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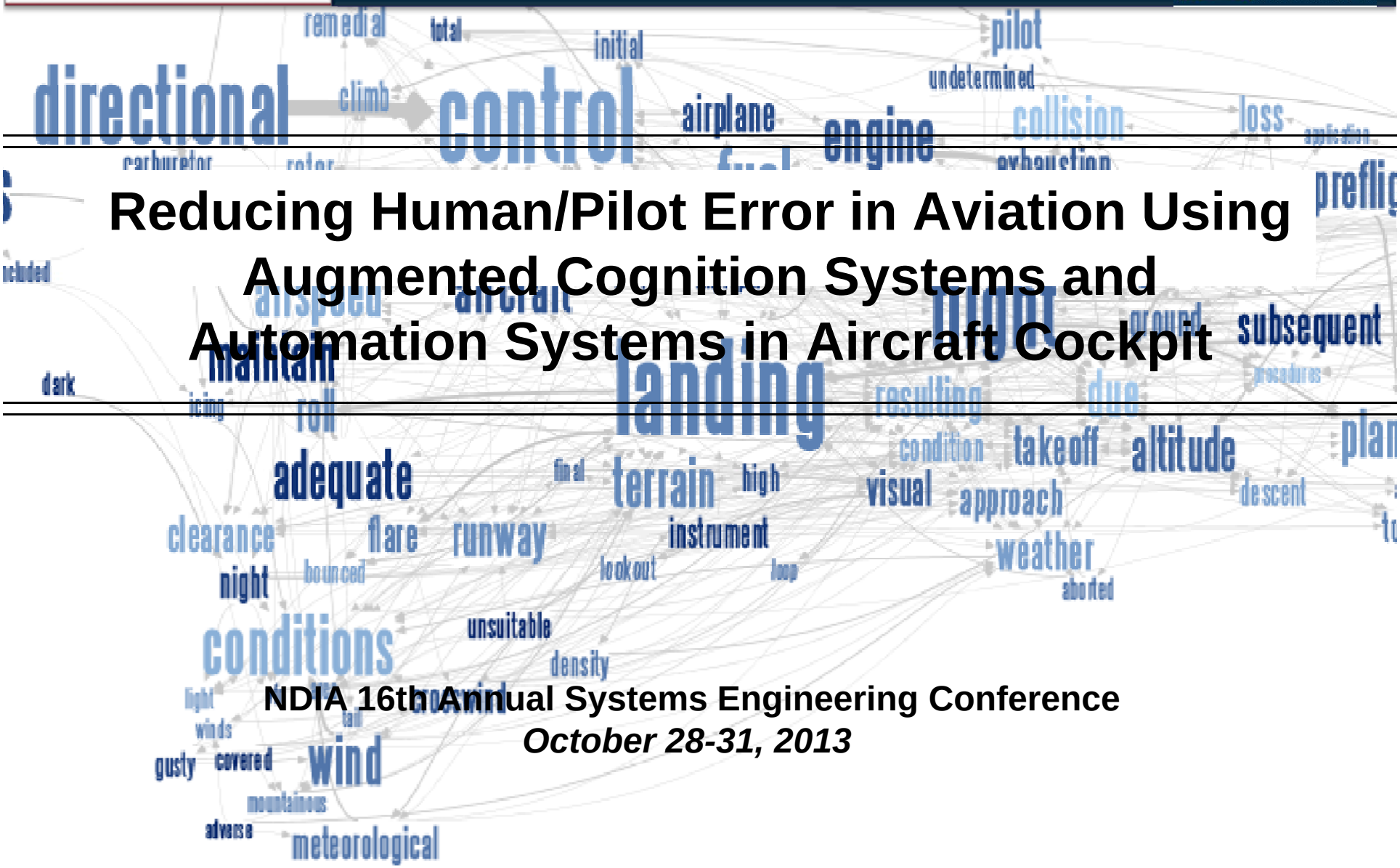

Reducing Human/Pilot Error in Aviation Using Augmented Cognition Systems and Automation Systems in Aircraft Cockpit

NDIA 16th Annual Systems Engineering Conference
October 28-31, 2013

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Agenda

- Introduction
- Conceptual Research Objectives
- Aviation Accident Analysis
- Flight Segments and Pilot Workloads
- Cockpit Workload and Task Saturation
- Ways to Assist Pilots with Workload
- Human/Pilot Augmented Cognition Systems
- Aircraft Augmented Cognition Systems
- Research Methodologies
- Proposed Concept
- Conclusion

Conceptual Research Objectives

- **Looking to Achieve,** Improvements in Air-Transportation Safety
- **Criteria for research success**
  - Be able to identify the shortfalls in Human-Machine interface and its integration in Cockpit systems
  - Be able to identify the shortfalls in Cockpit Automation and the integration of multi-complex aircraft operation systems
  - Be able to aid advancing the integration of cockpit systems with Human/Pilot and other aircraft systems, utilizing Augmented Cognition systems
  - Be able to develop a concept and make recommendation to fulfill these shortfalls in Cockpit systems
  - Be able to validate and prove the concept and recommendation by simulation
- **Questions To Answer,**
  - Is there any quantifiable relationship between degrading human performance attributed to pilot task saturation and the probability of an aviation accident?
  - Where could the principle of CONOPS of Augmented Cognition systems and Automation systems be applied in the aircraft cockpit system?
  - What safety shortfalls in aviation could be mitigated or otherwise improved by the application of Augmented Cognition systems and Automation systems principles?
- **Deliverable,** Recommendation and a new Concept of “Integrated” Augmented Cognition/Automation systems
- **Aspects of Systems Engineering,** Fundamental Theories of Systems Integration, Human-Machine Interface, Human-In-The-Loop, and Requirements Analysis

Who Will Care and Why

- **Primary stakeholders**
  - Aviation/Aerospace Companies
  - Airlines
  - Military Aviation
  - Civil Aviation
  - Pilots
  - Flight Crew
  - Air-Transportation Passengers

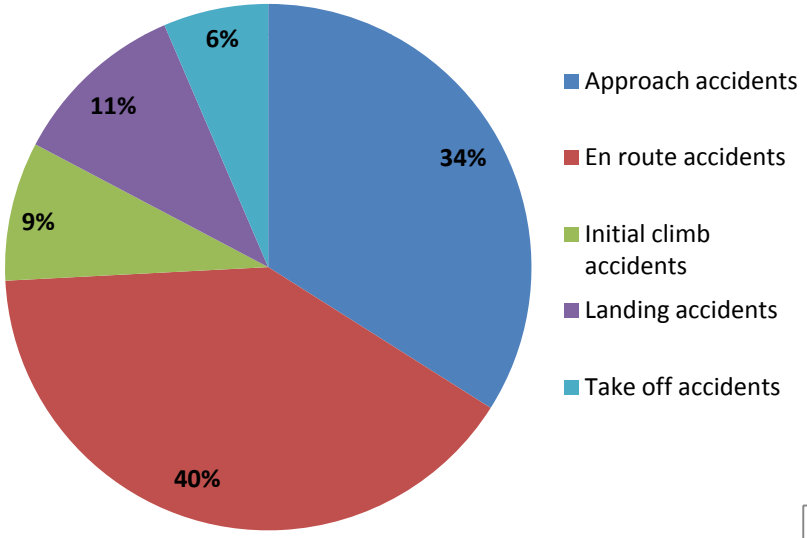
- **Interests in This Finding**
  - Simplifying the Use of Automation in Aviation Systems by Integrating the Augmented Cognition Systems Into the Cockpit Design

- **The Value of This Research**
  - Reducing Aviation Accidents by Reducing Human/Pilot Error in Aviation

Aviation Safety Network (ASN)

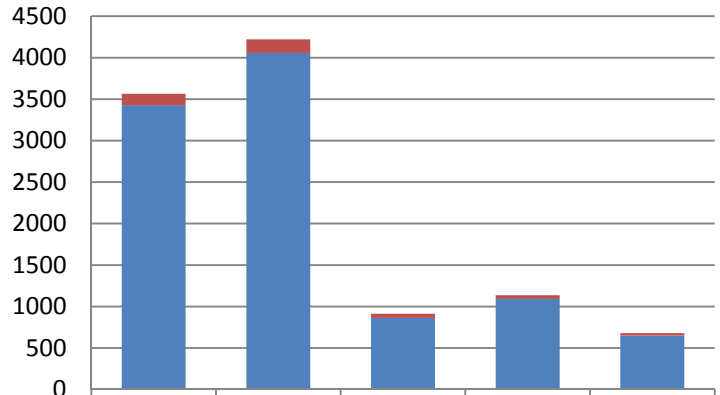
- The ASN Safety Database, updated every week, contains descriptions of over 15,800 airliner, military transport category aircraft and corporate jet aircraft safety occurrences since 1921.

- For this research we are considered here aircraft that are capable of carrying at least 12 passengers from the year 2000 to 2013.



Sum of Casualties

Summary



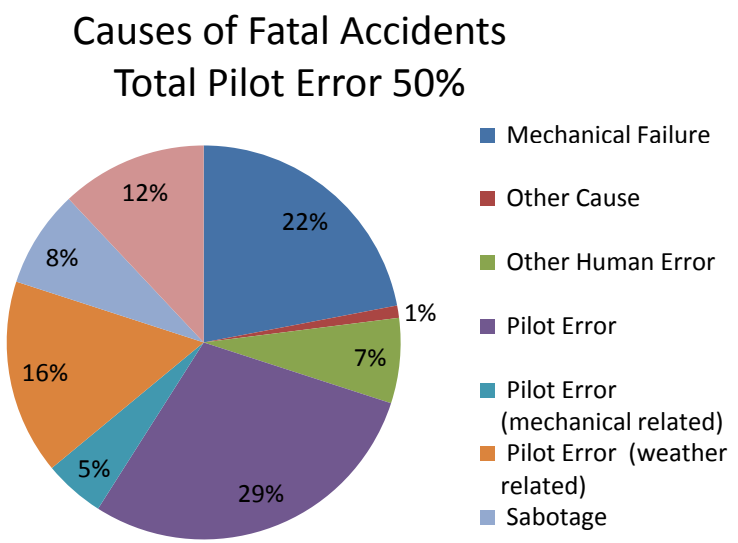
	Approach accidents	En route accidents	Initial climb accidents	Landing accidents	Take off accidents
Sum of Sum of Accidents	137	165	50	44	28
Sum of Sum of Casualties	3429	4056	862	1093	651

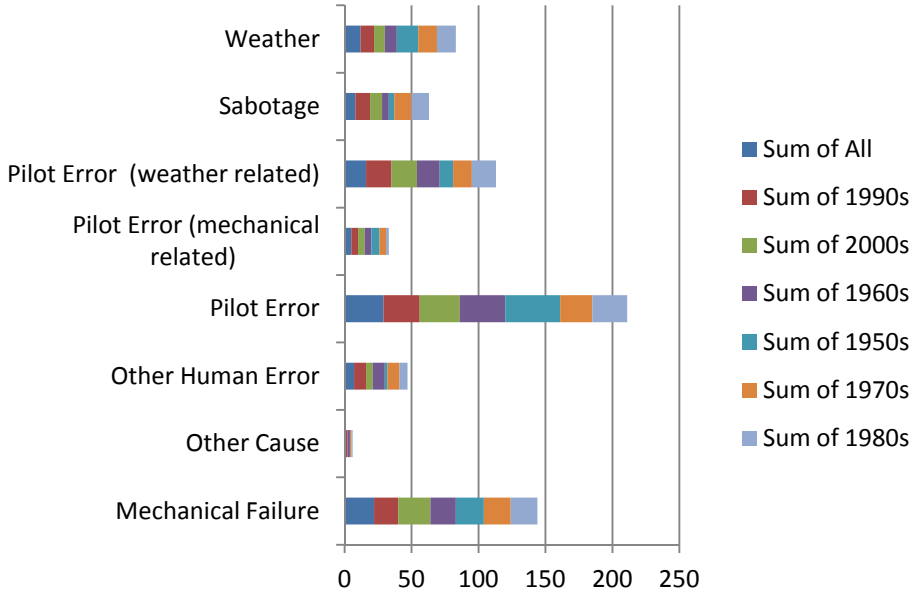
- Statistical information for common flight phases. The number of fatal hull-loss accidents and fatalities per year is given. The figures include corporate jet and military transport accidents.

Data Retrieved from: Aviation Safety Network (ASN) website, http://aviation-safety.net/database/, September 2013

Plane Crash Info

- The Figure below is compiled from the PlaneCrashInfo.com accident database and represents 1,085 fatal accidents involving commercial aircraft, world-wide, from 1950 thru 2010 for which a specific cause is known.
- This does not include aircraft with 18 or less people aboard, military aircraft , private aircraft or helicopters.



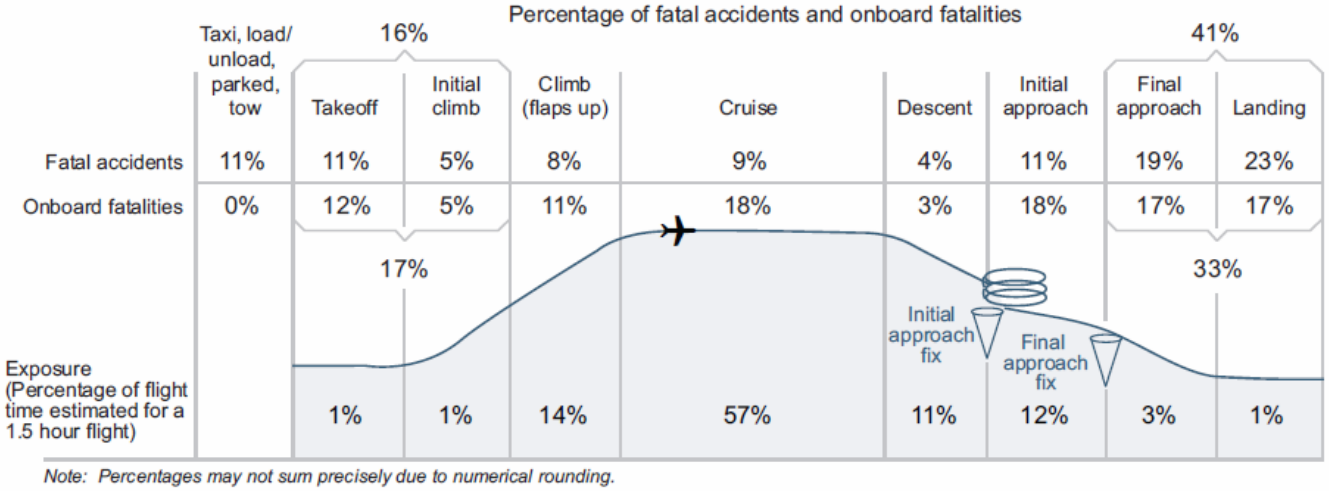


Data Retrieved from: PlaneCrashInfo.com, September 2013

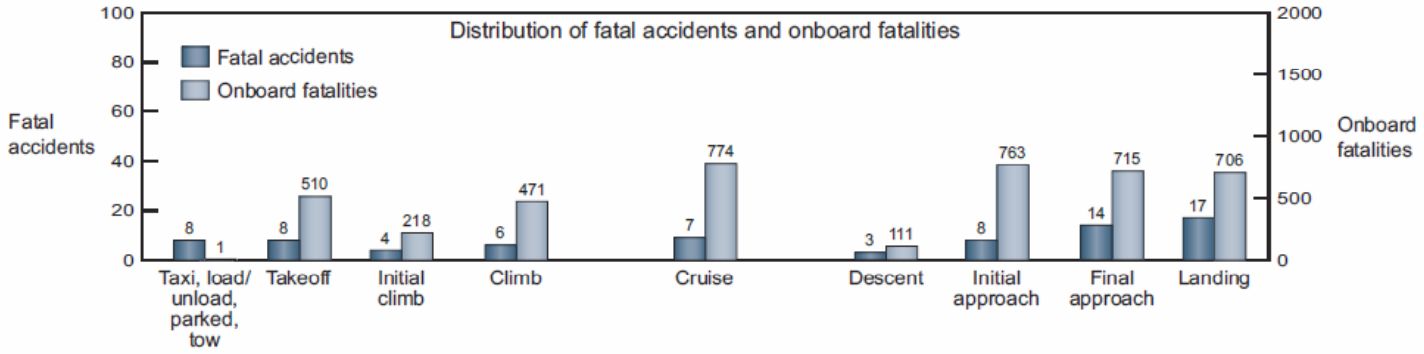
Boeing Statistical

Summary of Commercial Jet Airplane Accidents

- Fatal Accidents and Onboard Fatalities by Phase of Flight Worldwide Commercial Jet Fleet – 2003 Through 2012



Note: Percentages may not sum precisely due to numerical rounding.



2012 STATISTICAL SUMMARY, AUGUST 2013
Retrieved from: http://www.boeing.com/news/techissues/pdf/statsum.pdf

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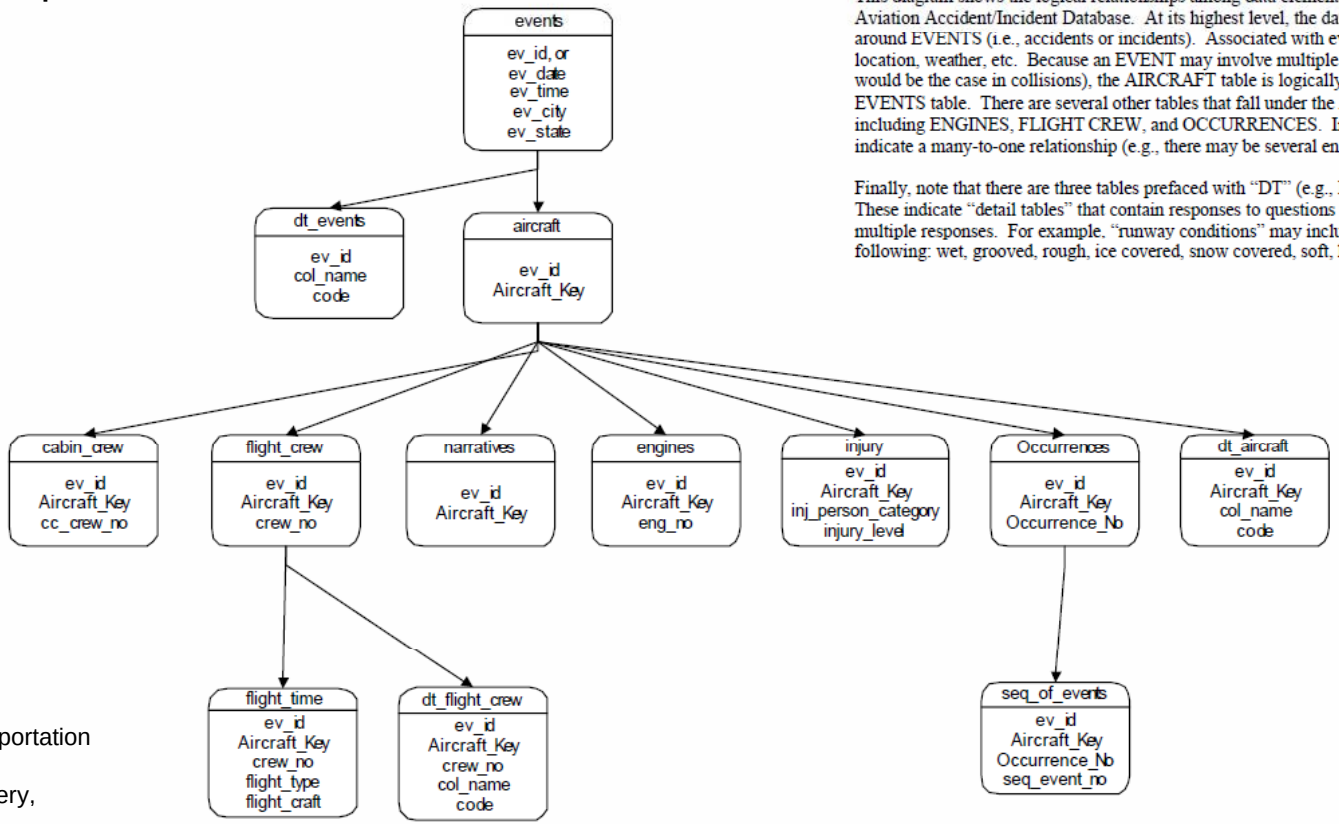
NTSB Aviation Accident Reports

- The NTSB aviation accident database contains information from 1962 and later about civil aviation *accidents* and selected *incidents* within the United States, its territories and possessions, and in international waters
- As of August 2013, NTSB Database contains more than 72,000 accidents and incidents reports

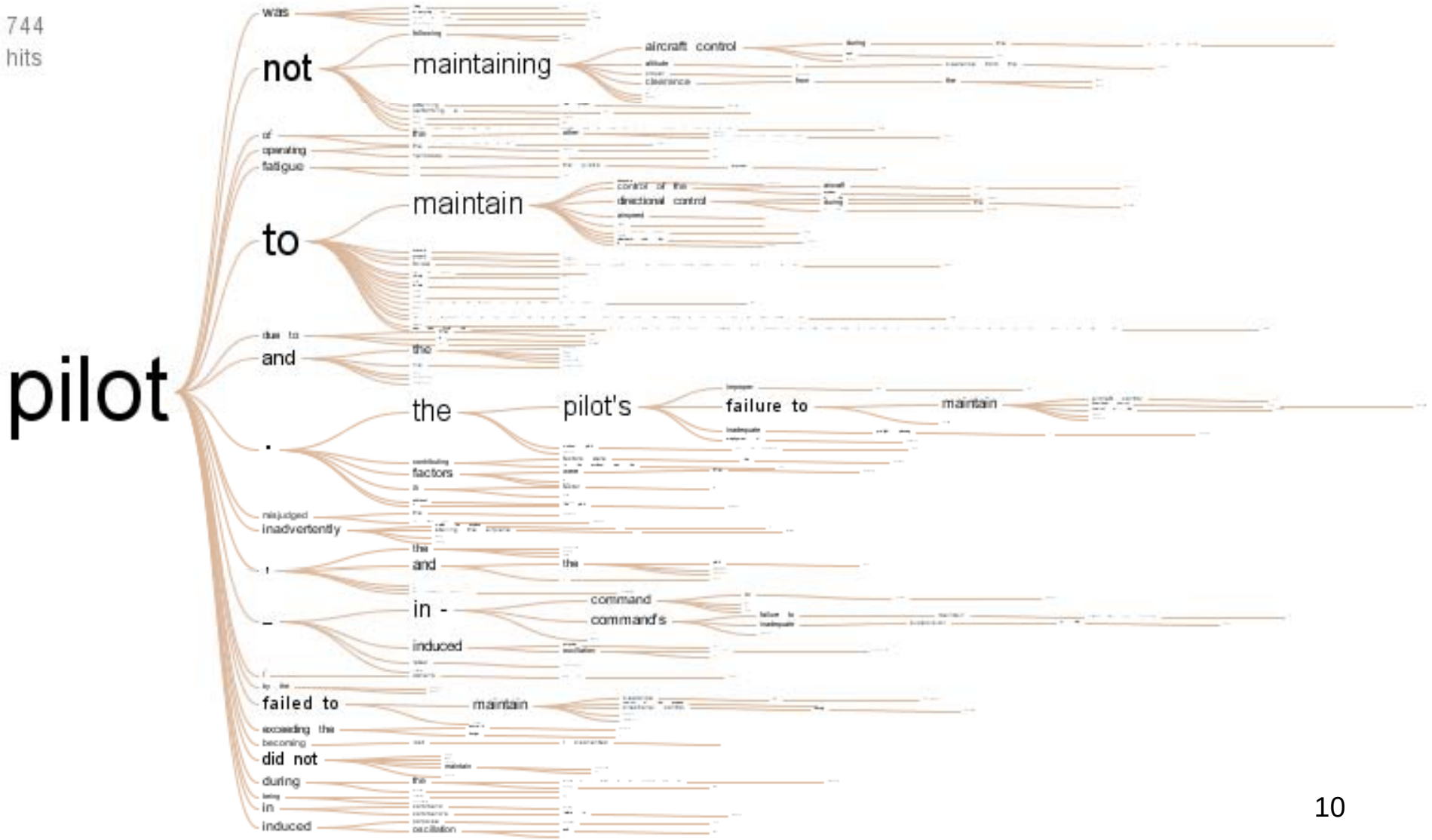


This diagram shows the logical relationships among data elements in the NTSB Aviation Accident/Incident Database. At its highest level, the database is organized around EVENTS (i.e., accidents or incidents). Associated with events are date, location, weather, etc. Because an EVENT may involve multiple AIRCRAFT (as would be the case in collisions), the AIRCRAFT table is logically structured under the EVENTS table. There are several other tables that fall under the AIRCRAFT table including ENGINES, FLIGHT CREW, and OCCURRENCES. In each case, they indicate a many-to-one relationship (e.g., there may be several engines on one aircraft).

Finally, note that there are three tables prefaced with "DT" (e.g., DT_AIRCRAFT). These indicate "detail tables" that contain responses to questions that may have multiple responses. For example, "runway conditions" may include any or all of the following: wet, grooved, rough, ice covered, snow covered, soft, holes, vegetation, etc.

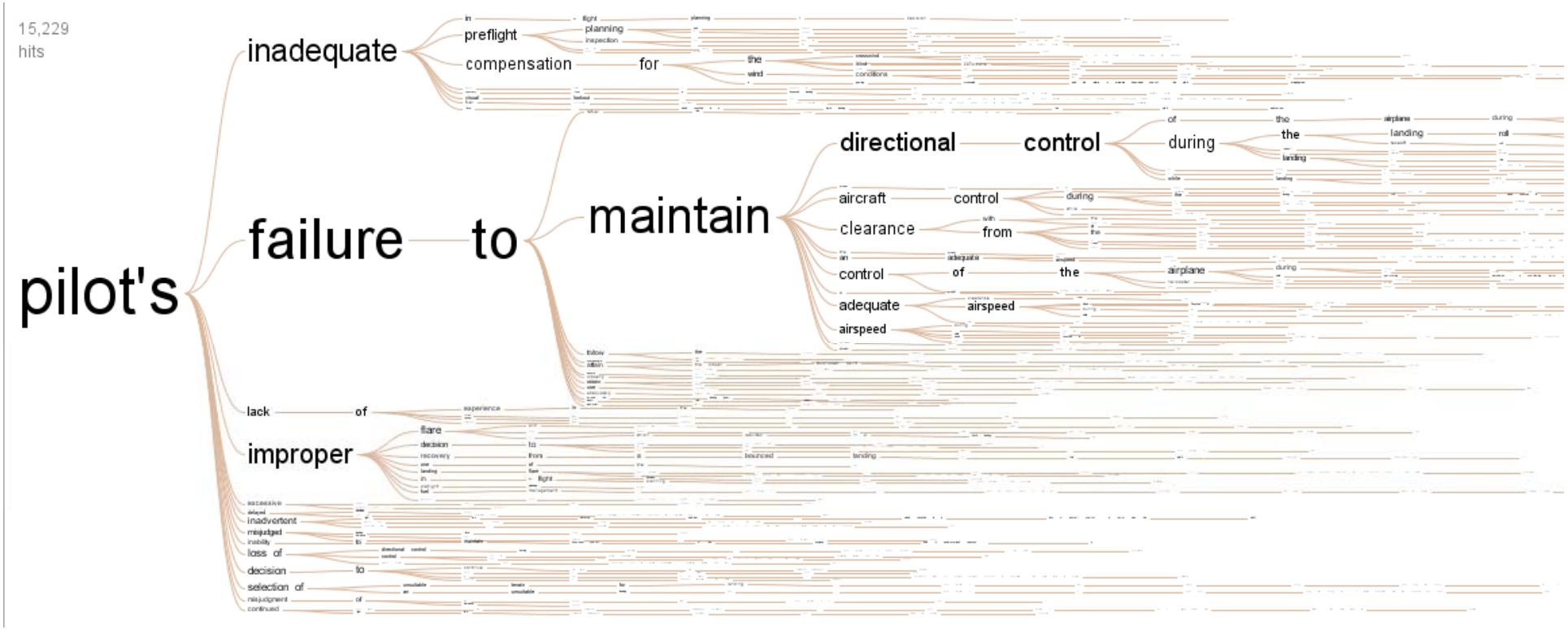
Retrieved from: National Transportation Safety Board (NTSB) website, http://www.ntsb.gov/aviationquery, September 2013

What Causes These Accidents?



Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?



Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

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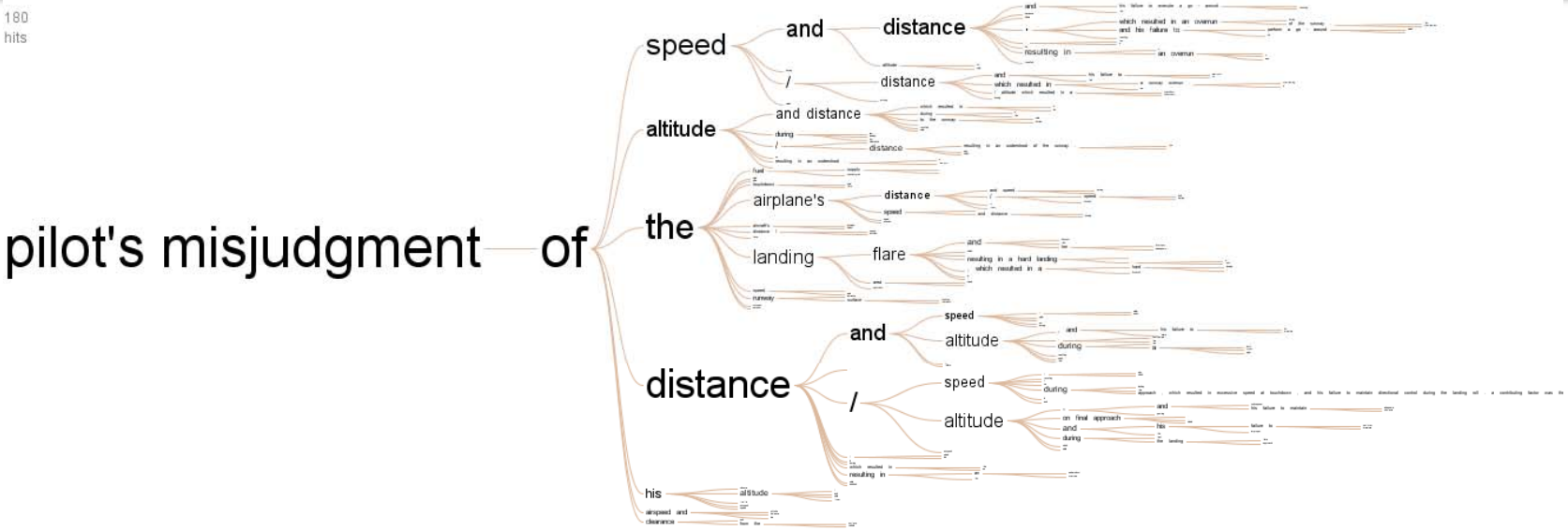

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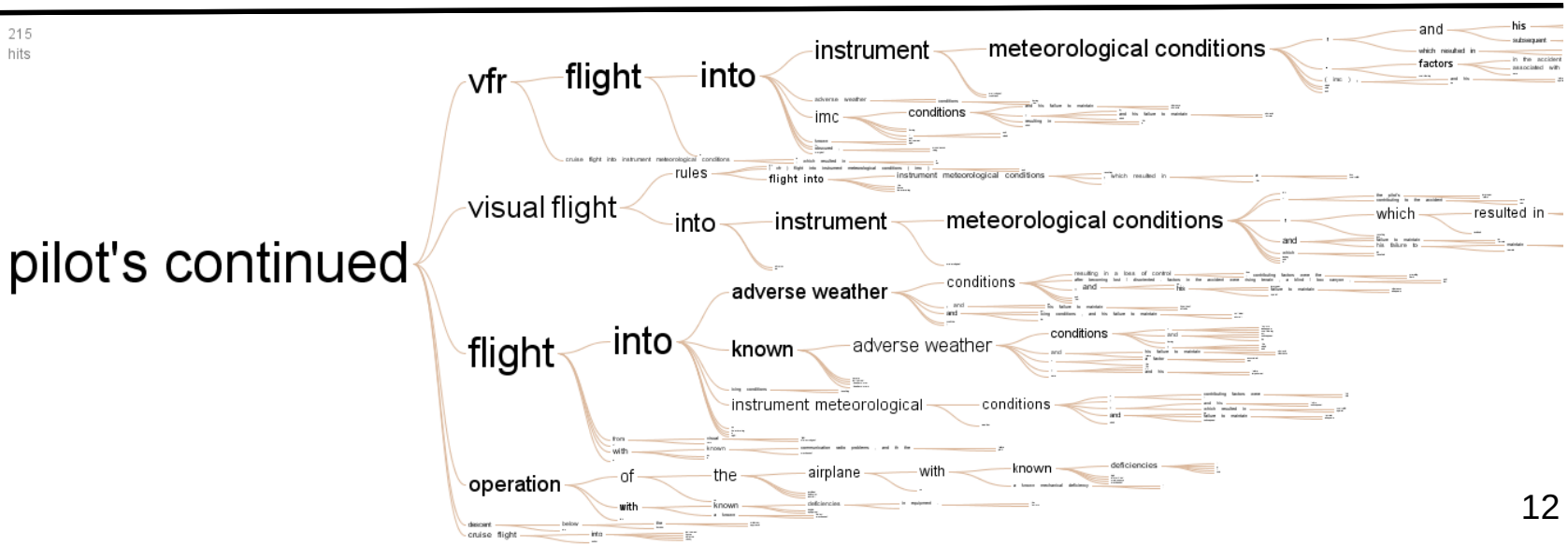

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What Causes These Accidents?

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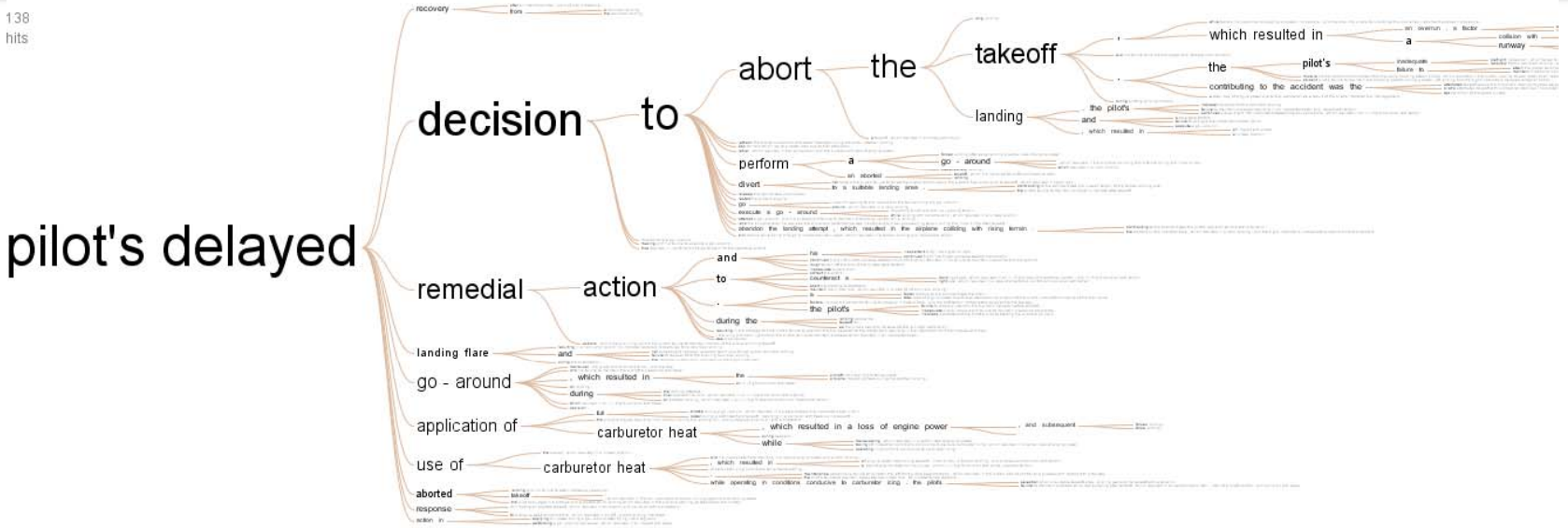

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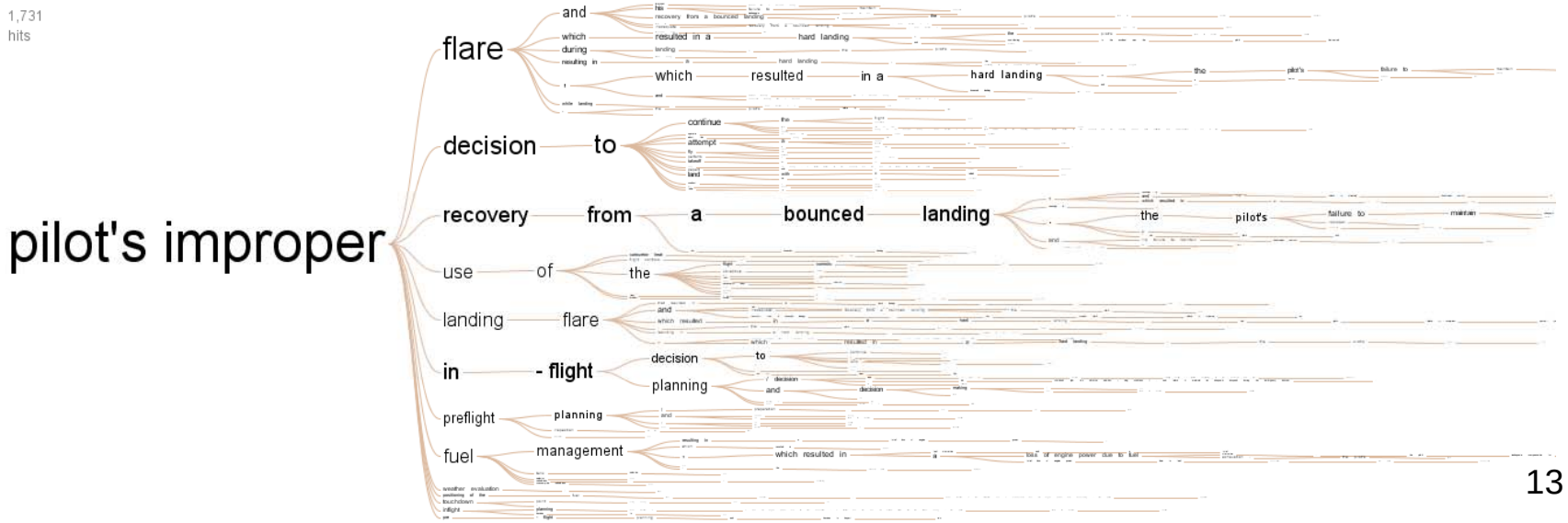

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What Causes These Accidents?

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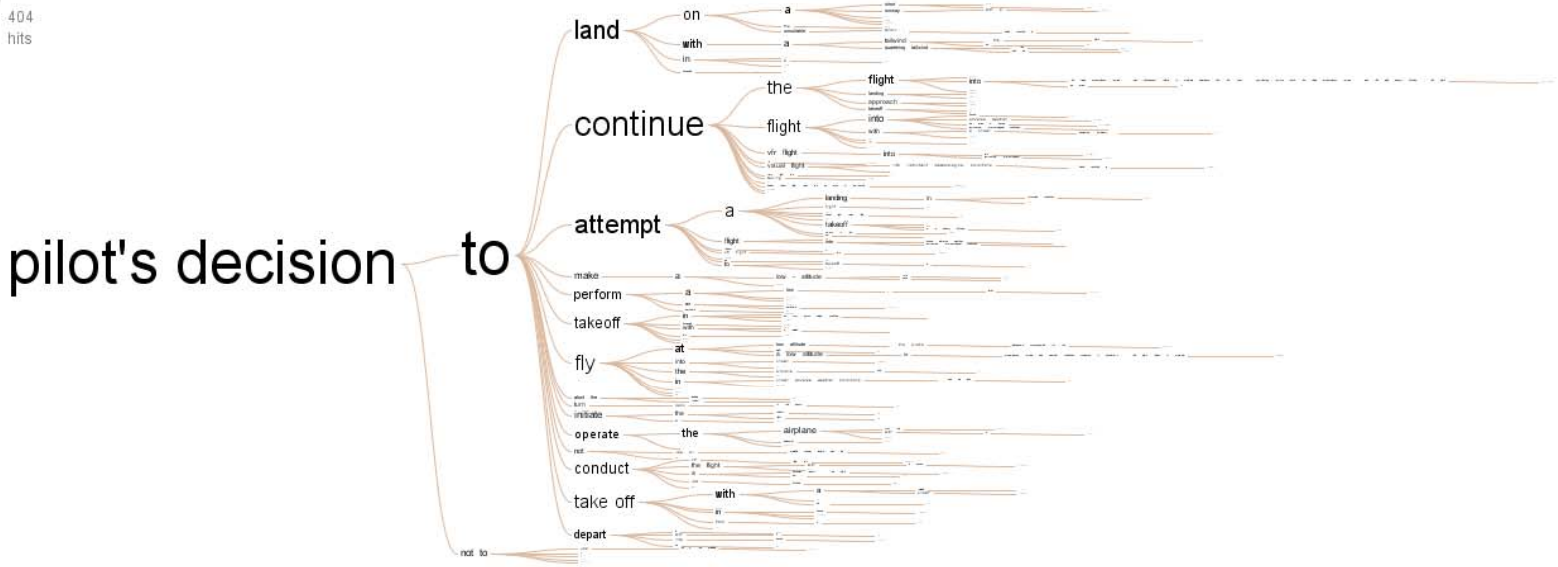

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Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

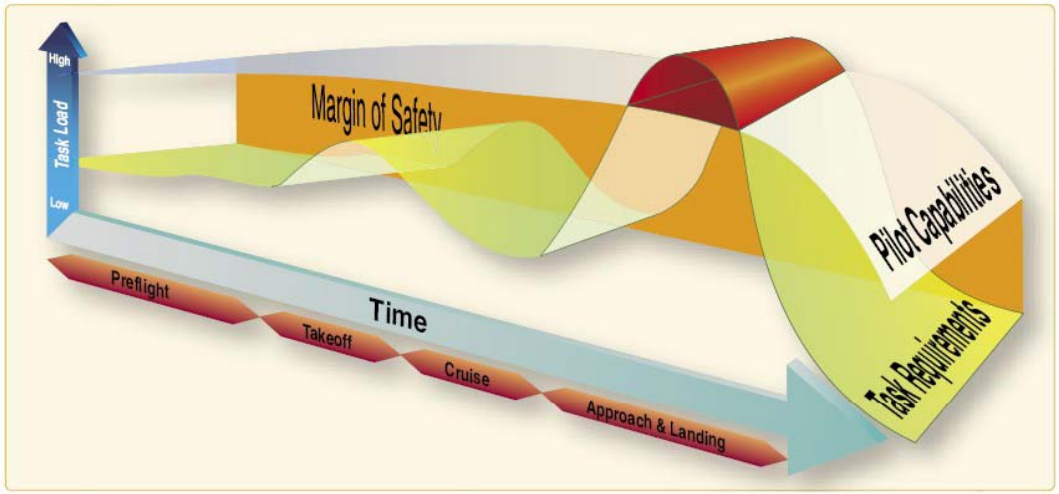
Advances in Aviation Technology

- Despite all the advances in technology to improve flight safety, one factor remains the same:
  - The human factor which leads to errors.
    - It is estimated that approximately 80 percent of all aviation accidents are related to human factors (FAA Pilot's Handbook of Aeronautical Knowledge, 2008)
    - While, greater than 50 percent of all human factors related aviation accidents are caused by pilot errors.
    - Vast majority of these accidents occur during Approach and Landing phase of the flight
  - Therefore the focused of this research is in the errors made by pilots during the Approach and Landing phase of the flight

Reference: FAA Pilot's Handbook of Aeronautical Knowledge , 2008

Flight Segments and Workloads

- The Pilot's workload differs in the different segments of the flight
  - Preflight- Low Workload
  - Takeoff and Initial climb- Medium Workload
  - En-route or Cruise- Low Workload
  - Approach and Landing- High Workload



- The Pilot has a certain capacity of doing work and handling tasks.
- However, there is a point where the tasking exceeds the pilot's capability.
- When this happens, tasks are either not done properly or some are not done at all.

Reference: FAA Pilot's Handbook of Aeronautical Knowledge, 2008

Cockpit Workload and Task Saturation

- Effective workload management ensures essential operations are accomplished by planning, prioritizing, and sequencing tasks to avoid work overload.

- Proper use of checklists. While the cockpit checklist has long been viewed as a foundation of standardization of cockpit procedures and safety, the improper use, or the non-use, of the cockpit checklist by pilots is often refer to as a key contributing factor to aircraft accidents.

- Recognizing a work overload situation is also an important component of managing workload. The first effect of high workload is that the pilot may be working harder but accomplishing less. As workload increases, attention cannot be devoted to several tasks at one time, and the pilot may begin to focus on one item. When a pilot becomes task saturated, there is no awareness of input from various sources, so decisions may be made on incomplete information and the possibility of error increases.

- Fatigue, stress, and work overload can cause a pilot to fixate on a single perceived important item and reduce an overall situational awareness of the flight. A contributing factor in many accidents is a distraction that diverts the pilot's attention from monitoring the instruments or scanning outside the aircraft. Many flight deck distractions begin as a minor problem, such as a gauge that is not reading correctly, but result in accidents as the pilot diverts attention to the perceived problem and neglects to properly control the aircraft.

Reference: FAA Pilot's Handbook of Aeronautical Knowledge, 2008

How to Assist Pilots with Workload?

- Training
  - Authority of the pilot in command;
  - Communication processes, decisions, and coordination;
  - Workload and time management;
  - Situational awareness;
  - Effects of fatigue on performance, avoidance strategies and countermeasures;
  - Effects of stress and stress reduction strategies; and
  - Aeronautical decision-making and judgment training.
- Checklists
  - Flight procedures checklists
- Automations
  - Autopilot
  - GPS
  - Airplane Health Management (AHM)
- Augmented Cognition Systems
  - Pilot Cognition
  - Airplane Systems Cognition

Human Augmented Cognition Systems

- Augmented Cognition (Pilot Cognitive)
  - DARPA's Improving Warfighter Information Intake Under Stress (formerly Augmented Cognition) Program
    - Apply neuroimaging to solve human factors problems
  - Cognitive Cockpit (CogPit)
    - Joint QinetiQ/Alion/NAVAIR project to apply neuroimaging to aviation
- Constraints on Techniques
  - Equipment
  - Cost
  - Size
  - Power consumption
  - Comfort
- CogPit is a platform to develop cockpits that "read the pilot's mind" to provide the pilot with the right information at the right time (NAVAIR)

Retrieved from: NAVAIR Human Systems Department. LT Jefferson D. Grubb MSC USN, 2013

Aircraft Augmented Cognition Systems

- Augmented Cognition Systems (Airplane Cognitive Systems)
  - Hypotheses
    - Combining augmented cognition systems and automation systems in cockpit design reduces pilot in-flight errors
  - The main focus of this research is to collect, combine, and analysis the information from airplane systems including but not limited to:
    - Flight Management System
    - GPS
    - Airplane Health Management (AHM)
    - Autopilot
    - Automatic Landing System
    - Automatic Traffic Reporting Systems
    - Automated weather Reporting System
    - Flight Control
    - Surveillance Systems

Research Methodologies

- Expert Judgment
  - 10 pilots will fly the simulator three times each
    - With no automation
    - With automation
    - With augmented cognition and automation
  - Their performance would be measured
  - They will fill out a survey
- Simulation
  - Using airplane simulator (Redbird FMX1000) an in-flight emergency scenarios would be introduce under three different conditions
    - With no automation
    - With automation
    - With augmented cognition and automation
  - Pilots reactions and performances would be recorded and measured for this study

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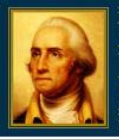
Proposed Concept



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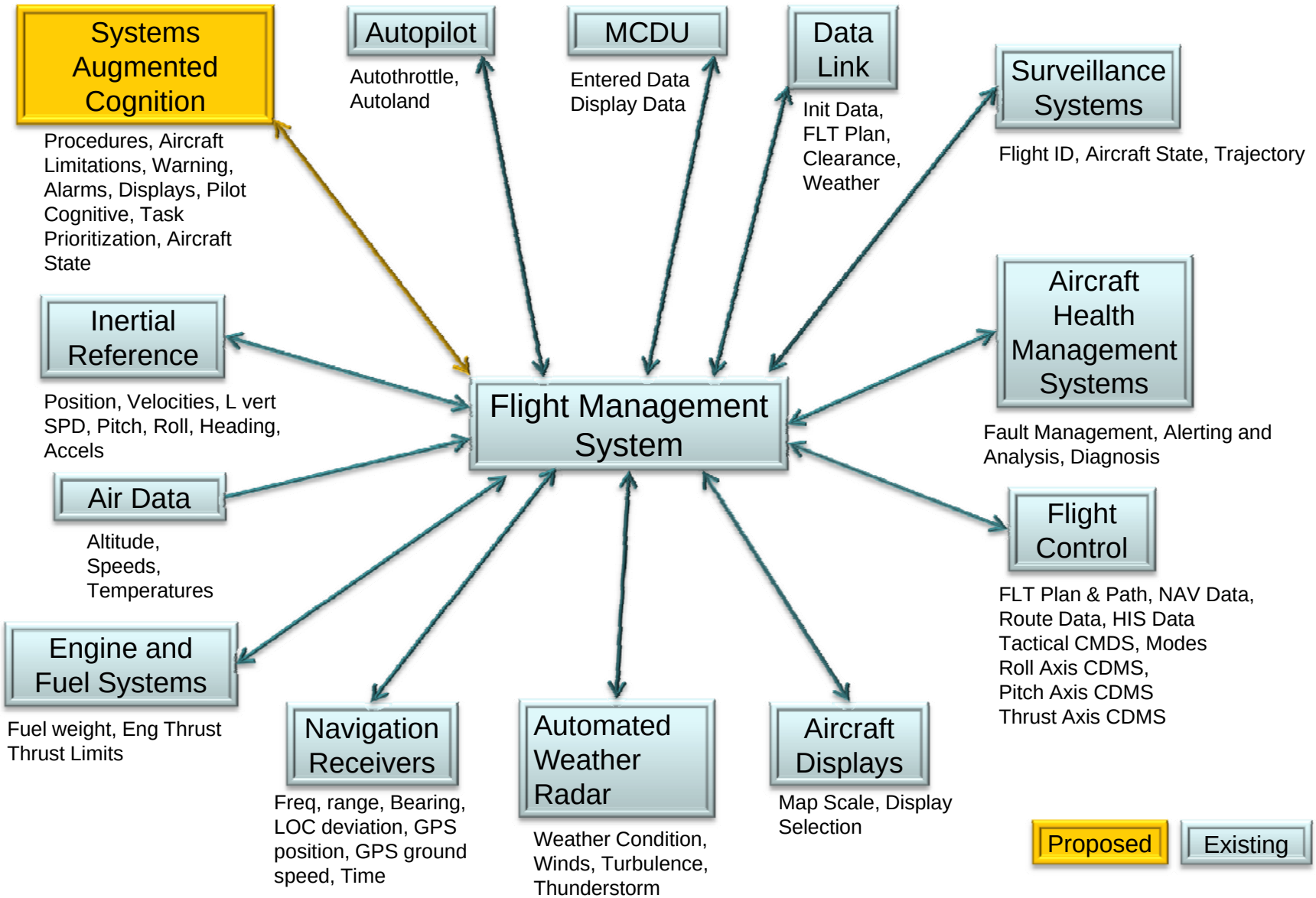


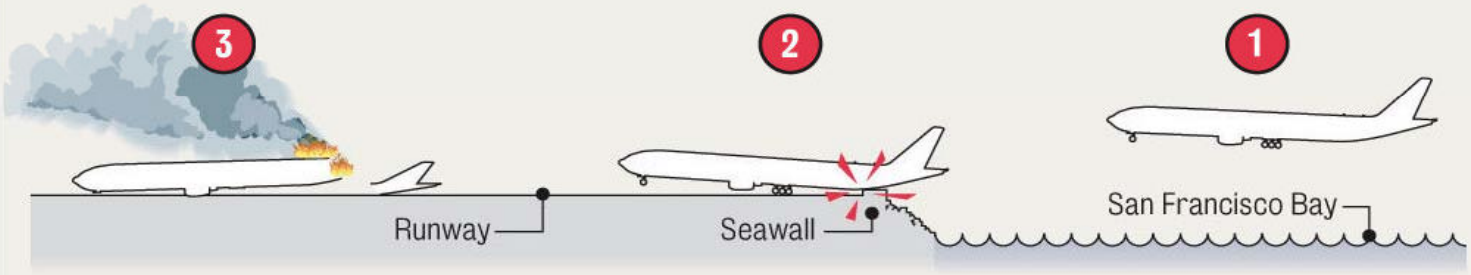
Proposed Concept

- The proposed augmented cognition system will check the aircraft and pilot performance against a set of procedures and limitation and will notify the flight crew of any
  - System failure or emergency
  - Deviation from the aircraft limitation and procedures
- By issuing alarm and warnings by both voice and display the system will capture flight crew's attention
- This system will prioritize the flight maneuvering procedures and announces the limitations
  - For example max. and min. airspeed for entering the approach,
- The prioritized work will be communicated to the crew way before arriving at the entry point for each flight segments
- It will also alarm the pilot if the aircraft starts to diverge from the procedures
- In other word, the aircraft augmented cognition system will create a virtual tunnel in the flight path and will assist the flight crew to stay within this path and operate the aircraft within the limitations by increasing the pilot's situational awareness, attentions allocation, and by reducing the pilot workload thru task prioritization

Crash at San Francisco Airport

POSSIBLE CAUSE OF CRASH AT SAN FRANCISCO AIRPORT

Based on witness accounts in the media and video of the wreckage, aviation expert Mike Barr speculates that the Asiana Airlines plane approached the runway too low, and some part of the plane may have caught the runway lip, the seawall at the end of the runway. Barr, a former military pilot and accident investigator, teaches aviation safety at the University of Southern California.



1. The Boeing 777 deploys its landing gear as it arrives at San Francisco International Airport.

2. Experts speculate that the plane might have struck the seawall.

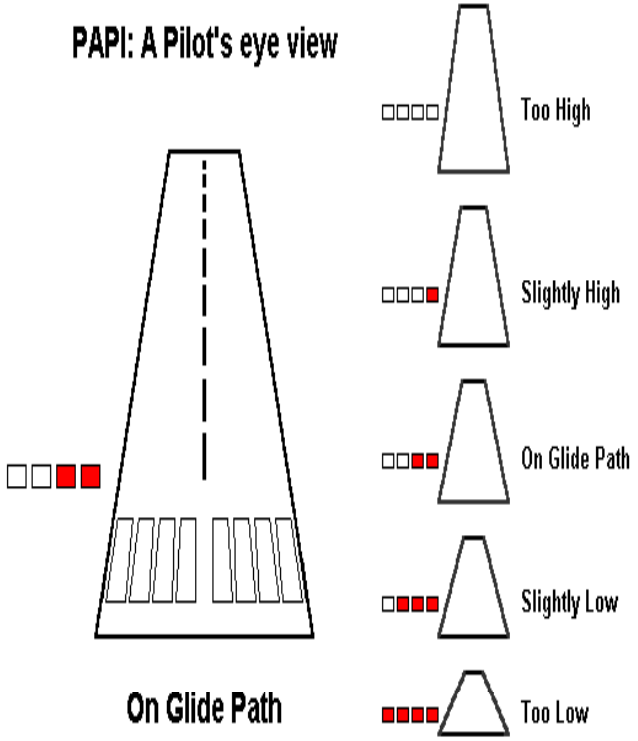
3. The tail breaks off. The rescue slides are deployed, and passengers jump out.

Sources: Federal Aviation Administration; National Transportation Safety Board

AP GRAPHIC

Asiana Airlines Flight 214

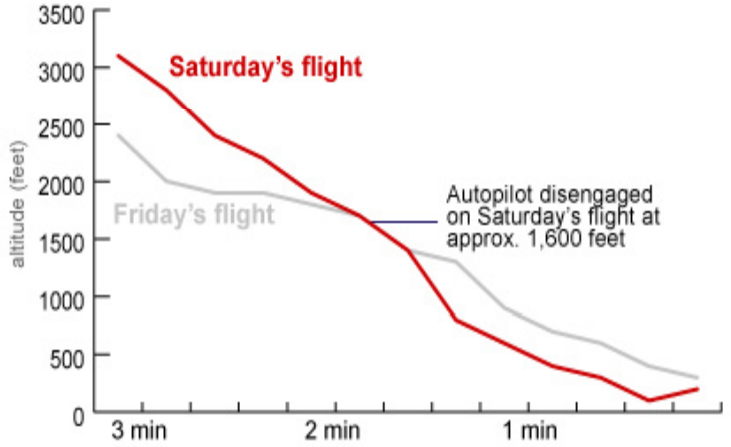
- The flight was cleared for a visual approach to runway 28L.
- Told to maintain a speed of 180 knots until the aircraft was five miles from the runway.
- According to the NTSB, the weather was fair and the aircraft was cleared for a visual approach. There is no indication yet of any problem, mechanical or otherwise, with no distress calls or other problem reports during the flight
- The pilots performed a visual approach assisted by the runway's precision approach path indicator (PAPI).
- The airplane crashed short of runway 28L's threshold.
- The NTSB noted that the main landing gear, the first part of the aircraft to hit the seawall, "separated cleanly from the aircraft as designed".
- Preliminary analysis indicated that the plane's approach was too slow and too low.
- Eighty-two seconds before impact, at an altitude of about 1,600 feet the autopilot was turned off, the throttles were set to idle, and the plane was operated manually during final descent.
- NTSB stated the pilots did not "set the aircraft for an auto-land situation ... They had been cleared for a visual approach and they were hand-flying the airplane.



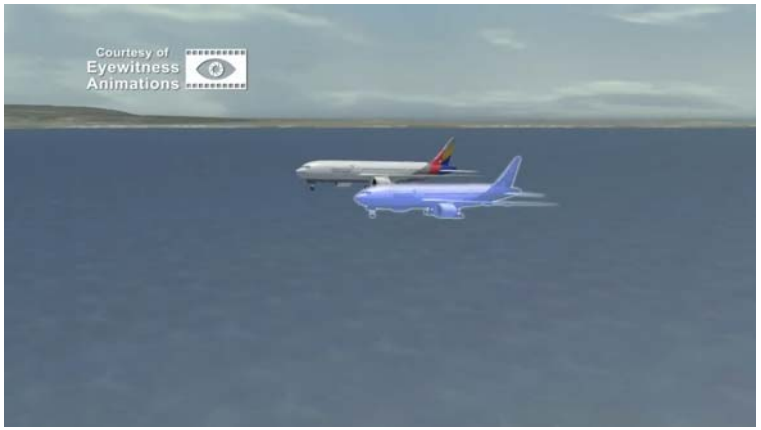
1) Retrieved from: Preliminary Report Aviation – DCA13MA120". National Transport Safety Board. August 14, 2013
2) Retrieved from: "NTSB Press Briefing (no. 2)". Press briefing by NTSB chairwoman Deborah Hersman uploaded to You Tube
3) Retrieved from: "Accident: Asiana B772 at San Francisco on Jul 6th 2013, touched down short of the runway, broke up and burst into flames". The Aviation Herald.

Asiana Airlines Flight 214

- Based on preliminary data, the NTSB said the plane's airspeed on final approach fell to 34 knots below its target approach speed of 137 knots.
- A preliminary review of FAA radar return data did not show an abnormally steep descent curve, although the crew did recognize that they began high on the final approach.
- At a height of 125 feet, eight seconds before impact, the airspeed had dropped to 112 knots.
- According to initial reports from the cockpit crew, the plane's autothrottle was set for the correct reference speed, but until the runway's precision approach path indicator (PAPI) showed them significantly below the glide path, the pilots were unaware the autothrottle was failing to maintain that speed.
- Seven seconds before impact, one pilot called for an increase in speed.
- The sound of the stick shaker (warning of imminent stall) could be heard four seconds before impact on the cockpit voice recorder.
- Airspeed reached a minimum of 103 knots (34 knots below the target speed) three seconds before impact, with engines at 50% power and increasing.
- The crew called for a go-around 1.5 seconds before impact.
- At impact, airspeed had increased to 106 knots.



Retrieved from: FlightAware.com. October 4, 2013



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Asiana Airlines Flight 214

- Hersman said: "In this flight, in the last 2.5 minutes of the flight, from data on the flight data recorder we see multiple autopilot modes and multiple autothrottle modes ... . We need to understand what those modes were, if they were commanded by pilots, if they were activated inadvertently, if the pilots understood what the mode was doing."
- Hersman has repeatedly emphasized it is the pilot's responsibility to monitor and maintain correct approach speed and that the crew's actions in the cockpit are the primary focus of the investigation

1) Retrieved from: Preliminary Report Aviation – DCA13MA120". National Transport Safety Board. August 14, 2013
2) Retrieved from: "NTSB Press Briefing (no. 2)". Press briefing by NTSB chairwoman Deborah Hersman uploaded to You Tube
3) Retrieved from: "Accident: Asiana B772 at San Francisco on Jul 6th 2013, touched down short of the runway, broke up and burst into flames". The Aviation Herald.

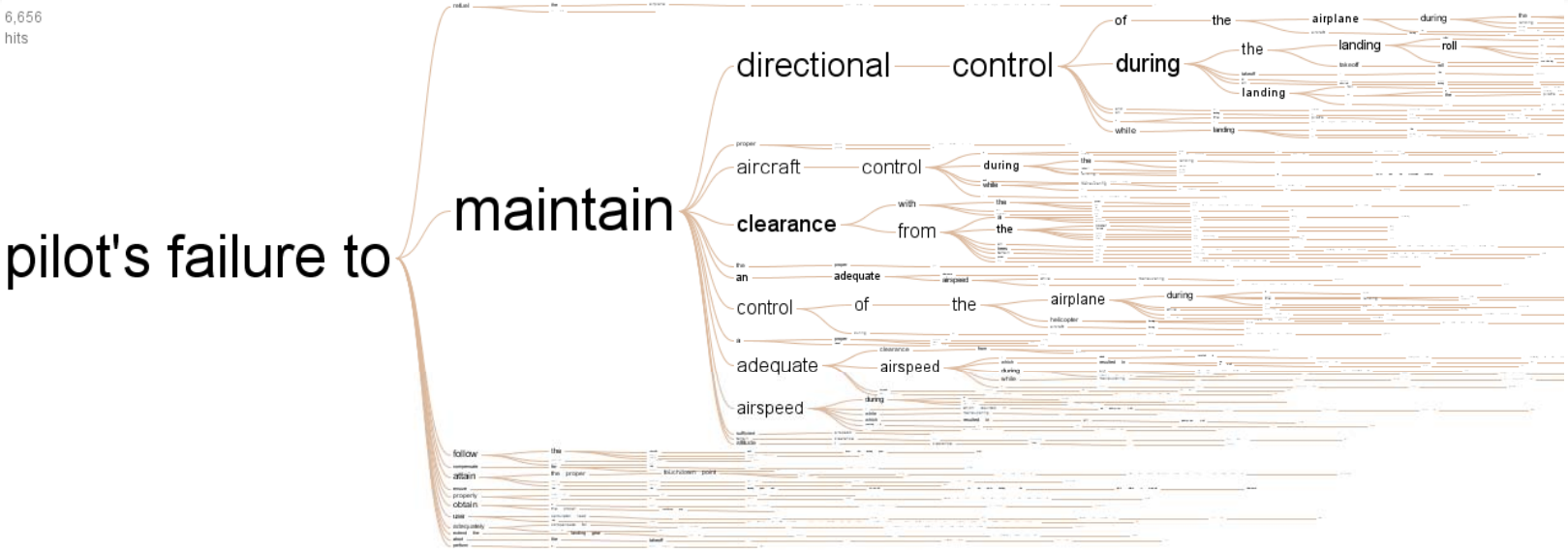
Conclusion

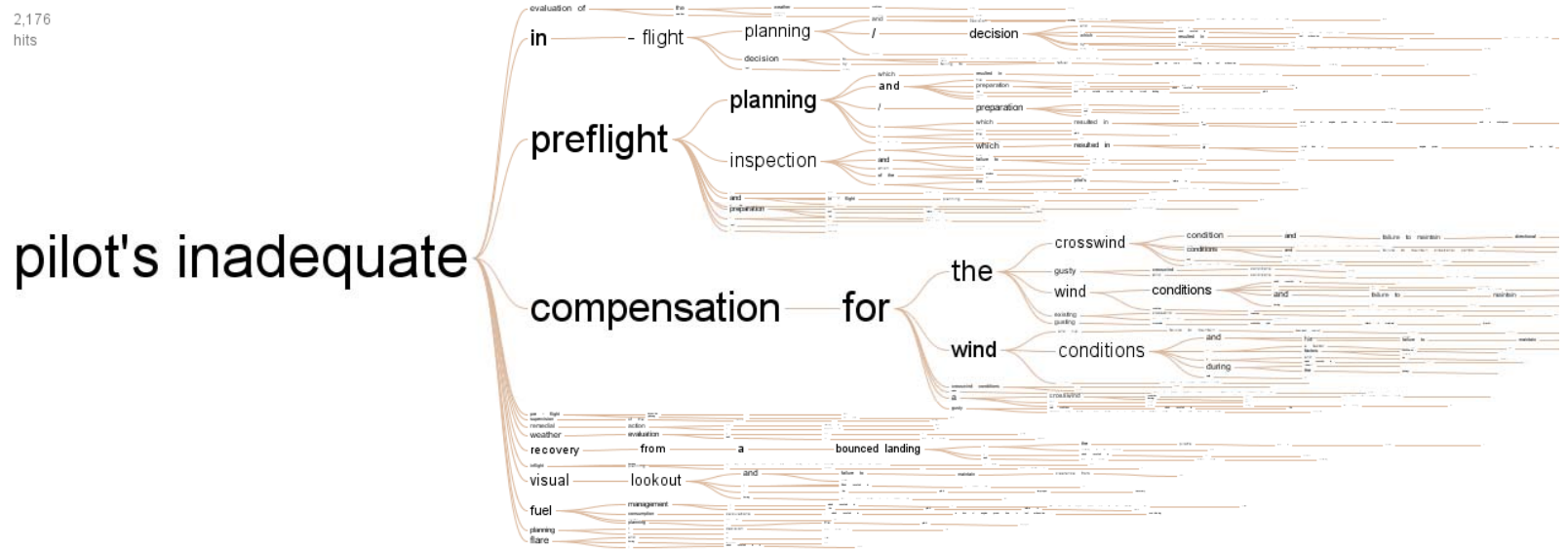
- Despite all training and advancements in avionics, the cockpit remains as a complex system
- Complexity of the system combined with pilot's fatigue, stress, and saturated work overload will increase the probability of human/pilot in flight errors
- Human augmented cognition system (CogPit) is a platform to develop cockpits that "read the pilot's mind" to provide the pilot with the right information at the right time (Jefferson D. Grubb)
  - The full closed-loop technology is not ready
  - Imaging equipment is bulky, temperamental, and uncomfortable
- In-Flight checklists and procedures are repeatedly being skip by flight crews under saturated workload
- The proposed aircraft augmented cognition system will create a virtual tunnel in the flight path and will assist the flight crew to stay within this path and operates the aircraft within the limitations
- It increases the pilot's situational awareness, attentions allocation, and reduces the pilot workload thru task prioritization

Retrieved from: NAVAIR Human Systems Department. LT Jefferson D. Grubb MSC USN, 2013

Backup

What Causes These Accidents?

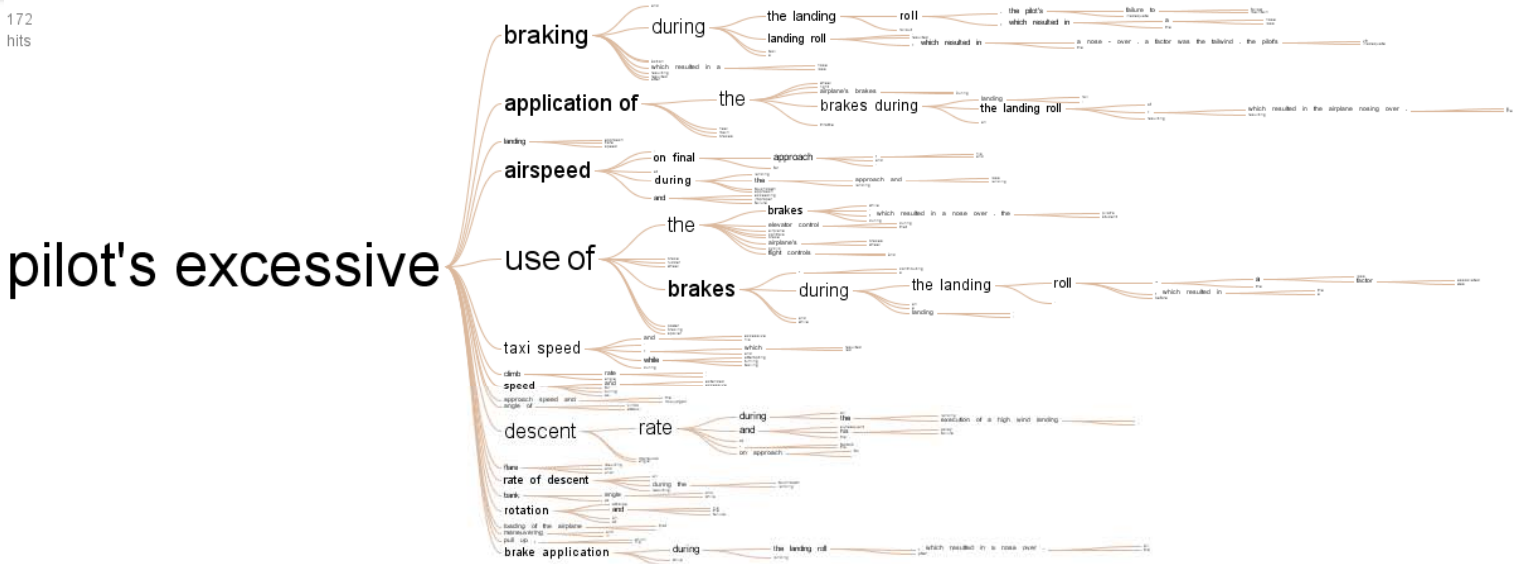




Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

172 hits



425 hits

Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

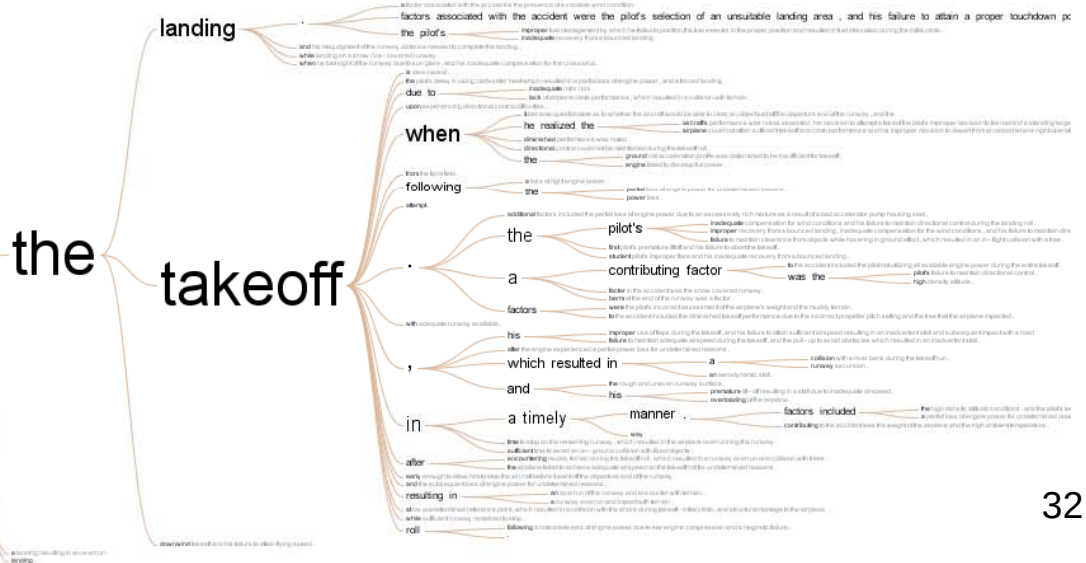
What Causes These Accidents?

62 hits

pilot's failure to perform

67 hits

pilot's failure to abort

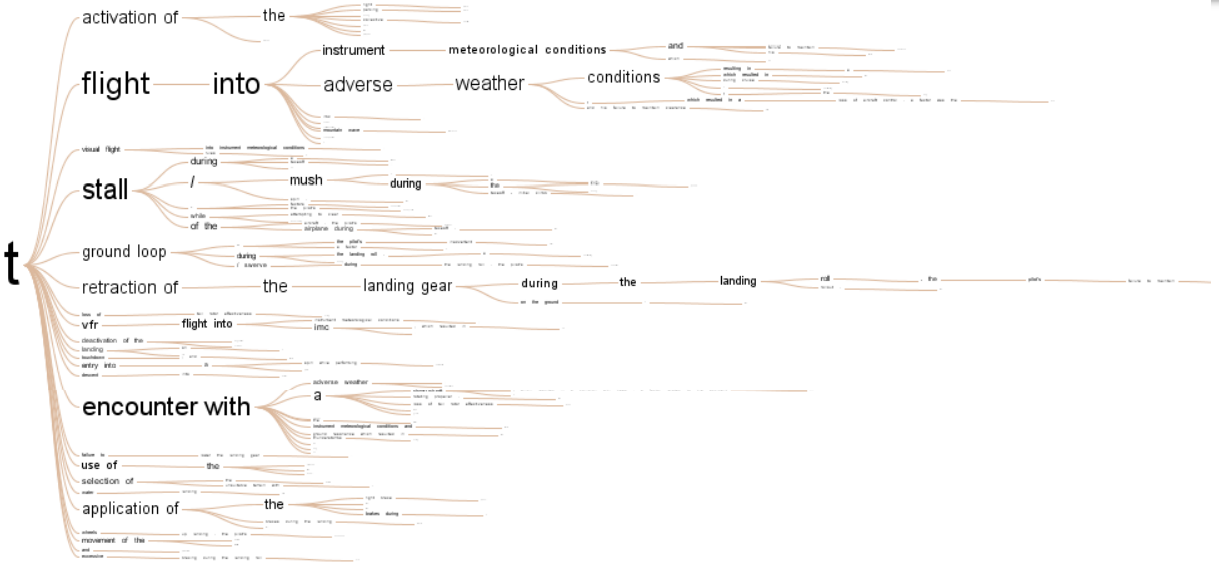


Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

306 hits

pilot's inadvertent



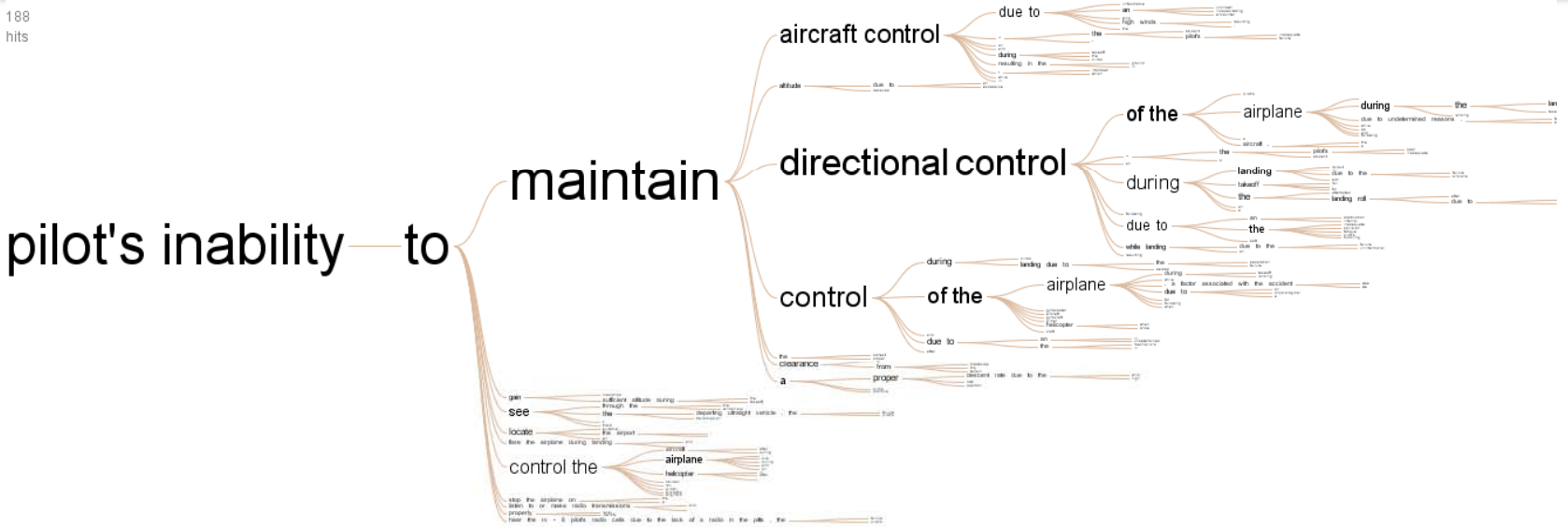
220 hits

pilot's misjudged

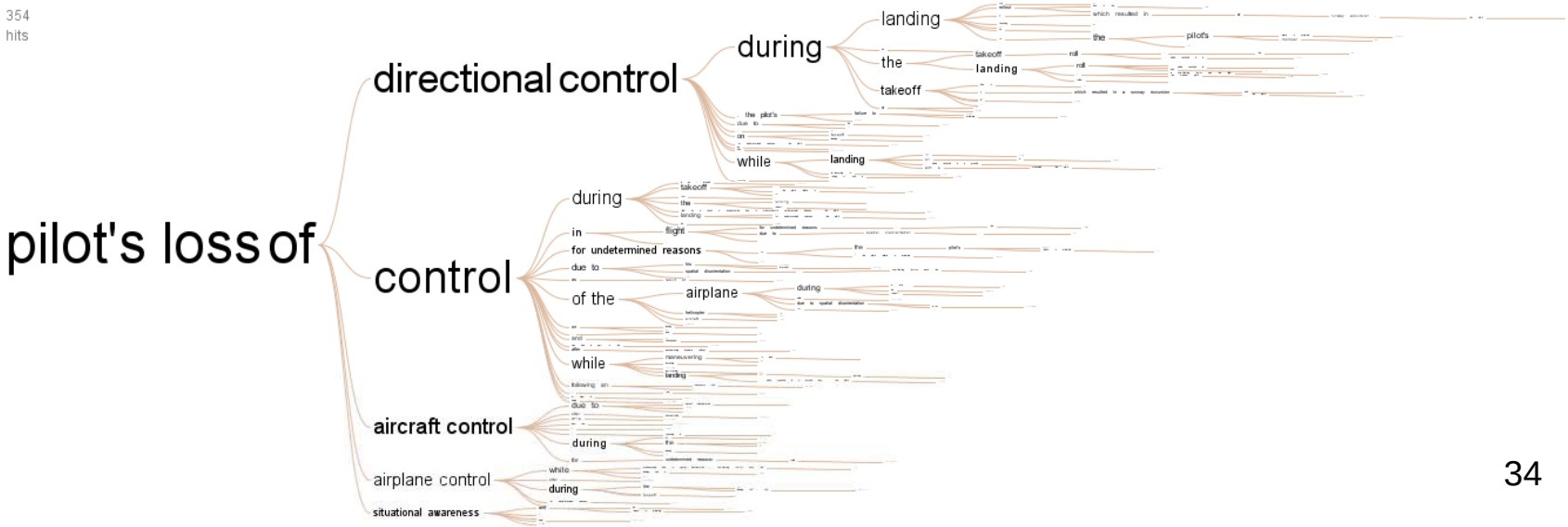
Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

188 hits



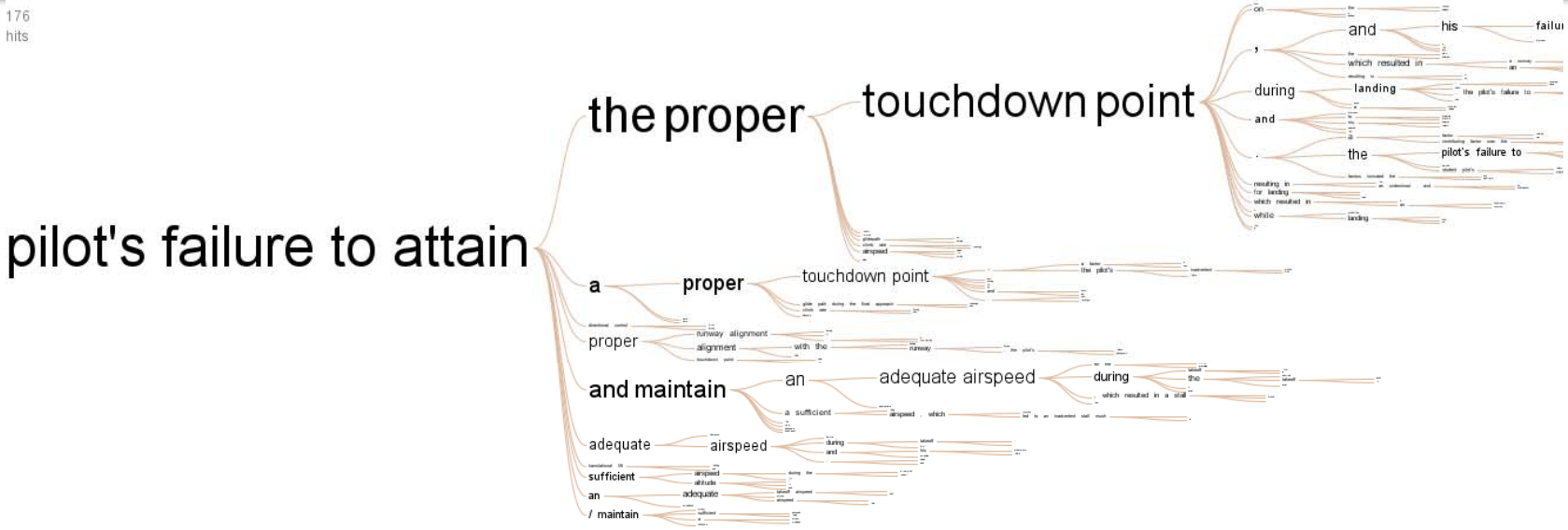
354 hits



Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

176 hits

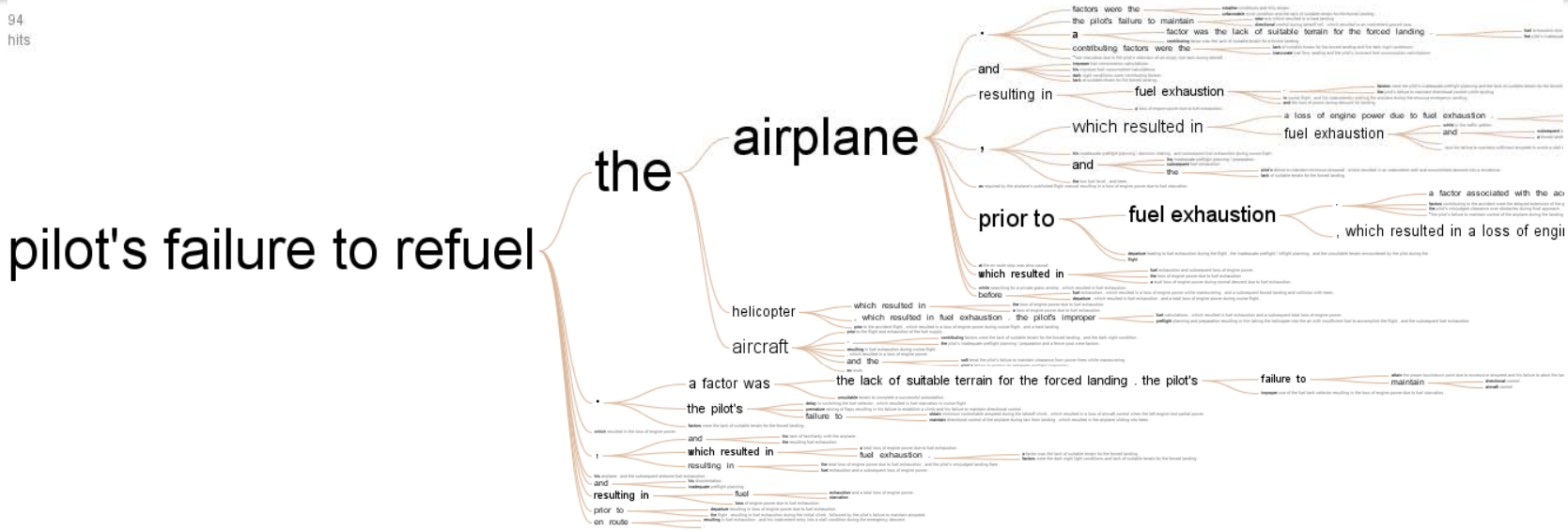


62 hits

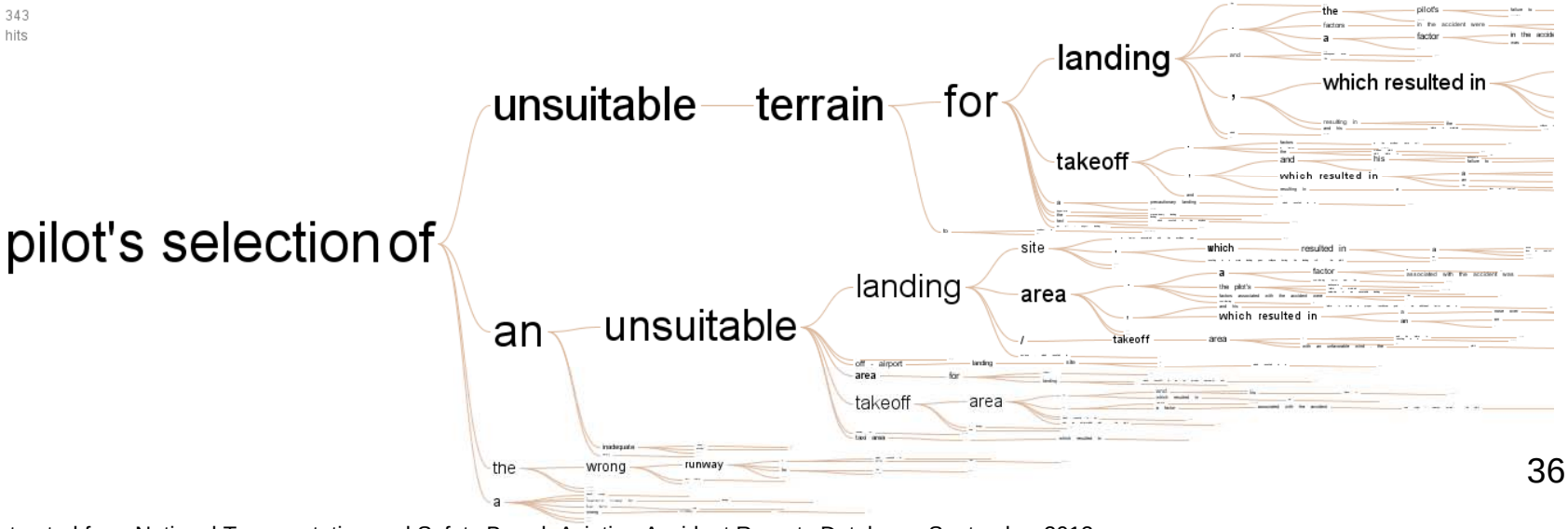
Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013

What Causes These Accidents?

94 hits



343 hits



Data extracted from National Transportation and Safety Board, Aviation Accident Reports Database, September 2013