omissions, can be found in most general and business aviation shops as well as most of the on-aircraft shops in commercial and regional airline sectors. In the systems blocks of the survey, all the elements from each of the systems groups appear to have a reasonable amount of relevance to many avionics technicians with the exception of microwave landing systems of the dependent navigation systems group and the ring laser gyro of the autonomous navigation systems group. These two elements had extremely low percentage of participants select them and those that did select them seemed to be selecting all the elements of the group. No selections for advanced theory and troubleshooting knowledge level were selected for ring laser gyro or microwave landing systems. The only selection for highly proficient performance level was from a technician in the general and business aviation sector that did not do component level repair. The conclusion drawn from this is that an aircraft electronics technician needs only a minimal knowledge of terms and basic facts about ring laser gyros and may not need any knowledge about microwave landing systems.

The advanced avionics group had two elements with very low percentages; fiber optics and micro electromechanical sensors (MEMS). The use of fiber optics in aircraft was discontinued for several years as it was deemed too fragile for the aviation environment. Recent improvements in fiber optic performance characteristics have led to a renewed use of this highly efficient transmission line in new production aircraft. The increased use of MEMS goes hand-in-hand with the increased use of fiber optics. MEMS provide a smaller, lighter means of sensing information and converting it to digital

signals at the point of sensing (Bertorelli, 2013). Once converted to digital signals, information can easily be processed and transmitted over fiber optic lines. Modern aircraft designs may include several MEMS in remote locations of the airframe sending data to a centrally located data acquisition unit. The data acquisition unit can compile all the data and transmit it over a single fiber optic line to a main computer for processing and distribution.

The increased use fiber optic transmission lines increases the chance for significant impact on the daily activity of aircraft electronics technicians. There is a need for substantial knowledge of the care and handling of this new age material. There is also a need for competent and highly proficient skill development in routing and termination of this advancing technology. Fiber optics may also present new challenges in learning to use new tools and new methods to troubleshoot and isolate faults. MEMS are generally self contained LRUs and offer little opportunity for internal repair in most shops. MEMS do present new challenges in learning to troubleshoot and isolate failures as they become integrated into more systems.

Fiber optics and MEMS are being used more and more as aircraft designers become familiar with the technology. These two elements represent new advances in technology that will increase in use on modern aircraft for years to come. The conclusion to be drawn from this is; even though these two items have low percentages in the study, they are established elements of new technology that are likely increasing in use and need to be part of a technician's knowledge, skills, and abilities.

Under the shop equipment question group, the RD-300 radar test set or equivalent received a very low percentage of selections. This may be due to the specialized nature of radar repair rather than a departure from the use of this type of test set. However, the increased availability of weather information sent directly to the cockpit through the new ADS-B systems may possibly lead to a decline in the use of onboard radar systems and a decline in the need for avionics technicians to have knowledge and skill with this type of test equipment (Federal Aviation Administration, 2010). But for now at least, radar is still a relevant technology for aircraft electronics technicians.

2. Research Question II

Do the knowledge, skills, and abilities required for aircraft electronics technicians differ depending on the industry segment they are working in; commercial or general aviation, aircraft or component manufacturing, aircraft or component servicing?

The aircraft electronics industry can be divided into three different business sectors; commercial and regional airlines, general and business aviation, and aviation manufacturing. These business sectors each fall under many of the same regulations as they all work on-aircraft or aircraft components. Many tasks performed by technicians in one sector are the same tasks performed by technicians in another sector. Each of these business sectors may also be unique in the requirements of the technicians doing the work. Some common tasks performed in one sector may not be required by technicians in another sector.

Training for technicians entering the aviation electronics industry is expensive for educators to produce and for students that pay for it. Providing training programs aimed

at meeting the requirements of all industry segments or all business sectors may not be the most effective method of training the technicians to fill the increasing job demand. Offering training specific to an industry segment or business sector could reduce training cost and time benefiting students, employers, and education providers. Providing textbooks with the appropriate balance between basic fundamental knowledge and an engineering level understanding would allow students to study material at a level relevant to the employment opportunities. The level of information and the level of application of information students are exposed to will direct the type of employment graduates are prepared for. By identifying the differences in the knowledge, skills, and abilities between the industry segments and between business sectors, we may be able to isolate specific training needs and thus reduce training time and cost.

The most noteworthy variations between the knowledge, skills, and abilities of technicians in the commercial and regional airlines sector and the general and business aviation sector was in the number of technicians working on-aircraft and the number of technicians working on-aircraft required to have an A & P certificate. Almost all general and business aviation sector technicians worked on-aircraft and only 18% were required to have an A & P certificate. The commercial and regional airlines sector had only 31% of technicians working on-aircraft and required 63% of those technicians to have an A & P certificate.

These numbers become more unbalanced when taking into consideration the types of services offered. The general and business aviation sector has almost all technicians working on the aircraft and performing avionics installations and nearly half these shops are performing airframe and powerplant inspections. Installation work requires

fabrication and installation of structural supports, tasks typically associated with skills learned in an airframe certificate program (Electronic Code of Federal regulations, Part 147, Appendix A, 2016). Airframe and powerplant inspections are usually performed by an A & P certificate holder. The commercial and regional airlines sector, where only 31% of technicians work on-aircraft had only 26% perform avionics installations, and roughly 20% of technicians perform airframe and powerplant inspections and yet, they require 63% of technicians working on-aircraft to have an A & P certificate.

The deficiency appears to be in the extremely low numbers of general and business aviation sector shops requiring an A & P certificate. This can be explained by the fact that the general and business aviation shops generally work under a repair station certificate which provides the authority for installation and inspection services when return to service of all work is signed by an authorized inspector. Commercial and regional airlines shops do not have this same type of authorization. Also commercial and regional airlines shops have fewer technicians working on the aircraft and may require those technicians to be qualified to work in all areas of the aircraft and to be able to sign return to service for their own work. This requires these technicians to have an A & P certificate.

In the commercial and regional airlines sector, 73% of the 26 participants, had 10 or more years of experience and of those, only one selected, includes work on-aircraft. All others worked on LRU's to a component level. It appears that in commercial and regional airlines sector the more experienced technicians work on LRU's to a component level. In the commercial and regional airlines maintenance structure line or on-aircraft technicians are often promoted into the intermediate or component level repair shops.

In the general and business aviation sector, 89% of the 47 participants, had greater than 10 years experience and of those only three selected does not include work on-aircraft. The remaining 83% had more than half also select LRU component level repair. In contrast to the commercial sector format at least half of the general and business aviation sector shops have the more experienced technicians still working on-aircraft and providing component level repair services. The structure of these maintenance facilities is often one where installers are supported by component level or bench technicians. These bench technicians serve as the on-aircraft troubleshooters and systems specialist, performing installation design and integration services secondary to their primary focus of LRU component level repair.

The commercial and regional airlines sector requires more technicians to have certificates, yet this sector does less on-aircraft work. The general and business aviation sector has more technicians working on-aircraft but requires fewer to have the A & P certifications. Both sectors have LRU and component level repair being done by technicians with a great deal of on-aircraft knowledge and experience. It appears that the industry has lots of technicians working on-aircraft that do not have an A & P certificate. The question then becomes, do all these technicians need certificates or do regulators and educators and need to rethink how they train and certify these technicians?

The A & P certifications can be a barrier to employment for some avionics technicians. Many airline jobs require an A & P certificate for avionics positions. Many A & P certificated mechanics lack the avionics knowledge, skills, and abilities to troubleshoot and repair many modern aircraft systems which incorporate more electronics in all aspects of airframe and powerplant design.

Conclusions can be drawn that specific training should be available that is directed at technicians wanting on-aircraft jobs. There is also a need for specific training directed towards technicians seeking aviation jobs in LRU and component repair. Primary training programs with specialization options aimed at specific systems or specific segments of the industry could provide this type of directed training. This type of system could allow students to add desired knowledge, skills, and abilities to a primary training program based on the specific job openings or technical interest.

3. Research Question III

When meeting the need for continuing education on advanced aircraft electronic systems what are the current methods of delivering technical training used in the different segments of the aircraft electronics industry?

The education of aircraft electronics technicians has typically come from military training or technical colleges and training centers. The data indicated approximately 80% of participants received their initial training from military, technical colleges, or training centers. Students graduating from these aircraft electronics training programs will likely go to work as entry level technicians. These technicians will need continuing education and training as systems, processes, and practices change. An additional goal of this study is to determine the current methods that are used to deliver technical training when meeting the need for continuing education on advanced aircraft electronic systems in the different segments of the aircraft electronics industry.

The fields of aviation and electronics are both constantly changing requiring continuing education to stay current on system advances and industry practices. Seventy percent of the participants in this study had greater than 10 years experience yet, the data

indicated 87.7% of participants agreed that advances in the last ten years have required additional technical training. It is widely accepted that there will be some on-the-job training in most work environments. However, the findings indicate most of the existing workforce of technicians, 71.6% learned the new knowledge, skills, and abilities necessary to maintain today's modern systems through on-the-job training. Only 13.5% of participants utilized technical colleges or training centers for learning new technical knowledge, skills, and abilities.

The aviation industry is currently undergoing a transformation as large numbers of the highly trained and experienced workforce reach retirement age (Adams, 2014). The departure of these knowledgeable and experienced technicians is going to leave a gap in the on-the-job training of the new workforce. Recent decisions to upgrade the aviation infrastructures have resulted in the need for modification to ground equipment and to aircraft systems (Federal Aviation Administration, 2010). The retiring workforce and the massive upgrade to aircraft and infrastructure have combined to create a flood of demand for qualified technicians. The industry will be turning to colleges, universities, and aviation technical schools to provide new technicians. The retiring experienced technicians will not be around to provide on-the-job training and the industry will likely need these education institutions to provide continuing education for technicians on new and advanced systems.

Conclusions may be drawn that changes need to be made in how the aviation industry views continuing education and how it is provided. Crossover training that can be achieved without a full length-constrained program could provide qualified technicians to the industry segments that need them with less cost and less training time.

This type of training could take the form of short programs to qualify existing mechanics in avionics systems or short programs to qualify avionics technicians in specific airframe or powerplant systems and processes.

As a final point of conclusion, training needs to become more flexible. The industry needs more technicians fast. Training organizations need to be able to respond to all aspects of the industry's training needs. Training needs to be available for entry level technicians on-aircraft or in the bench shop. Training needs to be available for existing electronics technicians and A & P technicians to learn new technologies. Training needs to be available for A & P technicians to gain electronics systems knowledge and aircraft electronics technicians to gain airframe or powerplant knowledge. Partnerships between the aviation industry, education, and certification organizations like NCATT are needed to develop new training and certifications that would provide the flexibility necessary to help ensure enough qualified technicians are ready to meet the challenges of the rapidly changing aviation environment.

Recommendations for Future Research.

1. Introduction of ADS-B information to the cockpit may prove to be a disruptive technology that leads to a drop in requirements for other systems that formerly provided this type of information such as TCAS and radar. Any new technology which displaces an existing system may be considered a disruptive technology and ADS-B has that potential. Follow up studies on this new technology as a disruptive technology needs to be conducted.
2. This study resulted in a low number of participants possibly due to the length of the survey. New studies need to be conducted that break up the elements of this

study into smaller segments. Separate studies for types of aviation training or aviation tools or knowledge of physics and math could provide more accurate and scalable results.

3. The amount of on-the-job training revealed by this study was surprising. On-the-job training can promote bad habits and ingrained cultural bias. Studies need to be conducted that focus on how on-the-job training is conducted, how effective is it, and how it can be improved.
4. The aircraft is an extremely complicated and complex marvel of the modern age. Care and maintenance of these machines requires extensive training in many different specialties. Regular periodic studies should be conducted every five years to evaluate the effectiveness of the training to meet the requirements of the industry and to ensure training is current and sufficient to protect the safety of all those who fly.

REFERENCES

- Adams, R. (2014, May). New maintenance techs short on numbers, skills. *AIN online*, Retrieved from <https://www.ainonline.com/aviation-news/business-aviation/2014-05-18/new-maintenance-techs-short-numbers-skills#>
- Aircraft Electronics Association.net. (2018). What is the AEA. Retrieved from <https://www.aea.net/aboutaea.asp>
- ASTM International. (2016). *Detailed overview*. Retrieved from https://www.astm.org/ABOUT/full_overview.html
- Aylward, B. (2015). The Space-based future of ADS-B. *Avionics News 52(11)*.
- Beechcraft Textron Aviation, (2016). Bonanza G36. Retrieved from: <http://beechcraft.txtav.com/en/bonanza-g36>
- Bertorelli, P. (2013, May 30). The Magic of MEMS. *AV web*. Retrieved from https://www.avweb.com/news/features/mems_faa_adsb_gyro_vacuum_ilevil_dyn_on_ahrs_efis_208787-1.html

- Brandon, E. (2014, June 16). The youngest baby boomers turn 50. *U.S. News and World Report*. Retrieved from <https://money.usnews.com/money/retirement/articles/2014/06/16/the-youngest-baby-boomers-turn-50>
- Brewster, L. (2008, August). *NCATT Aircraft Maintenance Technology*, 19, 24-27. Retrieve from <http://argo.library.okstate.edu/login?url=https://search-proquest-com.argo.library.okstate.edu/docview/223756325?accountid=4117>
- Burnside, J.E., (2015). Can your avionics be hacked? *Avionics News* 52(11).
- Buckwalter, L. (2010). *Avionics training: Systems, installation, and troubleshooting*. Leesburg, VA: Avionics Communications.
- Cessna Aircraft Company, (2015). *Cessna Skyhawk*. Retrieved from: <http://cessna.txtav.com/en/piston/cessna-skyhawk>
- Credential Testing Services, (2018). *ASTM NCATT certifications*. Retrieved from: <https://www.credentialtesting.com/astm-ncatt-certifications/>
- Duncan Aviation, (2018). *Straight talk books*. Retrieved from: <https://www.duncanaviation.aero/resources/straight-talk/>
- Dyen F.D. & Hall E. (2016). *Competency based education in Part 147 aviation maintenance technician schools* (White Paper). Retrieved from <http://www.atec-amt.org/uploads/1/0/7/5/10756256/atec-whitepaper-cbe-amts-20160506.pdf>
- Eismin, T. K. (1994). *Aircraft electricity & electronics*. New York: Glencoe.

Eismin, T. K. (2011). *Avionics: Systems and troubleshooting*. Weyers Cave, VA.: Avotek Information Resources LLC.

Electronic Code of Federal Regulations, Part 65 Certification: Airmen Other Than Flight Crewmembers. (2018). Subpart D: Mechanics. Retrieved from:
<https://www.ecfr.gov/cgi-bin/text-idx?SID=5d75377785c260d01d67cb5dc946d0ea&mc=true&node=pt14.2.65&rgn=div5#sp14.2.65.d>

Electronic Code of Federal Regulations, Part 65 Certification: Airmen Other Than Flight Crewmembers. (2018). Subpart E: Repairmen. Retrieved from:
<https://www.ecfr.gov/cgi-bin/text-idx?SID=5d75377785c260d01d67cb5dc946d0ea&mc=true&node=pt14.2.65&rgn=div5#sp14.2.65.e>

Electronic Code of Federal Regulations, Part 91 General Operating and Flight Rules, Subpart C: Equipment, Instruments and Certificate Requirements, (2018). Retrieved from https://www.ecfr.gov/cgi-bin/text-idx?SID=fc612f4d3cbe870e2a520cf60f16dced&mc=true&node=pt14.2.91&rgn=div5#se14.2.91_1205

Electronic Code of Federal regulations, Part 147 Aviation Maintenance Technician School, Appendix A: Curriculum Requirements (2016). Retrieved from https://www.ecfr.gov/cgi-bin/text-idx?SID=1eb735f70662b1ff557ad60a3185e805&mc=true&node=ap14.3.147.0000_0nbspnbspnbspn.a&rgn=div9

Federal Aviation Administration, U.S. Department of Transportation, (1995). Order 8260.38A. *Civil Utilization of Global Positioning System*. Retrieved from: <https://www.faa.gov/documentLibrary/media/Order/8260.38a.pdf>

Federal Aviation Administration, Flight Standards Service, (2008). Aviation maintenance technician handbook: General 2008. Government Printing office. Washington

Federal Aviation Administration, Flight Standards Service, (2009). *Advanced avionics handbook*. Retrieved from: http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/advanced_avionics_handbook/media/FAA-H-8083-6.pdf

Federal Aviation Administration, (2010). *ADS-B final rule*. (G.P.O. Publication No. 30160). Retrieved from: <https://www.gpo.gov/fdsys/pkg/FR-2010-05-28/pdf/2010-12645.pdf>

Federal Aviation Administration, (2015). Data & Research, Aviation Data & Statistics, Airmen & Aircraft, Data Downloads, Repair Stations. Retrieved from <http://av-info.faa.gov/repairstation.asp>

Federal Aviation Administration, (2016). *Advisory Circular AC No: 120-16G: Air Carrier Maintenance Programs*. Retrieved from: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-16G.pdf

Henderson, M. F. (1993). *Aircraft instruments and avionics for A & P technicians*. Casper, WY: IAP, Inc.

- Helfrick, A. (2015). *Principles of Avionics* (9th ed.). Leesburg, VA: Avionics Communications Inc.
- Inman, T. (2012). *Avionics: Beyond the AET navigation, communication, and installation*. Weyers Cave, VA: Avotek Information Resources LLC.
- Knauer, C. (April, 2018). ADS-B market drives shop to earn Part 145 certification. *Avionics News*, Aircraft Electronics Association, Lee's Summit Missouri.
- Gay, L. R., & Airasian, P. W. (2003). *Educational research: Competencies for analysis and applications*. Upper Saddle River, N.J: Merrill/Prentice Hall.
- National Center for Aerospace & Transportation Technologies, (2014). *NCATT aircraft electronics technician (AET) standard*. ASTM International. Retrieved from: https://www.astm.org/CERTIFICATION/DOCS/217.NCATT_AET_Standard.pdf
- National Center for O*NET Development, (2018). *Avionics Technicians. 49-2091.00*. Retrieved from <https://www.onetonline.org/link/summary/49-2091.00>
- Paur, J. (2013, January 17). How a battery grounded Boeing's revolutionary Dreamliner. *Wired*. Retrieved from <https://www.wired.com/2013/01/boeing-787-electric-fire-grounding/>
- Peri, R. (2018, August). The view from Washington: Maintenance technician training standards. *Avionics News*, Aircraft Electronics Association, Lee's Summit Missouri.

Prentice, B. & Costanza, D. (2017, April 24). Aging baby boomers cause aircraft mechanics shortage as global fleet expands, modernizes. *Forbes*. Retrieved from: <https://www.forbes.com/sites/oliverwyman/2017/04/24/looming-aircraft-mechanic-shortage-may-threaten-the-growth-of-the-global-fleet-and-raise-costs/#6bbb24b44984>

Jeppesen Sanderson, (2009). *A & P technician airframe textbook*. Englewood, CO.: Jeppesen Sanderson.

Sparks, J. (2007, March). Avionics technicians. *Aircraft maintenance technology*, 18, 24-27. Retrieved from <http://argo.library.okstate.edu/login?url=https://search-proquest-com.argo.library.okstate.edu/docview/223758860?accountid=4117>

Welsh, T. (2017, May). Mind The Gap: Innovations in talent acquisition. *Aircraft Maintenance Technology*, 28, 28-32. Retrieved from <http://argo.library.okstate.edu/login?url=https://search-proquest-com.argo.library.okstate.edu/docview/1900328973?accountid=4117>

U.S. Department of Labor, Bureau of Labor Statistics. (2017). *Occupational Outlook Handbook*, Retrieved from <https://www.bls.gov/ooh/installation-maintenance-and-repair/aircraft-and-avionics-equipment-mechanics-and-technicians.htm>

U.S. Department of Veterans Affairs. (2009). *What are KSA's*. Retrieved from: <http://www.va.gov/jobs/hiring/apply/ksa.asp>

Underwood, D., (2001, July). Avionics History: 1976: What a year for avionics. *Avionics*.

Retrieved from [https://www.aviationtoday.com/2001/07/01/avionics-history-](https://www.aviationtoday.com/2001/07/01/avionics-history-1976-what-a-year-for-avionics/)

[1976-what-a-year-for-avionics/](https://www.aviationtoday.com/2001/07/01/avionics-history-1976-what-a-year-for-avionics/)

APPENDICES

- Appendix A: IRB Approval
 - IRB Approval Letter
- Appendix B: Consent Information Sheet
 - Consent Information Sheet
- Appendix C: Request for Participation
 - Request for Participation
- Appendix D: Aircraft Electronics Technician Survey
 - Survey

Appendix A: IRB Approval Letter

Oklahoma State University Institutional Review Board

Date: Thursday, March 09, 2017
IRB Application No ED1720
Proposal Title: IDENTIFICATION OF KNOWLEDGE, SKILLS, AND ABILITIES
REQUIRED FOR AIRCRAFT ELECTRONICS TECHNICIANS

Reviewed and Exempt
Processed as:

Status Recommended by Reviewer(s): Approved Protocol Expires: 3/8/2020

Principal Investigator(s):
Christopher Bycroft Chad L. Depperschmidt
317 Willard
Stillwater, OK 74078 Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

- 1Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
- 2Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
- 3Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
- 4Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,



Hugh Crethar, Chair
Institutional Review Board

Appendix B: Consent Information Sheet

Participant Consent Information

If you consent to participate in this study, your name will not be associated with this research in any way. It is very important that you realize that: Your participation in this study is completely voluntary. There are no special incentives for your participation and there are no negative consequences for declining participation. You are free to withdraw your consent to participate in this study at any time by closing the survey in your internet browser. Your participation in this project will involve completing one on-line questionnaire that will require about 15 minutes of your time. The questionnaire will require you to make selections identifying and defining, the knowledge, skills, and abilities required for technicians in your work environment. You will also fill in demographic information about the segment of the aviation industry and the shop you work in.

It is not anticipated that you will suffer any risks of discomfort or inconvenience from participation in this research beyond those encountered in daily life. All information you provide on the questionnaires will be anonymous. No one, not even the research team will ever see or know your name or identity. Your name will not appear on the survey or questionnaire. All information you provide will be secured at all times through the secured website and by the researcher. The data from this study will be used only for research. No reference to your name or personal identity will be made at any time. Names of participants will not be provided to the researcher. Names will not be identifiable even to the researcher.

You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Primary Investigator: Christopher Bycroft, and doctoral candidate, College of education, Oklahoma State University, (918) 373-7052 or cbycrof@okstate.edu

Faculty Adviser: Dr. Chad Depperschmidt, College of education, Oklahoma State University, (405) 744-8146.

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

Appendix C: Request for Participation

**Request for Participation in an
Important Aviation Industry Study**

From: "Christopher Lee Bycroft" cbycrof@okstate.edu
To: <PARTICIPANT>
Sent: <DATE>
Attach: Consent Information Sheeet.doc
Subject: Research Study – Identification of Knowledge, Skills, and Abilities
Required for
Aircraft Electronics Technicians across the Aviation Industry

Dear <PARTICIPANT>:

I am working on a Doctorate in Education with an emphasis in aviation and space science at Oklahoma State University. The doctoral program requires an original research dissertation. In accordance with this requirement I am conducting original research to identify the knowledge, skills, and abilities (KSA's) required for aircraft electronics technicians in the modern aviation industry. The purpose of this study is to identify those KSA's of today's technicians as defined by knowledgeable experienced individuals working as or managing aircraft electronic technicians in various aviation environments. If your experience and expertise has you working as a technician or in a supervisory role overseeing the work of aircraft electronics technicians I would greatly appreciate your participation in this important research study.

The project will consist of an electronic survey accessible via internet. The survey will be given to varied and different aviation environments that employ aircraft electronics technicians. Participants will be asked to complete the survey examining the knowledge, skills, and abilities required by aircraft electronics technicians. The survey will also gather information to identify the specific environment or segment of the aviation industry the KSA's are used in. All participants will remain anonymous and all responses will be held in strict confidence.

The Survey contains a consent information sheet, please read it carefully. Indicate you are willing to participate in this research study by clicking the consent button at the bottom of the page. A copy of the consent information sheet for your records is available at your request. You may contact me at cbycrof@okstate.edu or you may call or text me at (918)373-7052 to receive a link to the survey. If you have any questions or problems, please contact me immediately. I look forward to working with you on this important research.

Sincerely,

Signed _____

Appendix D: Aircraft Electronics Technician Survey

Knowledge, Skill, & Ability

Survey Flow

Standard: Introduction (1 Question)
Standard: Consent Block (2 Questions)

Branch: New Branch

If

If I Acknowledge I have read the consent information and I agree to participate in this survey AGREE Is Not Selected

EndSurvey: Advanced

Standard: Qualifier Block (3 Questions)

Branch: New Branch

If

If Do you currently work as an avionics technician or work supervising avionics technicians? Yes Is Not Selected

EndSurvey: Advanced

Block: Shop Demographic (10 Questions)
Standard: Training in Your Environment (12 Questions)
Standard: Basic Avionics Systems (10 Questions)
Standard: Advanced Avionics Systems (2 Questions)
Standard: Shop Tools & Equipment and Processes (6 Questions)
Standard: Generals objectives (6 Questions)

Page Break

Start of Block: Introduction

This Research project is the being conducted to determine The Knowledge, Skills, and Abilities used by aircraft electronics technicians in today's modern aviation industry. **Research Objectives:** This research will help improve technical programs by **identifying current industry needs and practices**. This study will aid in development of new textbooks and training programs resulting in more effective technicians. The study will **connect Knowledge, Skills, and Abilities to specific sectors** of the industry. This will allow training to be targeted to individual industry sectors or offer options for students to focus their education towards desired industry segments. This study will **identify the training methods used by technicians**. This information is significant when planning training time and costs, and allowing training providers to offer more effective, less expensive training solutions. **Survey Process:** **You** will answer a series of questions about their work environment and the levels of knowledge, skill, and ability needed by technicians in their work-center. The survey is divided into sections including these topics: · Demographics about the shop you work in · The types of training you have received · Common and Advanced Aircraft systems you work with · Tools, Equipment, and Processes common in your environment **About the Author:** The author of this study is a doctoral candidate in the College of Education at Oklahoma State University. He has been an aircraft electronics technician and supervisor with more than 15 years' experience. He is currently an NCATT certified Master Instructor with more than 5000 classroom hours training technicians.

End of Block: Introduction

Start of Block: Consent Block

Participant Consent Information

If you consent to participate in this study, your name will not be associated with this research in any way. It is very important that you realize that: Your participation in this study is completely voluntary. There are no special incentives for your participation and there are no negative consequences for declining participation. You are free to withdraw your consent to participate in this study at any time by closing the survey in your internet browser. Your participation in this project will involve completing one on-line questionnaire that will require about 15 minutes of your time. The questionnaire will require you to make selections identifying and defining, the knowledge, skills, and abilities required for technicians in your work environment. You will also fill in demographic information about the segment of the aviation industry and the shop you work in. It is not anticipated that you will suffer any risks of discomfort or inconvenience from participation in this research beyond those encountered in daily life.

All information you provide on the questionnaires will be anonymous. No one, not

even the research team will ever see or know your name or identity. Your name will not appear on the survey or questionnaire. All information you provide will be secured at all times through the secured website and by the researcher. The data from this study will be used only for research. No reference to your name or personal identity will be made at any time. Names of participants will not be provided to the researcher. Names will not be identifiable even to the researcher. You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Primary Investigator: Christopher Bycroft, and doctoral candidate, College of education, Oklahoma State University, (918) 373-7052 or cbycrof@okstate.edu

Faculty Adviser: Dr. Chad Depperschmidt, College of education, Oklahoma State University, (405) 744-8146.

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

I Acknowledge I have read the consent information and I agree to participate in this survey

- AGREE
- DECLINE

End of Block: Consent Block

Start of Block: Qualifier Block

Aircraft electronics technicians and those leading or supervising technicians are being selected for participation in this study. Through your participation in this study, you will be helping the aircraft electronics industry to better understand what is required of technicians in the modern aviation environment.

Do you currently work as an avionics technician or work supervising avionics technicians?

Yes

No

How many years of experience do you have as an avionics technician

1-2

3-5

6-10

Greater than 10

End of Block: Qualifier Block

Start of Block: Shop Demographic

For the purpose of this study the terms **WORK CENTER** or **SHOP** are **INTERCHANGEABLE** and refers to a small group or team of technicians performing similar duties, utilizing the same resources and working under the same leadership. **Please answer the following questions about your shop environment.**

How many Aircraft Electronics Technicians work in your shop?

- 1-3
 - 4-6
 - 7-10
 - greater than 10
-

In **how many locations** does your company employ aircraft electronics technicians?

- Only 1
 - 2-5
 - 6-15
 - greater than 15
-

If your organization has **more than one shop** which employs aircraft electronics technicians, how many aircraft electronics technicians work in the whole organization?

- 6-15
 - 16-30
 - greater than 30
 - Unknown
-

Which **business sector** of the aviation industry does your shop primarily operate in?
(mark only one)

- Commercial or Regional Airlines
 - General & Business Aviation
 - Manufacturing
-

Does your shop require aircraft electronics technicians to have an **A&P license**?

- Yes
 - No
-

The work done by the aircraft electronics technicians in your shop:

- includes work **on aircraft**
 - does not** include work on aircraft
-

What class of aircraft does your shop work with? (mark all that apply)

- Reciprocating Engine Aircraft
- Turbo Prop aircraft
- Jet Aircraft

What type of aircraft does your shop work with? (mark all that apply)

Fixed Wing Aircraft

Rotor-craft

What services are provided by aircraft electronics technicians in your shop? (mark all that apply)

Avionics installations on aircraft

Avionics troubleshooting and repair on aircraft

LRU troubleshooting and repair [Modular level]

LRU troubleshooting and repair [component level]

LRU troubleshooting and repair [Overhaul level]

Instruments inspections

Instruments repair

Airframe inspections and repair

Power-plant inspections and repair

End of Block: Shop Demographic

Start of Block: Training in Your Environment

Please answer the following questions about Training and the Aircraft Electronics Technicians working in your shop.

What was the primary means used by **you** to receive your **initial technical training**? (mark only one)

- Military
 - Technical College or Training Center
 - Public School System
 - On-The-Job Training
 - On_Line Program
 - Self-Study
-

What is the main **type of training** used by technicians in your shop to receive **new technical training** (Mark only one)

- On-The-Job Training
- Self-Study
- Technical College or Training Center
- Seminars or Guest Speakers
- Technical Representatives
- Webinars

Have **advances** in technology in the last ten years **required additional training** for existing technicians in your shop?

- Yes
- No
- Unknown

If yes, what **type of additional training** was needed? (mark all that apply)

- Learning New Subjects
 - Learning New Tasks
 - Learning New Skills
-

If yes, identify the primary **method of training used** by your technicians to receive the **new training**? (mark only one)

- On-The-Job Training
 - Self-Study
 - Technical College or Training Center
 - Seminars or Guest Speakers
 - Technical Representatives
 - Webinars
-

TRAINING AND THE 2020 MANDATE Please choose the best answer to describe how the FAA mandate for ADS-B has impacted your Shop.

Has the 2020 mandate for ADS-B generated an **increased workload** for your shop?

- Yes, excessively
 - Yes, moderately
 - Yes, slightly
 - No, not at all
-

Has the 2020 ADS-B mandate generated a **need for additional technicians** in your shop?

- Yes, excessively
 - Yes, moderately
 - Yes, slightly
 - No, not at all
-

Has the 2020 mandate for ADS-B generated a **need for additional training** in your shop?

- Yes, excessively
 - Yes, moderately
 - Yes, slightly
 - No, not at all
-

If yes, what **type of additional training** was needed? (Mark all that apply)

- Learning New Subjects
 - Learning New Tasks
 - Learning New Skills
-

If yes, identify the **PRIMARY method of training used** by your technicians to receive the additional training? (Mark only one)

- On-The-Job Training
- Self-Study
- Technical College or Training Center
- Seminars or Guest Speakers
- Technical Representatives
- Webinars


End of Block: Training in Your Environment

Start of Block: Basic Avionics Systems

Select each of the communications systems that are applicable to your shop. (mark all that apply)

- VHF Comm
 - HF Comm
 - On-board Comm
 - Satellite Comm
 - In-Flight Entertainment
 - Not Applicable
-

Describe the Knowledge and Performance levels for Technicians performing Installation Service or Repair of each of these Aircraft Communications Systems.

	Systems Theory Knowledge	Operation and Testing
VHF Comm	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient
HF Comm	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient
On-board Comm	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient
Satellite Comm	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient
In-Flight Entertainment	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Basic Facts and Terms ... Adv. Theory and T/S	▼ Extremely Limited ... Highly Proficient

Select each of the Dependent Navigation Systems that are applicable to your shop.
(mark all that apply)

- ADF
- VOR
- DME
- Area Navigation
- Localizer/Glide Slope
- Marker Beacon
- GPS
- Microwave Landing systems
- Not Applicable

Describe the Knowledge and Performance levels for Technicians performing Installation Service or Repair of each of these **Dependent Navigation Systems**.

	System Theory Knowledge	Operation and Testing


ADF	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
VOR	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
DME	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Area Navigation	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Localizer/Glide Slope	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Marker Beacon	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
GPS	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Microwave Landing systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient

Select each of the Autonomous Navigation systems that are applicable to your shop.
(mark all that apply)

- Flight Management Systems
- Inertial Navigation System
- Inertial Reference System
- Ring Laser Gyros
- Automatic Flight Controls Systems
- Not Applicable

Describe the Knowledge and Performance levels for Technicians performing Installation, Service, or Repair of each of these **Autonomous Navigation Systems**.

	System Theory Knowledge	Operation and Testing

Inertial Navigation System	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Flight Management Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Inertial Navigation System	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Inertial Reference System	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Ring Laser Gyros	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Automatic Flight Controls Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient

Select each of the Basic Aircraft Systems that are applicable to your shop. (mark all that apply)

- Pitot/Static Air-data Systems
- Power Distribution Systems
- Generators / Voltage Regulators
- Aircraft Batteries Lead Acid and Ni-cad
- Lithium Aircraft Batteries
- Not Applicable

Describe the Knowledge and Performance levels for Technicians performing Installation, Service, or Repair of each of these **Basic Aircraft Systems**.


	System Theory Knowledge	Operation and Testing

Pitot/Static Air-data Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Power Distribution Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Generators / Voltage Regulators	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Aircraft Batteries Lead Acid and Ni-cad	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Lithium Aircraft Batteries	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
<input checked="" type="checkbox"/> Not Applicable	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient

Select each of the Pulse Systems that are applicable to your shop. (mark all that apply)

- Weather Radar Systems
- Mode A, C, and S Transponders
- TCAS / TIS
- ADS-B
- Ground Proximity Warning Systems
- Not Applicable

Describe the Knowledge and Performance levels for Technicians performing Installation, Service, or Repair of each of these **Pulse Systems**.

	System Theory Knowledge	Operation and Testing
Weather Radar Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Mode A, C, and S Transponders	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
TCAS / TIS	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
ADS-B	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Ground Proximity Warning Systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient

End of Block: Basic Avionics Systems


Start of Block: Advanced Avionics Systems

Select each of the Advanced Avionics Systems that are applicable to your shop. (mark all that apply)

- Basic 2 and 3 screen Electronic Flight Instruments
- Advanced Multi-Screen EFIS
- 429 and other Data Bus Formats
- Fiber Optics
- (MEMS) Micro-Electro-Mechanical-Sensors
- Airborne Internet Connectivity
- Engine Performance Analyzers
- Fly-By-Wire systems
- Not Applicable

Describe the Knowledge and Performance levels for Technicians performing Installation Service or Repair of each for these **Advanced Avionics Systems**.

	System Theory Knowledge	Operation and Testing

Basic 2 and 3 screen Electronic Flight Instruments	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Advanced Multi-Screen EFIS	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
429 and other Data Bus Formats	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Fiber Optics	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
(MEMS) Micro-Electro-Mechanical-Sensors	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Airborne Internet Connectivity	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Engine Performance Analyzers	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
Fly-By-Wire systems	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Knows Basic Facts and Terms ... Advanced Theory and Trouble Shooting	▼ Extremely Limited ... Highly Proficient

End of Block: Advanced Avionics Systems


Start of Block: Shop Tools & Equipment and Processes

Select each of the following **Shop Tools** that are applicable to your shop.

- Hot Air Solder Station
- Pneumatic Powered Hand Tools
- Electric Powered Hand Tools
- Grinders, Sanders,
- Sheet Metal Benders, Sheers, Saws
- Bering Press
- Not Applicable

Describe the Knowledge and Performance levels for
Understanding and Usage of the Following **Shop Tools**.

	Understanding Tools	Ability to use Tools

Hot Air Solder Station	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
Pneumatic Powered Hand Tools	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
Electric Powered Hand Tools	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
Grinders, Sanders,	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
Sheet Metal Benders, Sheers, Saws	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
Bering Press	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient
 Not Applicable	▼ Understands Tool Purpose ... Knows Care and Maintenance	▼ Extremely Limited ... Highly Proficient

Select each of the following **Shop Equipment Units** that are applicable to technicians working in your shop.

- Volt Meter
- O-Scope
- Battery Chargers
- Pitot/Static and Air Data Testers
- IFR 4000 Ramp Tester or Equivalent
- IFR 6000 Ramp Tester or Equivalent
- S-1403DL Mode-S Test Set or Equivalent
- ATC-1400A DME TXP Test Set or Equivalent
- RD-300 Radar Test Set or Equivalent

Describe the Knowledge and Performance levels for Understanding and Usage of the following **Shop Equipment**.

	Subject Knowledge	Task Performance

Volt Meter	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
O-Scope	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
Battery Chargers	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
Pitot/Static and Air Data Testers	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
IFR 4000 Ramp Tester or Equivalent	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
IFR 6000 Ramp Tester or Equivalent	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
S-1403DL Mode-S Test Set or Equivalent	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
ATC-1400A DME TXP Test Set or Equivalent	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient
RD-300 Radar Test Set or Equivalent	▼ Identify parts and controls ... Advanced understanding	▼ Extremely Limited ... Highly Proficient

Select the following elements of **Soldering and Wiring** that would be needed by Technicians in your shop. (mark all that apply)

- Basic Soldering Through Hole Components
- Advanced Soldering Surface Mount Components
- Crimping Tools and Processes
- Coax Routing and Repair
- Wire Harness Fabrication

Describe the Knowledge and Performance levels needed in your shop for each of these items associated with **Soldering and Wiring**.

	Task Knowledge	Task Performance
Basic Soldering Through Hole Components	▼ understands terminology ... resolves problems	▼ Extremely Limited ... Highly Proficient
Advanced Soldering Surface Mount Components	▼ understands terminology ... resolves problems	▼ Extremely Limited ... Highly Proficient
Crimping Tools and Processes	▼ understands terminology ... resolves problems	▼ Extremely Limited ... Highly Proficient
Coax Routing and Repair	▼ understands terminology ... resolves problems	▼ Extremely Limited ... Highly Proficient
Wire Harness Fabrication	▼ understands terminology ... resolves problems	▼ Extremely Limited ... Highly Proficient

End of Block: Shop Tools & Equipment and Processes

Start of Block: Generals objectives

Select each of these Basic Aviation Maintenance Requirements that is applicable to technicians in your shop. (mark all that apply)

- Aircraft Drawings (blueprints, graphs, charts)
- Weight and Balance
- Maintenance, Forms, and Records
- Fluid Lines and Fittings
- Corrosion Control
- Not Applicable

Describe the Knowledge and Performance levels for each of these items associated with the A&P Generals.

	Subject Knowledge	Task Performance
Aircraft Drawings (blueprints, graphs, charts)	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient
Weight and Balance	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient
Maintenance, Forms, and Records	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient
Fluid Lines and Fittings	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient
Corrosion Control	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient
<input checked="" type="checkbox"/> Not Applicable	▼ knows basic facts ... has advanced understanding	▼ Extremely Limited ... Highly Proficient

Describe the Performance levels needed in your shop for each of these items associated with the A&P generals requirements for **Mathematics**.

	Task Performance
Extract roots and raise numbers to a given power	▼ Extremely Limited ... Highly Proficient
Determine areas and volumes of various geometrical shapes	▼ Extremely Limited ... Highly Proficient
Solve ratio, proportion, and percentage problems	▼ Extremely Limited ... Highly Proficient
Perform algebraic operations	▼ Extremely Limited ... Highly Proficient

Describe the Knowledge levels needed in your shop for each of these items associated with the A&P generals requirements for **Basic Physics**.

	Subject Knowledge
The principles of simple machines	▼ knows basic facts ... Not Applicable
The principles of sound, fluid, and heat dynamics	▼ knows basic facts ... Not Applicable
The principles of basic aerodynamics; aircraft structures; and theory of flight.	▼ knows basic facts ... Not Applicable

Describe the Performance levels needed in your shop for each of these items associated with the A&P generals requirements for **Processes** and Materials.

	Task Performance

Perform precision physical and mechanical measurements	▼ Extremely Limited ... Highly Proficient
Perform precision electrical and electronic measurements	▼ Extremely Limited ... Highly Proficient
Identify & select proper hardware, materials, & components	▼ Extremely Limited ... Highly Proficient

Describe the Performance levels needed in your shop for each of these **Basic Aircraft Ground Operations** associated with the A&P generals requirements.

	Task Performance
Ground Operation Aircraft Servicing and Taxi	▼ Extremely Limited ... Highly Proficient

End of Block: Generals objectives

VITA

Christopher Lee Bycroft

Candidate for the Degree of

Doctor Education

Thesis: IDENTIFICATION OF KNOWLEDGE, SKILLS, AND ABILITIES
REQUIRED FOR AIRCRAFT ELECTRONICS TECHNICIANS

Major Field: Applied Educational Studies with emphasis on Aviation and Space Science

Biographical:

Education:

Completed the requirements for the Doctor of Education in Applied Educational Studies with emphasis on Aviation and Space Science at Oklahoma State University/ Stillwater/ Oklahoma in December, 2018

Completed the requirements for the Master of Arts/ Master of Business Administration at Northeastern State University/ Broken Arrow/ Oklahoma/ United States in 2011

Completed the requirements for the Bachelor of Science/ in Industrial Operations Management/ at Northeastern State University/ Broken Arrow/ Oklahoma/ United States in 2005

Experience:

Avionics Program Coordinator - Lead Instructor / Spartan College of Aeronautics and Technology / Tulsa / Oklahoma 2008 – present

Avionics Installation/ Tulsair Beechcraft / Tulsa / Oklahoma / 2003-2008

Adjunct Instructor Electronics Program / ITT Technical Institute / Tulsa / Oklahoma/ 2006 - 2007

Supervisor Manufacturing / FW Murphy/ Tulsa / Oklahoma 2001 – 2003

Desktop Support / Sebring Systems Technologies / Tulsa / Oklahoma / 2000 – 2001

Avionics Installation Supervisor / Southern Avionics and Communications / Mobile / Alabama / 1989 - 1999