From Daedalus to Smartphones and NextGen: The Evolution of Accident Investigation Tools and Techniques

Jay F. Graser
ISASI #: AO6169
Vice President, Gemini Technologies
Gainesville, VA
Jay.Graser@gemitek.com

ABSTRACT

The tools and techniques that we have used to collect and analyze accident-related data have evolved over centuries, if not millennia. Imagine prehistoric man watching his first bird, wondering if he too could fly and his predicting the outcome if he failed and plummeted to the ground. A simple interpretation of seventeenth century Newtonian Laws predicts that what goes up must come down. From those early observations to present day, we have used tools and techniques ranging from visual inspection to full scale modeling and crash tests to collect data and predict the causes of aviation accidents. Did Daedalus predict the outcome of his wings' performance when he warned Icarus not to fly too close to the sun? When a balloon crashed in Tullamore, Ireland in May of 1785, resulting in the destruction of 100 houses, did aviation experts begin to consider predicting potential causes of aviation accidents? If in 1908 the Wright brothers had propeller stress test data, could they have prevented the death of Lt. Selfridge? From these events onward, we have used various data collection and analysis tools to move from reaction to prediction. What tools and techniques could be coming in the future and where will we find them?

This paper will consider:

- A history of the tools and techniques used to predict aviation accidents
- How those tools and techniques have moved from reactive to predictive
- Aviation safety outcomes that could be attributed to this evolution
- The effects of information glut on predictive analysis
- Collection and analysis techniques that can be drawn from various disciplines
- Nontraditional data sources to support prediction
- The impact information technology trends, such as smartphones cloud computing
- How NextGen factors in to the future of accident prediction
- Potential tools and techniques for the future

From Daedalus to Smartphones and NextGen: The Evolution of Accident Investigation Tools and Techniques

Jay F. Graser
ISASI #: AO6169
Vice President, Gemini Technologies
Gainesville, VA
Jay.Graser@gemitek.com

ABOUT THE AUTHOR

Jay Graser is a retired USAF officer with 34 years of aviation experience. His exposure to aviation safety ranges from being crew during a major aircraft accident to pioneering Level D flight simulators. At Galaxy Scientific, his team deployed the On-line Aviation Safety Inspection System (OASIS) to 4,000+ users. Presentations include: "Viral Learning: Taking Advantage of All Channels to Learning" to the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC); "Expedient Application of Simple Gaming for Learning and Assessment," to the 7th Annual Innovations in e-Learning Symposium; and "Investigation Enhancement through Information Technology," to the ISASI, 2003 Annual International Seminar.

INTRODUCTION

In an accident investigation, how we collect and analyze data drives timely and accurate safety related changes in the aviation industry. While we are continually bombarded by more technology, we cannot lose sight of the fact that we are still dealing with the positive and negative aspects of have having humans in the process. Tools and techniques have evolved around the available technology throughout history, but in the end, the human in the equation becomes the critical factor. Our benefiting from those tools and techniques is dependent our willingness to adopt and apply them as well as act on what they are telling us. This is further complicated by the complexity and ambiguity of measuring human factors and behavior.

TOOLS AND TECHNIQUES HISTORY

The history of aviation accident investigation tools and techniques is intertwined with multiple aspects of human existence. Tools and techniques that may have been considered heresy or witchcraft centuries ago are now considered reputable science. Certainly as man's understanding of the world around him has evolved, so have the tools available to analyze flight and its inherent dangers.

Early Man

We can only suppose what prehistoric man must have thought with regard to flight. As I first considered this idea from his perspective, it seemed trivial compared to the daily rigor of survival. Did early man even have the time to contemplate what birds were doing? Maybe he envied their ability to fly to safety or cursed them for flying away when he tried to catch them as food. However, we can learn from early man. In order to survive, he had to remain aware of his situation and be constantly vigilant. Any complacency on his part would mean giving up his life to the elements, predators or any number of hazards. While the hazards of flight were probably not first on his mind, we can apply his survival skills and instincts to the analysis of flight. To some degree, our dependence on the very tools we have learned to trust, such as checklists, autopilots and process automation may have dulled the situational awareness needed to survive.

Ancient Inventors

Some of what we consider modern tools and techniques can be traced back to ancient inventors. For example, the Roman poet Ovid wrote of the inventor Daedalus in 8 A.D. While Daedalus was a mythical character, he gives us an idea regarding the thinking of the time. As the legend goes, Daedalus and his son Icarus were imprisoned in a tower in order to keep Daedalus from giving away the secret of the labyrinth. Daedalus had built the labyrinth for king Minos to hold the Minotaur, a mythical half man, half bull. In order for Daedalus and Icarus to escape from the tower, Daedalus fashioned wings from feathers that were secured with string at the mid-point and wax at the base. He warned Icarus not to fly too close to the sun in order to avoid melting the wax holding the feathers in place. He also cautioned his son not to fly too close to the sea so as to avoid getting the feathers wet. Unfortunately, Icarus became too exuberant and flew close enough to the sun to melt the wax, resulting in the wings failing and Icarus plummeting into the sea and drowning (1). In a surface analysis of what we know, was this pilot error or a material failure? Icarus as the pilot was trained not to fly too close to the sun, but it appears he became complacent, lost situational awareness and flew his aircraft beyond the limits of its construction. What was the root cause of the pilot error? Did he not understand the training? Was he fatigued and therefore flying with impaired judgment? Only Ovid knew the answers to these questions, but it becomes a good, early example to examine.

Daedalus' warning to Icarus and the subsequent results can fit well in to the 5M approach to accident investigation.

The 5M Model illustrates five integrated elements in any system (2):

Mission:	functions that the system needs to perform
Man:	human operators and maintainers
Machine:	equipment used in the system including hardware, firmware, software, human-to-system interface, and avionics
Management:	procedures and policies that govern the system's behavior
Media:	environment in which the system is operated and maintained

The scenario of Icarus' fate fits into at least three aspects of the 5M Model. The man erred in that he did not apply the training he was originally given. The machine failed due to the material's sensitivity to heat and the media (or environment) played into this in the heat of the sun or the feathers' potential exposure to seawater.

Centuries later, another inventor provides more potential examples of accident investigation tools and techniques. Da Vinci's experimentation with flight certainly showed an observation of the same laws of physics and the properties of aerodynamics that we use in accident investigations today. He wrote in the 1500s that "A bird is an instrument working according to a mathematical law." His experiments applied mathematics to help explain how birds fly (3). Today, we use those same mathematics to explain why an aircraft might have stopped flying. From a practical perspective, Da Vinci took us from simply observing flight characteristics to capturing them in an objective mathematical expression. Consider that this concept of a mathematical law is the basis for the modeling and simulation that we use to routinely recreate accident scenarios.

Today's Basic Tools

Typically investigators carry wrenches, screwdrivers and devices peculiar to their specialty. All carry flashlights, tape recorders, cameras, and lots of extra tape and film (4). The NTSB Major Investigations Division (AS-10) has two "flyaway" suitcases available for use during the investigation. The two kits contain such things as a video camera and tape, laptop computer, printer, various charging devices, film, administrative supplies, and copies of the investigator's manual. (5) The tools themselves are rather straightforward, the key is in the evidence these tools allow them to collect and how we make sense of that evidence.

Recorders

Instrumentation available to support accident investigations includes cockpit voice recorders, flight data recorders and quick access recorders. Flight data recorders were suggested as far back as 1941, but were put on hold until 1947 due to a lack of parts during the war. Even as late as the 1960s flight recorders may have been installed, but not necessarily turned on, especially for training flights (6). Newly manufactured aircraft are required to be equipped with a flight data recorder that collects a minimum of 88 parameters. As aircraft systems become more complex, we can expect the number of available parameters to grow. In 1998, Barry Sweedler, NTSB Office of Safety Recommendations and Accomplishments Director, presented to the 4th World Conference On Injury Prevention and Control the case for having more parameters available. For example, in the ATR-72 accident in Roselawn, Indiana in October 1994, the flight data recorder captured information on 115 parameters, as opposed to the currently required minimum of 88. Reading out the recorder in the NTSB laboratories, they were able to spot the telltale, rapid movement of an aileron control and issue safety recommendations within a week. Conversely, B737 incidents where as few as five parameters were being recorded took several years before the NTSB could make recommendations regarding the 737 rudder system. Mr. Sweedler also pointed out the value of using Quick Access Recorders for their ability to be easily downloaded after each flight in order to identify deviations from procedures and drive improvements. (7)

DATA COLLECTION AND ANALYSIS

In order for data to be of any use it needs to drive the appropriate action. Data collection and analysis challenges include consistent and objective collection at the point of occurrence, data standardization such as using common descriptions and units of measures, filtering out bias of the person doing the collection, data normalization, equal access to data, statistically valid interpretations of the data and recognizing the significance of the data in order to drive action.

Aviation Safety Information Analysis and Sharing (ASIAS) System

The Aviation Safety Information Analysis and Sharing (ASIAS) is one solution to providing equal access to data. The ASIAS system connects 131 data and information sources across the aviation industry and is integrated into the Commercial Aviation Safety Team (CAST) process. Of those sources, 46 are safety databases, 78 are hybrid databases, and seven are standards datasets. There are currently 42 member airlines participating in ASIAS. Since it began in October 2007, the program has evolved to the point that ASIAS now has access to Flight Operations Quality Assurance (FOQA) programs from 24 operators and Aviation Safety Action Partnership (ASAP) data from flightcrews, maintenance and other employees from 40 operators. ASIAS is also accessing reports in the Air Traffic Safety Action Program (ATSAP), which provides air traffic controllers with a way to report potential safety hazards. Other Air Traffic Organization (ATO) employees will be added to the program in the future. One major accomplishment is that seven of CAST's 76 safety enhancements have been derived from forward-looking data analysis in ASIAS. Additionally, ASIAS stays connected to CAST's safety enhancements to track the effectiveness of those safety interventions. ASIAS presently has four CAST metric categories in active monitoring comprising 51 distinct metrics. Infoshare, a semiannual closed-door meeting of more than 500 airline safety professionals, facilitates sharing of safety event identification and mitigation. It's linked to ASIAS for early detection and analysis of safety issues.

The FAA plans to eventually expand ASIAS to 64 databases. Current examples include:

- ACAS (Aircraft Analytical System)
- ASAP (Aviation Safety Action Program)
- ASDE-X (Airport Surface Detection Equipment, Model X)
- ASPM (Airspace Performance Metrics)
- ASRS (Aviation Safety Reporting System)
- ATSAP (Air Traffic Safety Action Program)
- FOQA (Flight Operations Quality Assurance)
- METAR (Meteorological Aviation Report)
- NFDC (National Flight Data Center)
- NOP (National Offload Program office track data)
- SDR (Service Difficulty Reports)
- TFMS (Traffic Flow Management System)
- TOPA (TCAS Operational Performance Assessment)

ASIAS uses FOQA and ASAP data from 40 air carriers that represent 95 percent of commercial operations in the National Airspace System.

Available data includes:

- Current number of ASAP reports: 110,000
- Current number of FOQA reports: 8.1 million operations
- Current number of ATSAP reports: 50,000.

The FAA plans to increase the numbers and types of participants following a phased expansion plan to include other parts of the aviation community. ASIAS will include domestic corporate general aviation, military, helicopter, manufacturers, and other government agencies (8).

Info Glut

The amount of data available from ASIAS and other sources is staggering. While it would seem like a good thing to have as much data as possible, when is it too much and therefore a glut of information? Data is not much good to the aviation community unless it can be analyzed in a timely manner. For the answer to dealing with what appears to be a glut of data, we can to turn to the companies that derive their living making sense of large volumes of information, such as Google, Facebook and Amazon. For example, Google processes over 20 petabytes (one million gigabytes) of data per day and this is only expected to increase as more processing and data storage is done away from the end-users hard drive using cloud computing. Also, Amazon is growing at such a rate that it adds as much capacity to its data centers each day as the whole company ran on in 2001 (9). Despite this daily torrent of data, these companies have been able to develop algorithms that drive daily business decisions. This puts the contents of ASIAS into perspective. Rather than potentially limiting the flow of data in order to make it more tolerable, we should be leveraging existing expertise in data analysis and taking advantage of new sources of data, such as smartphones and the flow of data that will become available through NextGEN.

REACTIVE TO PREDICTIVE

The transition from reactive to predictive can be considered along a continuum. While it would be nice to think that we always progress along the continuum toward predictive, human nature has shown that while we have the tools available to predict and possibly prevent some accidents, our emphasis swings back and forth from reaction to prediction and back again. Unfortunately, sometimes it takes the reaction to a fatal accident in order galvanize people into action. It is our responsibility as aviation professionals to continually put the emphasis on the tools and techniques that support prediction and accident prevention, rather than reaction.

No Reaction

When a balloon crashed in Tullamore, Ireland in May of 1785 and destroyed over 100 homes, the reaction was not quite what we might have expected today. If this were to happen in modern times, there would have been a cry for limiting balloon operations over populated areas and an increase of available fire protection. Instead, despite the event’s coverage in the newspapers of the region, they took virtually no action at all. In fact, a fire brigade wasn’t even commissioned until 1886 when the tobacco factory burned down (10).

Reaction

When Army Signal Corps Lieutenant, Thomas E. Selfridge was killed in 1908, he was considered the first casualty of powered flight. The Wright brothers' reaction to the event was swift. Immediately after the crash, Lorin Wright told reporters, 'My brothers will pursue these tests until the machines are as near perfect as it is possible to make them, if they are not killed in the meantime." (11) In this case, testing was driven by a reaction, rather than initiated as an effort to predict an accident.

Evolving from reaction to prediction has been facilitated by changes in policies and directives over the years. Early in the history of aviation, the objective of an accident investigation was to apportion blame. The guidance first established in 1928 by the US National Advisory Committee for Aeronautics applied a credit system of factors. For example, an accident could be determined to be 70% pilot error (Man) and 20% mechanical failure (Machine) and 10% weather (Media). However, the International Civil Aviation Organization (ICAO), Convention on Civil Aviation ("Chicago Convention") of 1944 and further refinements in 1946 and 1947 began a shift from identifying blame to sharing lessons learned. This later became Annex 13 of the Convention (12). Annex 13 paved the way for information sharing, such as ASIAS, that would emphasize lessons learned to the benefit of all stakeholders in the prediction and prevention of accidents, rather than laying blame as a reaction to the accident.

Prediction

In order to predict potential accidents, we need to be able to take the data we have and extrapolate it into the future. Representing aviation systems as a mathematical or physical model gives us a way to do this. Da Vinci was well known for his scale drawings and models of aircraft and today we have evolved to high fidelity Level D simulators that allow us to train pilots with such accuracy that they are fully qualified by the time they reach the actual aircraft. These same simulators are used to run through a multitude of emergency scenarios in order to help develop procedures to deal with almost any failure. In addition to modeling the performance of the aircraft, we can use process large volumes of data in order to identify potential accident risks. Along these lines, the Indian Air Force (IAF) has developed the Accident Probability Factor (APF) Calculator. This software uses actuarial science and mathematical algorithms to analyze archived data of the last thirty years to predict accident probabilities of flying (13). Additionally, equipment manufacturers collect data during component testing. This data is used to create mathematical models of aircraft components and systems that predict when they will fail. For example, Mean Time Between Failure (MTBF) is a common metric used to predict when parts will fail. Airlines spend millions of dollars a year in preventative maintenance to replace parts based on these component failure predictions. Also, mathematical models and simulations of ever increasing air traffic and how best to route them have helped to address the Management aspect of 5M and driven efforts such as NextGEN. Weather models tell us where and when to fly, this combined with the flexibility of route planning offered by NextGEN will simplify routing flights around weather hazards. These factors combined cover at least the Machine, Media and to some degree the Management aspects of the 5Ms.

However, if 50% of aircraft accidents can be attributed to pilot error (see Table 1 below), it seems important to emphasize tools and techniques that allow us to model the Man aspect of 5M? Dr. Steven Hursh of Johns Hopkins states that current models of fatigue in combination with models of how work/rest schedules limit expected levels of sleep can provide surprisingly accurate predictions of the tendencies of the average person and the risk of performance failure. Properly conceived, models of the average person can predict increases in accident risk and severity. Modeling of the effects of fatigue have been ongoing with agencies such as the Department of Defense, Department of Transportation, NASA and the FAA resulting in various fatigue risk management tools (14).

Cause	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**	**All**
Pilot Error	41	34	24	26	27	30	29
Pilot Error (weather related)	10	17	14	18	19	19	16
Pilot Error (mechanical related)	6	5	5	2	5	5	5
Total Pilot Error	**57**	**56**	**43**	**46**	**51**	**54**	**50**
Other Human Error	2	9	9	6	9	5	7
Weather	16	9	14	14	10	8	12
Mechanical Failure	21	19	20	20	18	24	22
Sabotage	5	5	13	13	11	9	9
Other Cause	0	2	1	1	1	0	1

Table 1: Causes of Fatal Accidents by Decade (percentage) (15)

FUTURE TOOLS

The discovery of future tools may be dependent mostly on our willingness to apply them. The following quote is from a 1966 report regarding flight recorders. “Because of the flight recorder's ever increasing importance in aviation, it is imperative that everyone associated with accident investigation and prevention should become familiar with this instrument, not necessarily with its mechanical and electronic features, but with its role in the investigative process, what it can and cannot do and, above all, its potential.” Consider that at the time the report was written, flight recorders had been in use to some degree as early as 1941 (16). Yet, 25 years later, we see the above plea to include them in the investigative process. What is the next future tool or technique, like the flight recorder, and are we prepared to integrate it into the investigative process? Will it take us 25 years to begin applying it in the investigative process? Along these same lines, the following are tools that may have potential, but we cannot take another 25 years to integrate them into our processes.

Smartphones

There are several aspects of smartphones and similar devices that could be helpful, including additional datapoints for an investigation, prediction of accident risks, ongoing training and performance support. For example, leading up to an accident, passengers may be talking on their cell phone. While current US regulations prohibit this, during a dire emergency passengers and crew may disregard the regulation. In the case of the 9/11 hijackings, we were able to learn a great deal by analyzing the conversations between the passengers and the ground. Also, some airlines are beginning to allow talking on cell phones at altitude. Virgin Atlantic announced in May of 2012 its newest Airbus widebody will be equipped to allow talking while over the ocean, far away from land, and other planes so equipped will follow. This is not a new occurrence; some Middle East carriers started allowing cell phone calls in flight a couple of years ago. (17) While constant talking is probably annoying to those sitting around them, it creates another data source for an investigation. Consider the additional voice data that may help investigators if an emergency occurs and a cell phone is able to pick up audio of the event that can provide additional clues. In the case of the 1996 Valujet crash in the Everglades, the first indication that there was a fire aboard was when shouts of "fire" were picked up by the cockpit voice recorder from the passenger cabin. (18)

While the inadvertent audio picked up by a cell phone in operation during an emergency may seem to be of limited value, consider that smartphones also measure parameters such as acceleration, attitude and GPS location, depending on what functions may be turned on at the time. Many smartphones track and store this data, which in the future could become helpful in an investigation. In one possible application of this notion, if smartphones survive the impact, their GPS function could be used to more readily locate scattered wreckage co-mingled with the phones.

As a performance support tool, a smartphone could fulfill many roles. In order to predict risk from fatigue, exercises could be programmed into the phone that allow the pilot to periodically test his fatigue level, including before, during cruise and after a flight. This would serve two purposes. It would give the crew a better and more objective awareness of their fatigue level and the data collected could be transmitted to a central database and be analyzed for trends related to fatigue and other critical performance factors. The smartphone could also be used for problem solving exercises to ensure pilots are not simply following routine checklists, but remain situationally aware and able to prioritize and solve problems. How many aircraft have crashed because the crew was involved in troubleshooting something as simple as a blown indicator light, but lost situational awareness and the priority to “aviate” first.

Current prediction tools are still very general about the factors that increase accident risk. It is virtually impossible to apply them to a specific flight that is about to occur and change a potentially disastrous outcome. However, consider the ability to analyze thousands of factors in real time in order to predict the risks of a particular upcoming flight. Using a smartphone as a terminal to cloud applications we could place the power to change the outcome in the hands of the schedulers and the pilots preparing to fly, rather than just long range planners and managers. Factors such as current weather, crew dynamics, fatigue and the particular aircraft’s vulnerabilities could all be summarized into a hand held interface that facilitates decisions in real time.

Smartphones can also be applied as a performance support tool during an investigation. Rather than rely on paper-based collection tools or carrying around a tablet computer, a smartphone can be used during the collection of data, such as documenting the location of crash debris. For example, the GPS in the smartphone allows the investigator to take a picture that is synchronized to the location where the picture was taken and the voice-to-text function allows the investigator to document comments at the time and place the evidence or debris is located. This reduces the possibility that the data could get lost or distorted by waiting until they are back at the command post to enter their observations into their laptop. Additionally, current off-the-shelf smartphone apps enable the device to read barcodes that might be on aircraft parts and with addition of a small, blue tooth enabled reader, the phone can also read RFID tags (19). Since many components have barcodes on them and some suppliers have started using RFID tags, this would make identifying and cataloging parts found at the scene much easier and reduce the risk of entry errors.

Human Behavior Measures

In a June 2012 CBS interview, David Soucie, author of Why Planes Crash: An Accident Investigator's Fight for Safer Skies, discusses an "atrophy of vigilance." He notes that while tools such as checklists ensure every item during a flight is considered, they tend to automate the decision process. Repeatedly following checklists by rote, we can lose situational awareness and miss the obvious. The checklists tend to dull our ability to apply basic problem solving (20). The following is an anecdotal example of this phenomenon. During my career in aviation training, I have noticed a cycle from training only procedural knowledge with no theory to teaching aviators deeper theory and systems knowledge and encouraging them to apply basic problem solving in addition to the procedures. While it can be more expensive to take the time to train the foundational theories and systems knowledge, the result is the ability to solve problems that may not have been considered when the checklist was written. As a case in point, in the early 1980s the USAF trained foundational knowledge of theory and systems knowledge to their C-5 Galaxy crewmembers. However, in the mid to late 1980s, the C-5 aircrew training focused less on foundational knowledge and more on simply following procedures. In short, the latter approach was analogous to "flip the switch per the checklist, but don't be concerned with why you flip the switch." As the procedurally trained crewmembers were deployed to make up crews and integrated with those crewmembers having more foundational understanding, there were complaints from the field. While the C-5s are not the oldest airplanes in the USAF fleet, their complexity combined with their age make them somewhat temperamental to operate and maintain. The substance of the complaints from the field was that the procedurally trained crew members were not given the skills and understanding needed to apply basic problem solving to the myriad of possible failures and potential workarounds. This meant that either sorties would be delayed or missions aborted in flight, due to an inability to resolve the problem. Yet, the foundationally trained crews were more readily able to go beyond the constraints of the procedures and checklists in order to solve problems. Their solutions were often creative, yet technically legal, and kept the aircraft flying and able to complete the mission.

What tools are in the future that could be used to measure and trend behaviors that indicate complacency? Once those behaviors are identified, can we predict the potential for an accident and put exercises in place to reduce complacency and increase situational awareness and problem solving? Our most valuable tools may be those that measure these behaviors and allow us to put in place tools to change the behaviors. Aircrew members are pressed for time to begin with, so the answer is not necessarily spending time in more traditional training. The answer may be designing into the aircraft events that prompt the aircrew to respond in ways that show they are situationally aware. One potential approach may be creating mobile applications that allow aircrew to practice problem solving on their smartphone while deadheading to their next location or during other down time.

NextGen

NextGen's satellite-based routing will provide precise data regarding the aircraft's position to both air traffic controllers and other aircraft. Automatic Dependent Surveillance–Broadcast (ADS-B) enablers broadcast the aircraft's position and certain other data. Ground receivers and other aircraft within range can receive these broadcasts and use them for their own applications. Using ground receivers across the country, controllers will receive and process precise ADS-B broadcasts to provide air traffic separation and advisory services. This data precision will be invaluable to accident investigators in reaction to an accident. NextGen will also enhance safety management via the Safety Analysis System (SAS), which will provide an automated environment for analyzing, predicting and addressing National Airspace System (NAS)-wide safety risks and enable users to extract information from multiple databases and systems. With a functioning SAS, the Air Traffic Organization (ATO) will be able to collect, assimilate, share, analyze and view information to ensure all NAS users have a consistent view of system safety. SAS will facilitate risk-based decisions and enhance the agency's predictive capabilities. SAS, an internal ATO system, will complement ASIAS by drawing data directly from some NAS sources not tied to ASIAS. SAS will also be capable of sharing safety data with the ASIAS platform (21).

SUMMARY AND CONCLUSION

The evolution of tools and techniques used in the investigation, prediction and prevention of aircraft accidents has only been limited by the available technology and our willingness to apply it. We can see that even in the time of Daedalus they considered factors such as weather and aircraft design limitations, yet in the end the failure was the human in the process. Hopefully, future tools and techniques will focus on harnessing the human aspects of the process, such as situational awareness, problem solving and survival.

REFERENCES

1. Ovid, (8 AD), *Metamorphoses*. Trans. A.D. Melville (1986), Oxford, England: Oxford University Press
2. Unknown Author (2008), *Air Traffic Organization, Safety Management System Manual*, Washington, D.C.: Federal Aviation Administration
3. Loon, Rael and Loon, Hélène (2005), *Birds: The Inside Story*, Singapore: Kyodo Printing Company
4. Unknown Author (2012), *The Investigative Process at NTSB,* Retrieved July 2, 2012, from http://www.ntsb.gov/investigations/process.html
5. Unknown Author (2002), *National Transportation Safety Board Aviation Investigation Manual Major Team Investigations*, Washington, D.C.: National Transportation and Safety Board
6. Allen, B. R. and Leak, John S. (1966), *The Potential Role of Flight Recorders In Aircraft Accident Investigation*, Washington, D.C.: US Civil Aeronautics Board

7. Sweedler, Barry M. (1998), *Data Collection and Improved Technologies,* 4th World Conference On Injury Prevention and Control, Amsterdam, The Netherlands: World Heath Organization
8. Unknown Author (2012), *Fact Sheet – Aviation Safety Information Analysis and Sharing (ASIAS) System*, Retrieved July 12, 2012, from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=13732
9. Gallagher, Sean (2012), *The Great Disk Drive in the Sky: How Web Giants Store Big—And We Mean Big—Data*, Retrieved July 12, 2012, from http://arstechnica.com/business/2012/01/the-big-disk-drive-in-the-sky-how-the-giants-of-the-web-store-big-data/
10. Byrne, Michael (2007), *The Tullamore Balloon Fire - First Air Disaster in History*, Retrieved July 13, 2012 from http://www.offalyhistory.com/articles/72/1/The-Tullamore-Balloon-Fire---First-Air-Disaster-in-History/Page1.html
11. Wald, Matthew L. (2008), *Flight's First Fatal Trip*, New York, NY: New York Times
12. Unknown Author (2009), *History of Air Accident Investigation*, Retrieved July 9, 2012 from http://www.erebus.co.nz/Investigation/HistoryofAccidentInvestigation.aspx
13. Unknown Author (2011), *IAF develops accident probability factor calculator*, Retrieved July 13, 2012, from http://www.indiablooms.com/NewsDetailsPage/2011/newsDetails030611t.php
14. Hursch, Steven, R., (2008), *Potential for Modeling Tools*, Presented at the FAA Fatigue Management Symposium: Partnerships for Solutions; Vienna, VA: FAA
15. Unknown Author (2012), *Causes of Fatal Accidents by Decade*, Retrieved July 13, 2012 from http://www.planecrashinfo.com/cause.htm
16. Ibid, Allen and Leak (1966)
17. Belden, Tom (2012), *The inevitable happens: Cell phones allowed in flight*, Retrieved July 8, 2012 from http://www.philly.com/philly/blogs/wingingit/The-inevitable-happens-Cell-phones-allowed-in-flight.html
18. Ibid Sweedler (1998)
19. Unknown Author (2010), *BlueBerry + BlackBerry: RFID UHF reading and Bluetooth transmission BlackBerry By TERTIUM*, Retrieved July 13, 2012 from http://www.youtube.com/watch?v=y570jMIqiq8
20. Soucie, David (2012), *Why Planes Crash (CBS This Morning Interview with Charlie Rose)*, Retrieved July 13, 2012 from http://www.cbsnews.com/video/watch/?id=7412058n
21. Unknown Author (2012), *NextGen Implementation Plan, Washington*, DC: FAA