MIT International Center for Air Transportation

Single Pilot Operation: Motivation, Issues Architectures and Con-Ops

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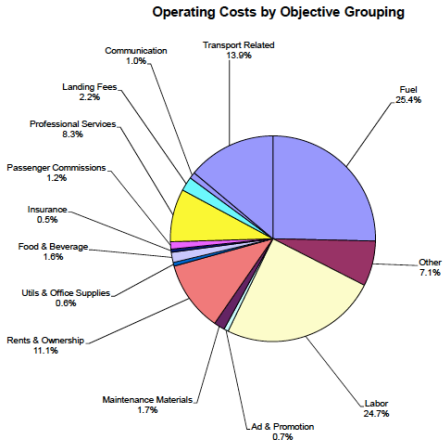
Hypothesis – Nominal Flight Operations Can be Reliably Managed by Single Pilot with Current or Near Term Systems

Motivation for SPO

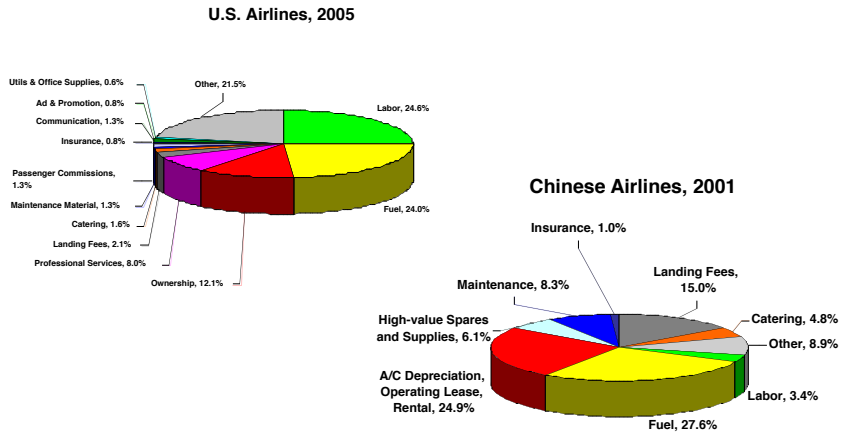
- **Air Carrier (Part 121)**
  - Cost
    - Labor
    - Training
    - Accommodations
  - Flexibility
    - Scheduling
    - Pilot pool
- **Business and Personal Aviation (Part 91)**
  - Safety
  - Flexibility
    - Owner Operator
  - Cost

Typical Cost Structure (US Airlines) 2010



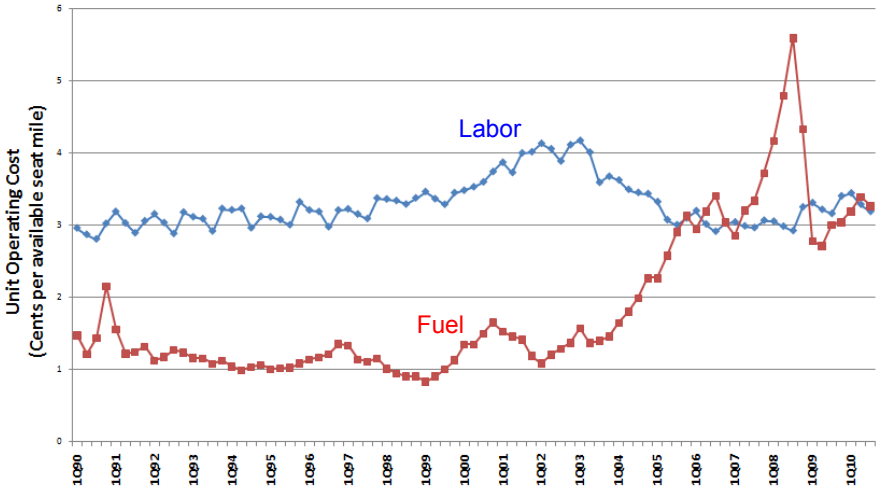
Source: "ATA US Airline Cost Index: Major & National Passenger Carriers, Q3 2011.

Comparison of Cost Structure Chinese vs. US Airlines



Source: "Cost Analysis of China Airline Industry", Aviation Industry Development Research Center of China, 10/14/2003.
ATA US Airline Cost Index: Major & National Passenger Carriers,

Fuel and Labor Unit Cost Trends
US Data

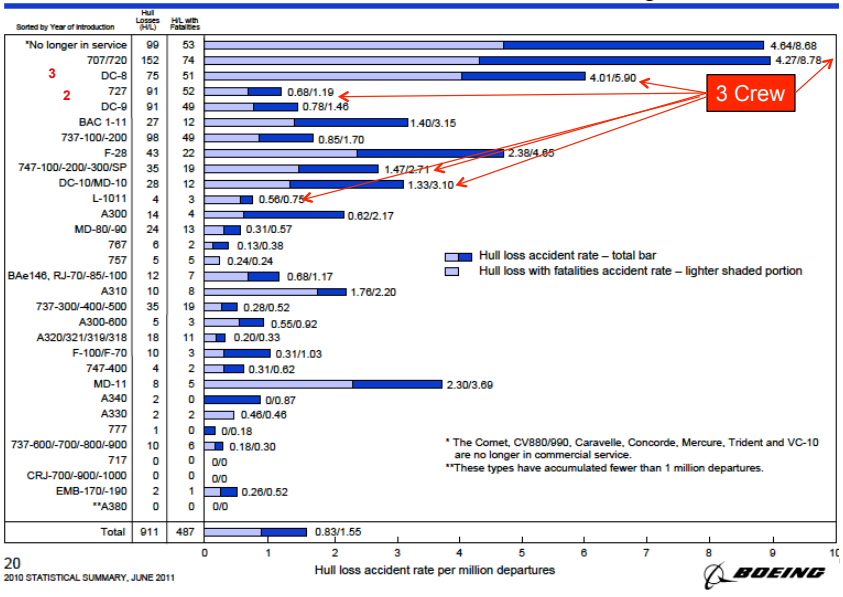


Data source: ATA U.S. Airline Cost Index (Data to 2010 Q3)

Air Carrier Crew Trends

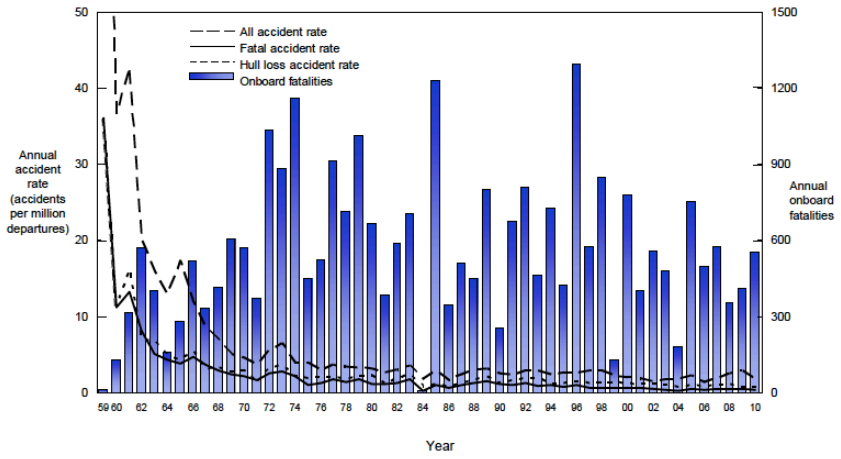
- **Crew of 5**
  - **Captain, First Officer, Flight Engineer, Navigator, Radio Operator**
- **4 - Radio Operator (1950s)**
  - Tuned Radios, SELCAL, Satellite Communication
- **3 – Navigator (1970s)**
  - IRS, Area Navigation, Satellite Navigation
- **2 - Flight Engineer (1980s)**
  - Systems Simplification
  - Engine Indication and Crew Alerting Systems (EICAS)
- **1 ? First Officer**
  - Ground Decision Support, Cabin Crew Backup
- **0 ? Captain**
  - Cargo or Passenger Carrying UAV's?

Accident Rates by Airplane Type
Hull Loss Accidents – Worldwide Commercial Jet Fleet – 1959 Through 2010



Accident Rates and Onboard Fatalities by Year

Worldwide Commercial Jet Fleet – 1959 Through 2010



BOEING

Single Pilot IFR Accident Rates

- **"Analysis of accidents during instrument approaches". Bennett CT, Schwirzke M.**
  - Analysis of 25 Years of Data
  - VFR approach accidents more frequent than IFR (14.82 vs. 7.27 accidents/100,000 approaches) but less severe
  - SPIFR accident rates are not much higher than dual-pilot IFR (DPIFR), 7.27 vs. 6.48 accidents/100,000 approaches
  - Night SPIFR accident rate is almost 8 times the rate of day IFR, 35.43 vs. 4.47 accidents/100,000 approaches
- **AOPA Air Safety Foundation**
  - 1983-1999
  - 61 single-engine daytime accidents occurred with two pilots on board, compared to 1,170 single-engine daytime accidents with one pilot.

Certification Considerations

	Probable	Improbabl	Extremely Improbable
Catastrophic Accident			
Adverse Effect On Occupants			
Airplane Damage			
Emergency Procedures			
Abnormal Procedures			
Nuisance			
Normal			

Descriptive Probabilities

Probability (per unit of exposure)

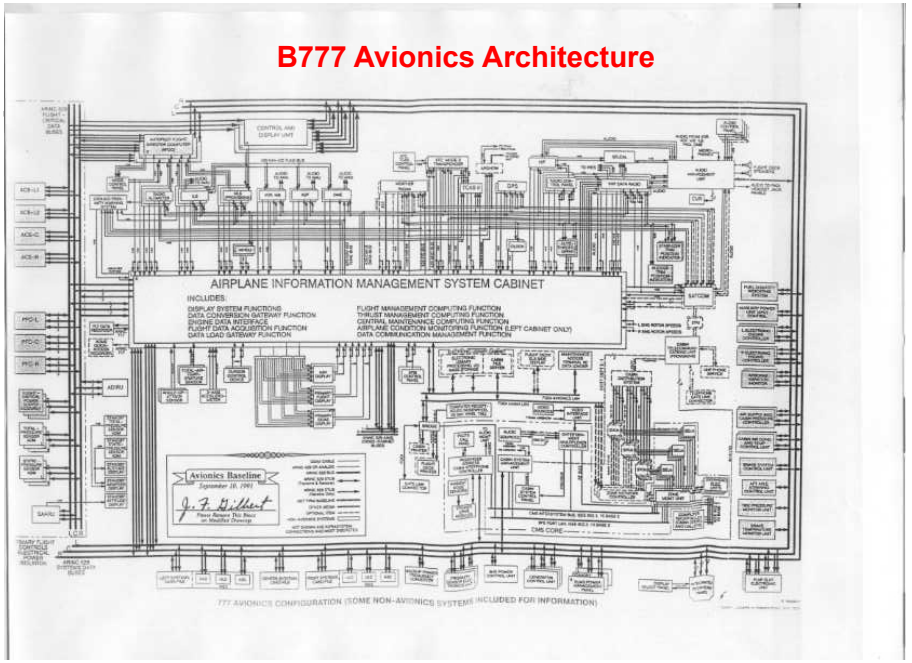
1	FAR	JAR
		Frequent
10E-3	Probable	
		Reasonably Probable
10E-5		
		Remote
10E-7	Improbable	
		Extremely Remote
10E-9		
	Extremely Improbable	Extremely Improbable

What is the correct unit of exposure : Flight hour, Departure, Failure

Reliability Architectures

- **Failure Modes and Effects Analysis**
- **Avoid Single String Failure**
  - Cannot guarantee 10E-9
- **Fail Safe, Fail Operational**
- **Redundancy Architectures**
  - Dual Redundant for Passive Failures
    - e.g. Wing Spar
  - Triple Redundancy for Active Systems
    - 777 Fly By Wire
      - Sensors
      - Processors
      - Actuators
      - Data Bus

B777 Avionics Architecture



Functional Requirements for Dual Crew

- **Failure Mode Based**
  - Physical
    - Crewmember incapacitation rate historically around 1/month
  - Judgment
-

Rate of Crew Incapacitation

- **US had 47 events (flights) between 1983 and 1988**
  - CAMI Repot “In-Flight Medical Impairment of US Airline Pilots: 1993-1998”, DeJohn, Wolbrink, Larcher
  - 39 incapacitations, 11 impairments, 3 cases of multiple crew members

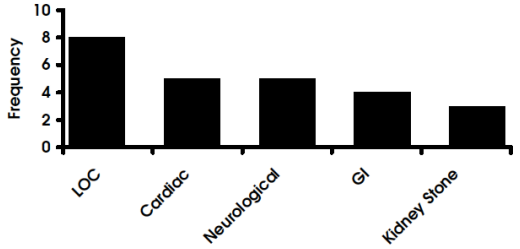
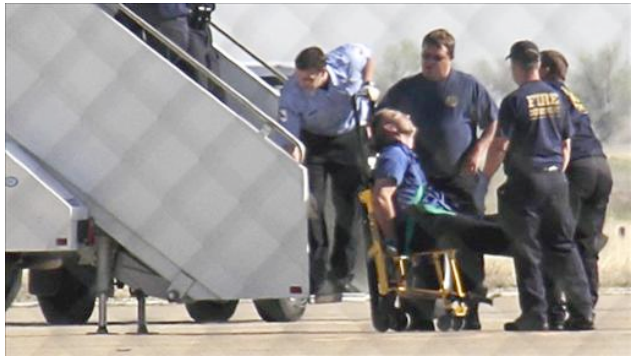


Figure 3. Frequent categories of in-flight medical incapacitation.

Recent JetBlue Event



Functional Requirements for Dual Crew

- **Failure Modes**
  - Physical
    - Crewmember incapacitation rate historically around 1/month
  - Judgment
- **Strength Based**
  - Hydraulic Failure
- **Task Based**
  - Degraded mode operations (eg pressurization failure)
  - High density airspace
  - Diversions
  - Passenger in-flight emergency
  - Inspection
  - Evacuation
  - Toilet

Redundancy Architectures Part 121

- **Judgment Redundancy**
  - Virtual Co-Pilot - Enhanced Dispatch
    - Comm and Surveillance Systems Support Real-Time Interaction Over Most of the World (need Bandwidth)
- **Physical Redundancy**
  - Flight Attendant – Backup Pilot
    - Re-think cockpit doors
  - Automated Backup
    - Optionally Piloted Vehicle
  - Ground Based Backup
    - Remotely Piloted Vehicle
    - Drives Comm Security Standard

Redundancy Architectures

Optionally Piloted Vehicles

- **Aurora Centaur OPA**

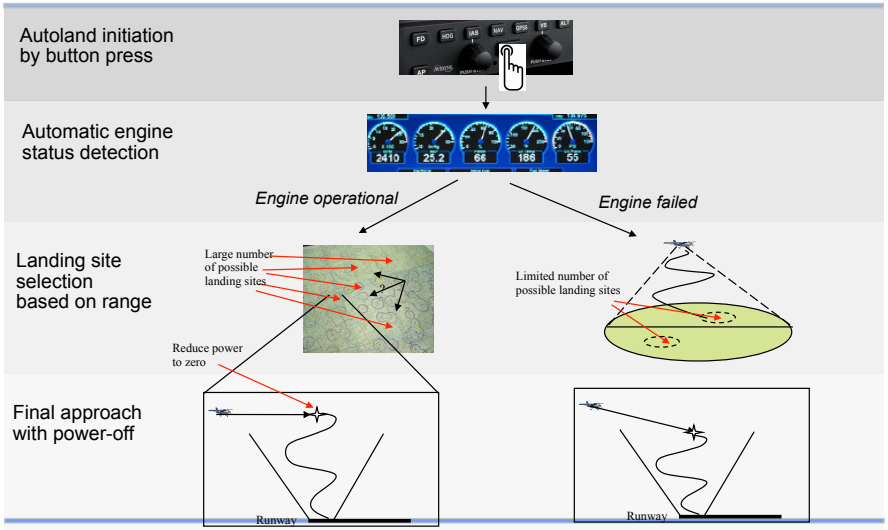
Redundancy Architectures Part 91

- **Judgment Redundancy**
  - GA Dispatch Services (cost, liability)
  - In Flight Dispatch, Decision Support Services
  - Cockpit Decision Support Systems
    - Virtual Flight Instructor
    - "Do you really want to do that Dave?"
- **Physical Redundancy**
  - Untrained Passenger
    - Simplified Flight Mode
  - Automated Backup
    - Optionally Piloted Vehicle
    - Emergency Landing Capability (eg Seigel)
  - Ground Based Backup (cost)

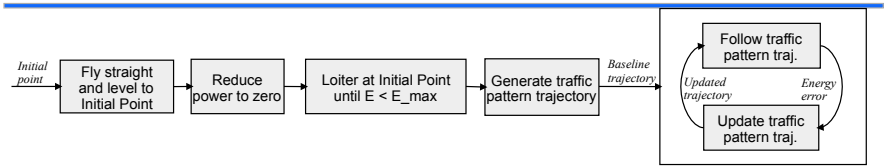
Digital Autopilots with Recovery Function Avidyne DFC 90

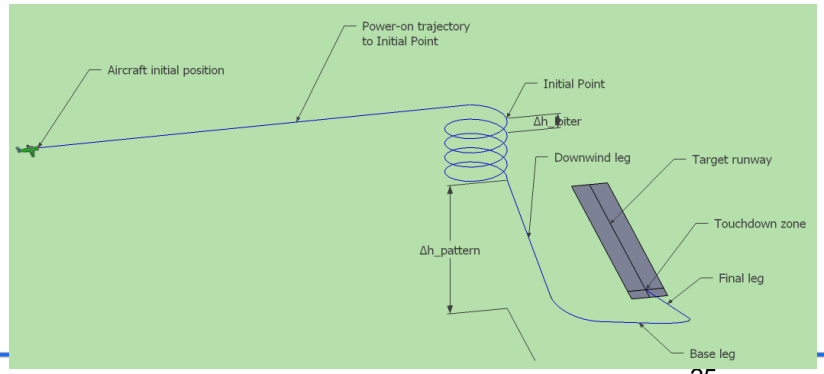
Autoland System Concept for General Aviation

Diania Seigel ICAT 2011-9



Example Trajectory Plan





Additional Thoughts

- **Communication and Control Architectures**
  - Integrity and Security Requirements
- **Boredom Issues**
- **Public Acceptance**
- **Will Complexity of Next Gen Procedures Offset**
- **Non-Normal Operations**