Visualization at Boeing

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Why Visualization?

- Broadest communication channel to the human brain
  - Acquires 80+% of all data communicated to a human
- Brain must process data to gain insight
IVT (Integration Visualization Tool)

- FlyThru transitioned to IVT (Interim -> Integration Visualization Tool) and PCs for the 787 in early 2000’s (John Gass, Bill McGarry, Nik Prazak, Richard Clark, et al.)
- Linked to geometry configuration management systems (EPIC/DIRECT, Enovia)
- 20,000 registered users across BCA/BDS programs
Massive Model Visualization

- Dave Kasik started investigating ways to visualize entire aerospace products in 2004 in collaboration with organizations around the world
On-Board a Commercial Airplane

Source: J. Farricker
Flight Test Data Channel and Bandwidth Growth

Source: T. Reeber
Data Acquisition and Airlines

Engineering, Operations & Technology | Information Technology

- Airplane
  - Airplane Modifications
  - Aircraft Doc Services
  - Spare Parts Management
  - Aircraft Provisioning
  - Maintenance Planning
  - Freighter Conversion
  - Fleet Management
  - Inventory Management
  - Engineering Support
  - Materials Management

- Prepare
  - Manpower Planning
  - Flight Planning
  - Dispatch
  - Fuel Management
  - Load Management
  - Flight Scheduling

- Plan & Control
  - Crew Pairing & Rostering
  - Wx & NOTAMs Support
  - Crew Training
  - Departure Control (flight)

- Fly
  - Flight Tracking
  - Fleet Tracking
  - Crew Tracking
  - Aeronautical Info Mgmt
  - Flight Optimization
  - Cabin Services

- Disruption Management
  - Flight Re-Planning
  - Fleet Recovery
  - Crew Recovery
  - Passenger Recovery

- Post Flight
  - AOG Recovery
  - Field Service
  - Data Recording and Reporting
  - Data Analysis

- Airplane Health Management
  - Line Maintenance
  - Heavy Checks
  - Maintenance Management
  - Document Management
  - Component Services

- Gate Management
  - Turnaround Management
  - Ground Traffic Flow

- ATM/Airspace
  - PBN Services
  - Airspace Design
  - Flow Management
  - Surveillance

- Passenger
  - ATC Coordination
  - Airport Coordination
  - ATM Coordination

- Information Management
  - Distribution Mgmt & Product
  - Mobile Services
  - Web Services
  - Legacy System Integration

Source: D. Kinney
787 in Flight
Analytics Overview

- Analysis vs. Analytics
  - When dealing with digital data, analysis is the detailed examination of any size and number of data collections
- Analytics is the science behind analysis
- In practice, analytics requires understanding the
  - Cognitive processes
  - Data acquisition
  - Tools
  - Techniques & methods
  - Results communication patterns

  that let people obtain an optimal or reasonable decision based on existing data.
Gain Insight through Data Analysis

- Situation awareness
  - Command and control

- Tracking and visibility
  - Determine status

- Causal chain analysis
  - Determine why something happened

- Hypothesis testing
  - Explore possible explanations

- Detecting anomalies and correlations
  - Prevent event occurrences

- Prediction/Forecasting
  - Improve quantities ordered

- What-if studies
  - Explore alternatives

- Summarizing
  - Communicate results

Well suited for advanced visual analytics tools that allow interactive exploration and assessment of complex data.
Mapping Types of Analysis to Tools

<table>
<thead>
<tr>
<th>Type of Analysis</th>
<th>Tools</th>
<th>IN-SPIRE</th>
<th>Starlight</th>
<th>Excel</th>
<th>TA C</th>
<th>Saffron</th>
<th>Jigsaw</th>
<th>Geotime</th>
<th>Tableau</th>
<th>Spotfire</th>
<th>SAS</th>
<th>SPSS</th>
<th>SAS Analytics</th>
<th>COGNOS</th>
<th>Star Analytics</th>
<th>Analyst Notebook</th>
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Visual Analytics

Formal definition: “The science of analytical reasoning facilitated by interactive visual interfaces.”

Translation: Rapidly explore large, complex datasets to gain new business insight using interactive visualization.

Detect the expected and discover the unexpected

References:

- *Illuminating the Path*, nvac.pnl.gov (free download), 2005
- Special Issue: Foundations and Frontiers of Visual Analytics, Information Visualization, vol. 8, no. 4, Winter 2009
Variations of Non-Geometric Data Visualization

Automated Reports
[Cognos, Crystal Reports, Business Objects]

Information Visualization
[Tufte, ManyEyes]

Best on numeric data
[Statistics, Clustering]

Excel, PowerPivot
[Pivot tables, Histograms]

Visual Analytics
[Active data exploration, Highly interactive]

Numeric
Text
Streaming Video
Automated Reports

Images produced with Cognos software
Information Visualization

Napoleon's March to Moscow

John Snow, Cholera, 1854 and today
Bird Strike Project

The threat by the numbers:
- Approximately 1 bird strike per 2,000 flights
- Around 20 strikes per day on jet transport category aircraft alone
- About 1 in 10 strikes are damaging
- The reported costs average $123 million per year
- However, 80% of strikes go unreported, and the true cost could be as high as $615 million per year

Other factors:
- Increasing traffic
- Bigger, quieter engines
- Twin-engine configurations
- Increasing bird populations
Aviation Safety Goal

10-9
Sources of Aviation Safety Data

- **Continued Airworthiness**
  - Safety Data (Long Beach)
  - Safety Data (Puget Sound)

- **Accident Investigation**
  - FAA ASIAS (FAA)
  - FAA ASIAS (NASA)
  - SDR (FAA)
  - ASRS (NASA)
  - EGPWS (Honeywell)

- **Data Warehouse**
  - Internal Data
  - External Data

- **Continued Airworthiness**
  - Safety Data (Long Beach)
  - Safety Data (Puget Sound)

- **Operator Messages**

- **Reliability Data**

- **Health Management**

- **Product Development**

- **Systems**

- **Propulsion**

- **Structures**

- **External Data**
  - MITRE ASIAS
  - PDARS (FAA)
  - Other Manufacturers
  - ASAP
  - FOQA

- **Internal Data**
  - FAA Preliminary Reports
  - 1001 Crash.com
  - FAA Lessons Learned
  - WAAS (FAA)
  - NMACS (FAA)
  - Air Disasters
  - FAA Data Sets
  - Airclaims
  - Media Reports
  - WikiPedia
  - LOSA (UT)
  - EGAIRS
  - EGPWS (Honeywell)
  - ADS (FAA)
  - CADORS (Canada)
  - Safari
  - AxWeb

- **Data Warehouse**

- **Engineering safety data analysis**
Approach

- Project paired
  - Roger Nicholson, Boeing ATF and bird strike SME
  - Andrew Wade, intern (Simon Fraser University, Canada) and visual analytics tool expert

- Results achieved during a 3-month period
  - 4 design affecting decisions for different Boeing models
    - 787
    - 747-8
    - 777
    - 737, 707, 727, P8-A
  - Change to pilot training material

- Used two COTS systems, Tableau and IN-SPIRE
  - IN-SPIRE for text and hypothesis testing
  - Tableau for numeric data
NAR: SECONDS AFTER ROTATION WE HIT A BIRD. THE BIRD STRUCK THE AIRPLANE WITH AN AUDIBLE THUD AND STRUCK THE FO'S WINDOW. HE WAS FLYING. I MONITORED ENG INDICATIONS CLOSELY AND DETECTED NO SIGN OF ABNORMALITY. WE CONTINUED THE CLB ON PROFILE. A FEW SECONDS LATER A STRONG SMELL OF SMOKE ENTERED THE COCKPIT AND PERSISTED. FO CONFIRMED THAT ALL ENG INDICATIONS WERE NORMAL AND CONTINUED STANDARD CLB. SMELL AND SMOKE WERE STRONG. I MADE A DECISION TO RETURN TO ZZZ DUE TO SMOKE AND SMELL. CALLED ZZZ AND DECLARED AN EMER, ANNOUNCED BIRD STRIKE AND REQUESTED TO RETURN TO ZZZ.
Example

- 767-300, 4/2/01, Paris, during climb, 12,000 ft, 250 knots, multiple ducks
Damage Assessment
Time and Location Analysis
Improve Factory Safety Project

- Look at data to understand impact of repetitive stress injuries, including cost.
- 777 Body Structures investigated historical data to understand how it aligned with injury data.
  - Pilot study done with Excel for 777 Forward Body Structures.
  - Analysis based on three years of historical production data, and tested the limitations of Excel.
- Bird strike project showed potential for visual analytics.
Types of Changes

Address back problems

Address multiple problems
Objectives

- Discover how BCA can reduce its manufacturing injuries

Approach

- Identify and answer relevant driving questions using:
  - Visual Analysis
  - Statistical analysis
  - Paired analysis approach
- Communicate actionable information to leadership

Accomplishments

- Conducted an analysis of the performance and effectiveness of BCA’s key Safety Metrics, TIP Quality and IRS Quality.

Next Steps

- Build Initial visualizations for new Production Stability Analysis
- Leverage statistical tools to supplement visual analysis of high-severity text documents.
Low-end Visualization

- A Low End Visualization capability requires solutions to several related problems:
  - A place to host the visualization data or the ability to generate appropriate data on the fly.
  - A low cost mechanism with which a supplier or customer can navigate to and retrieve the model they want to view.
  - Low cost visualization tool(s).
  - Identification of a suitable data format.
The 787 program uses 3D Model-Based Definition (MBD) processes to define their engineering type design information. Suppliers and customers require the distribution, query, display and retrieval of 3D MBD engineering type design data for downstream applications like manufacturing, inspection and maintenance engineering. EID supports the query and retrieval of authoritative 3D MBD in CATIA native format, STEP AP203 and Universal 3D (U3D) PDF formats.

### Data
- CATIA V5
- Product structure
- Engineering Authority (Exact Geometry and Topology)
- GD&T and notes
- Open standards

### Viewer Functions
- Geometry/Product structure associativity
- Retrieve product structure
- Transparency/color
- Measurement
- Section Cuts

### Implementation Architecture
- Multiple hardware & operating systems
- Adobe Reader (plug-in or standalone) for viewing and interrogation of the data, Right Hemisphere for translation
- Multiple browsers
- REDARS + CDW for geometry + product structure

Source: D. Briggs
High-end Visualization

- Where performance and capacity are critical
  - ‘Instant’ load time (less than 1 minute)
  - Performance to interactively manipulate up to 1 billion polygons at 10Hz or faster
  - Product structure with 200,000 separate parts and 2 million instances
  - Selection and feedback in .25 seconds or less
Potential Applications

- Design in context
- Design reviews/error checking
- Tracing systems
- Engineering and manufacturing analysis
  - Mechanisms, weights, manufacturing simulation, etc.
- Electro-magnetic analysis
- Safety
- Survivability
- Complete part context
  - Quality inspection
  - Assembly instructions
- Massive 3D scans and points
- Part dimensions and tolerances
- Airplane-in-a-box (totally disconnected)
- Human model (large model done in ICIDO)
- Part catalogs
- Training and familiarization
- Maintenance instructions
- Sales and marketing (as animation)
Challenges

Data:

- Access
  - Acquiring the access to internal data can be problematic due to:
    - Security concerns
    - Unclear understanding of the benefits (Managing Expectations)
    - Organizational preservation/immune responses

- Quality
  - The quality of the data can be unfit for analysis due to:
    - Too little data (Managing Expectations)
    - Inconsistent or improper formatting (Managing Expectations)
    - Irrelevance to the analysis task
    - Text provides numerous opportunities for misspelling, vagueness, undetectable inferences
Summary

- Develop a better understanding of analysis using visualization
- Significant opportunities to expand visualization technology in industry
- Moving advanced technology into practice is a contact sport