Lessons Learned from Industry

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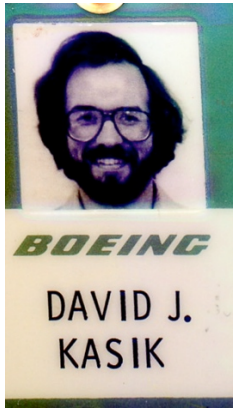
A Bit About Me

- Involved in computer graphics since 1969
- Retired Boeing Senior Technical Fellow
- ACM Fellow
- General curmudgeon about over promising and under delivering
- Stand-in on starship bridges



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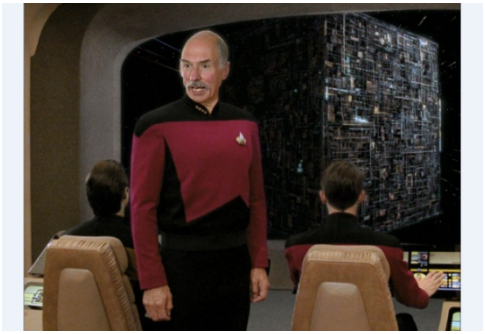

Now

Main Topics

- Look at computing technology initiated and motivated in Boeing
- Advancing technology transition

The Past: Boeing and Computing

- Computer graphics
- Human model
- b-trees
- B-spline surface rendering
- Fractals
- User interface management systems
- Industrial-strength NURBS Algorithms
- IGES
- Augmented reality
- Voxmap PointShell (collision detection)
- FlyThru/IVT
- Massive model visualization
- Visual analytics
- Text analytics

Computer Graphics

- According to Wikipedia, computer graphics *has made computers easier to interact with, and better for understanding and interpreting many types of data. Developments in computer graphics have had a profound impact on many types of media...*
- The term came from Boeing-Wichita's Verne Hudson in 1960. Bill Fetter popularized it.


computer graphics
AIRCRAFT APPLICATIONS
In June 1960, eport prepared by
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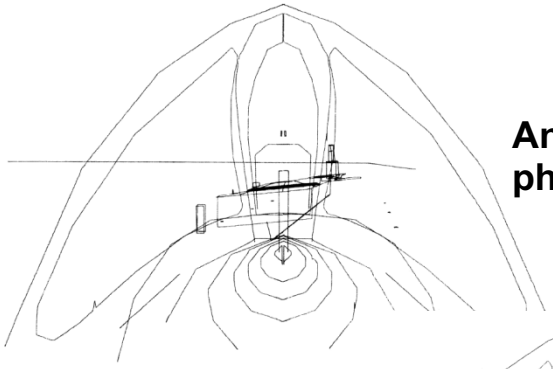
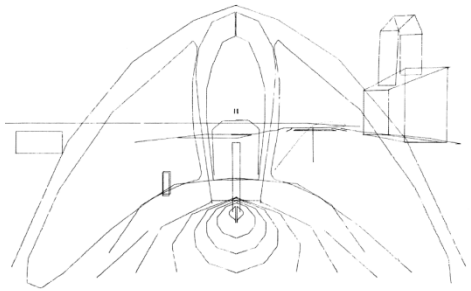
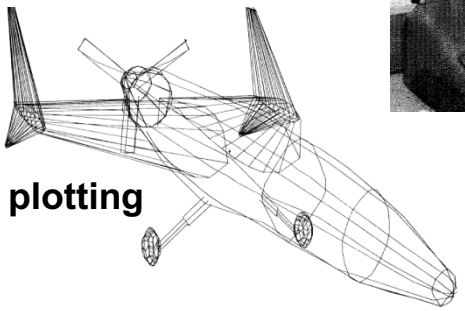
Aircraft Systems Division,
The Boeing Company
D3-4124-1 March 15, 1962

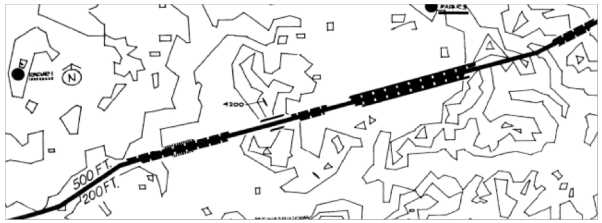


Animation by photography





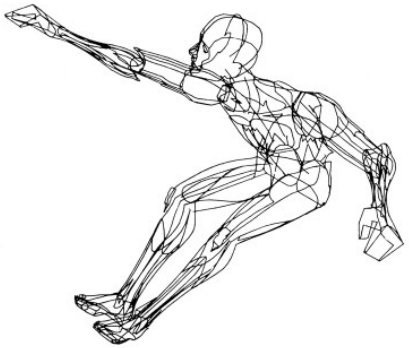
3D-2D plotting

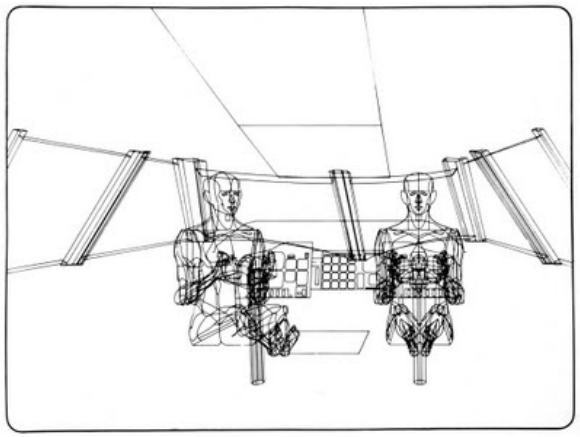


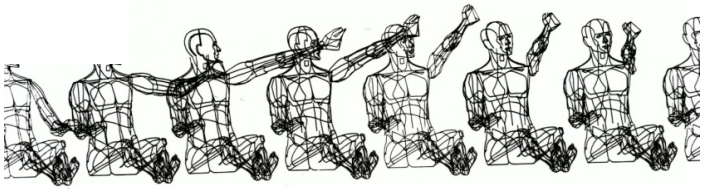
Contour plots

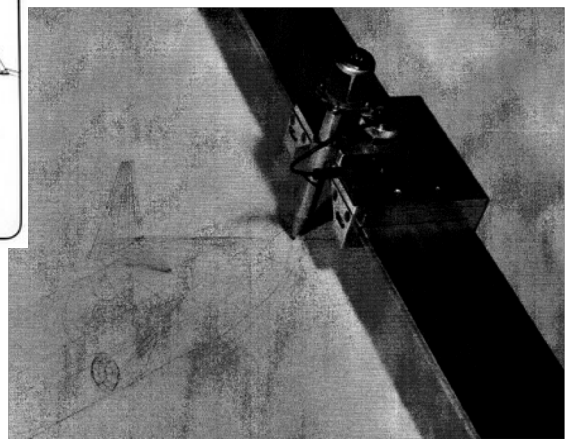
Human Model

- Fetter developed BOEMAN, the first computer model of a human body in 1964
- Used a pen plotter to do reach studies for an aircraft carrier



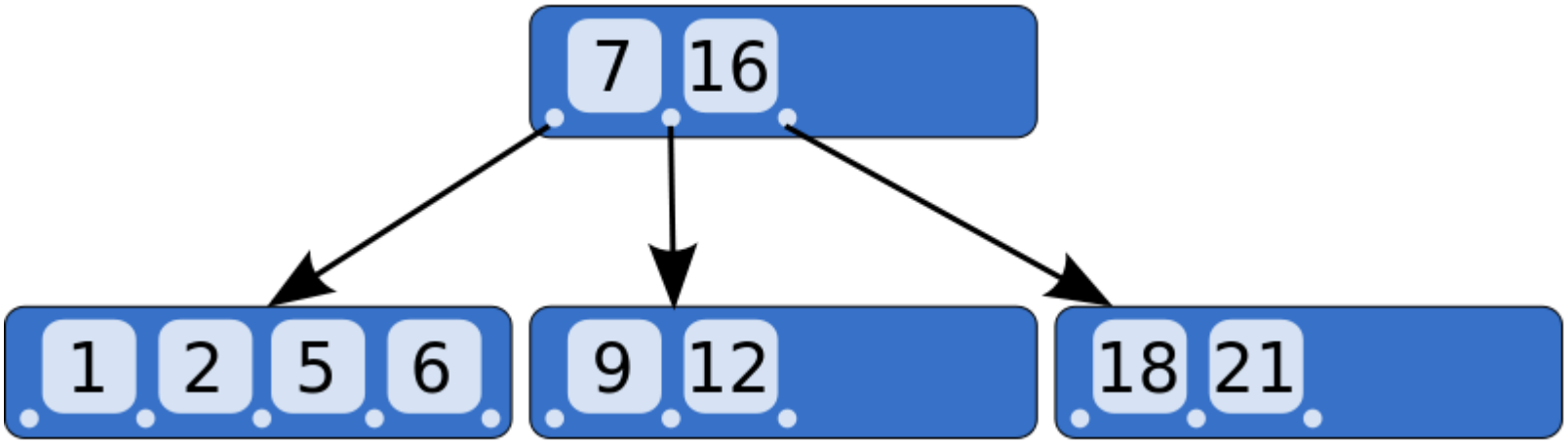






b-trees

- **Foundational technology for indexed database searches**
- **Invented at Boeing in 1972**
  - See etymology section in http://en.wikipedia.org/wiki/B-tree.



B-spline Surface Rendering

- **Jeff Lane and Loren Carpenter**
- **Cover article of Communications of the ACM, "Scan line methods for displaying parametrically defined surfaces", 1980**
- **Technique still in use in all CAD and visualization tools used in Boeing**
- **P.S.: Jeremy Jaech developed direct NURBS surface rendering in 1981**
  - Left Boeing for dream job at a start-up
  - One of two developers of Aldus PageMaker
  - Left Aldus to found Visio

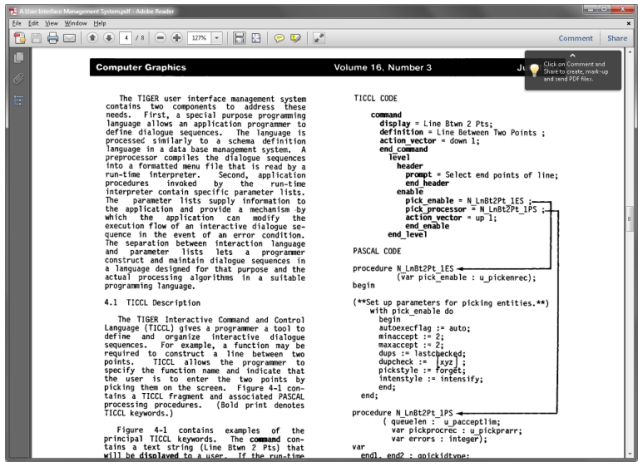
Fractal Animation

- Loren Carpenter
- Produced, directed film called *Vol Libre* (https://vimeo.com/5810737)
- Resulted in standing ovation at SIGGRAPH'80

Courtesy: L. Carpenter

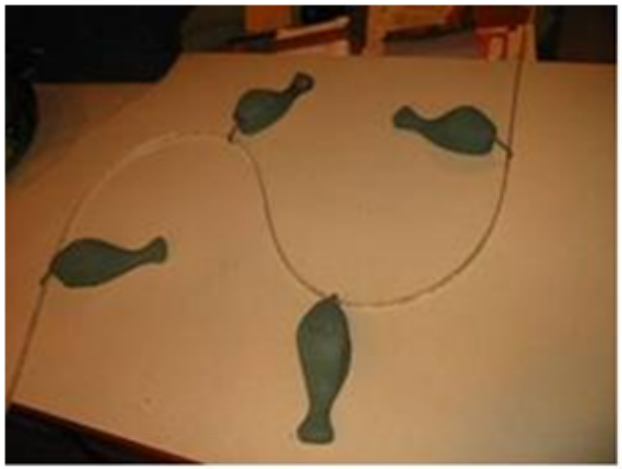
User Interface Management Systems

- **Started as part of the TIGER research project in 1980**
- **Designed by Dave Kasik and initially implemented by Loren Carpenter. Randy Houser, Hank Ramsey, and Steve Jensen handled UIMS evolution.**
- **The UIMS idea improved**
  - The user experience with defaults, generic selection, etc.
  - The programmers' development of complex interactive sequences
- **Originally published at SIGGRAPH'82**
- **Documented programmer productivity improvements (IEEE CG&A, 1988); COTS tools from Apollo and others**

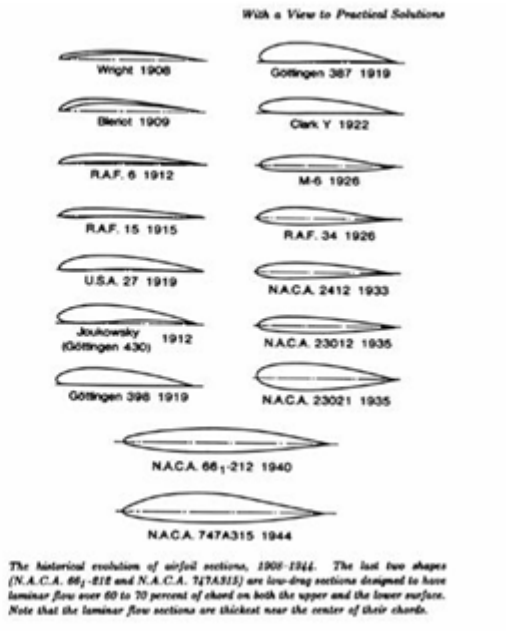


Industrial Strength NURBS Algorithms

- Extended academic math research (Cox-deBoor) to account for lofting use of splines.
- Implemented in the TIGER research system in 1980-1981
- Spearheaded by Bob Blomgren, Eugene Lee, Dick Fuhr, et al.
- Continued and expanded by Dave Ferguson, Tom Grandine, et al.
- Grandine and Fritz Klein developed first reliable surface-surface intersector in late 1990's
- Basis for CATIAV5, UG/NX, ProE. Still moving forward in Boeing as GEODUCK
- Tom Melson et al. developed a parametric surface-based system at Douglas in early 1980's



A physical spline



IGES

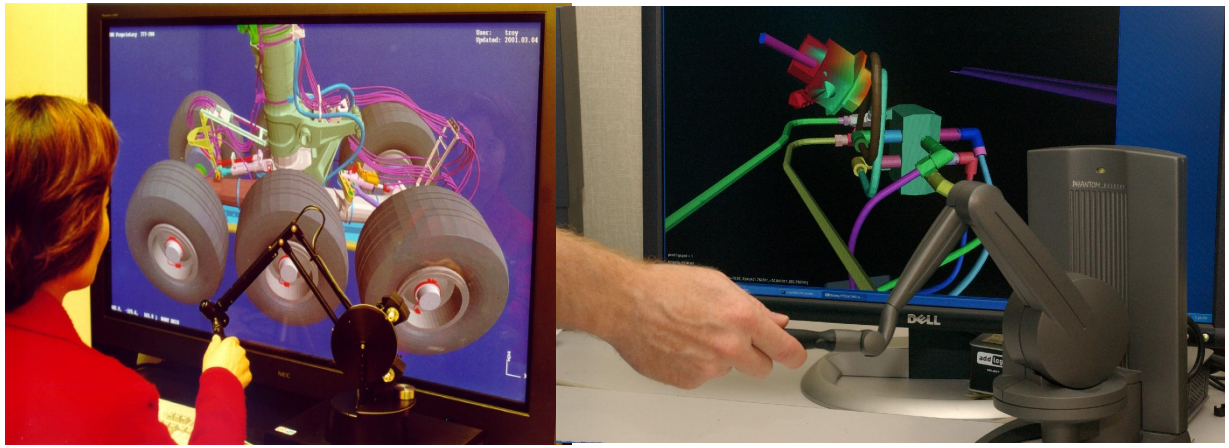
- **Outgrowth of the Boeing CIIN (CAD/CAM Integrated Information Network)**
  - Exchange data between Computervision (757) and Gerber IDS (767) drafting systems
  - Extended to Applicon and others
- **Walt Braithwaite and Mike Liewald proposed CIIN as a national data interchange format standard in the early 1980's**
- **CIIN became IGES (Initial Graphics Exchange Specification)**
  - Boeing added non-uniform rational b-spline curves and surfaces in the mid-to-late 1980's
- **Became standard interchange format across industry.**
- **Pre-cursor to STEP for interchange and archive.**

Augmented Reality

- Term coined by Boeing's Tom Caudell in 1990
- Applications evaluated (Caudell, David Mizell) in Boeing proved impractical
- Boeing continues to invest in Augmented Reality
- Little in production use.

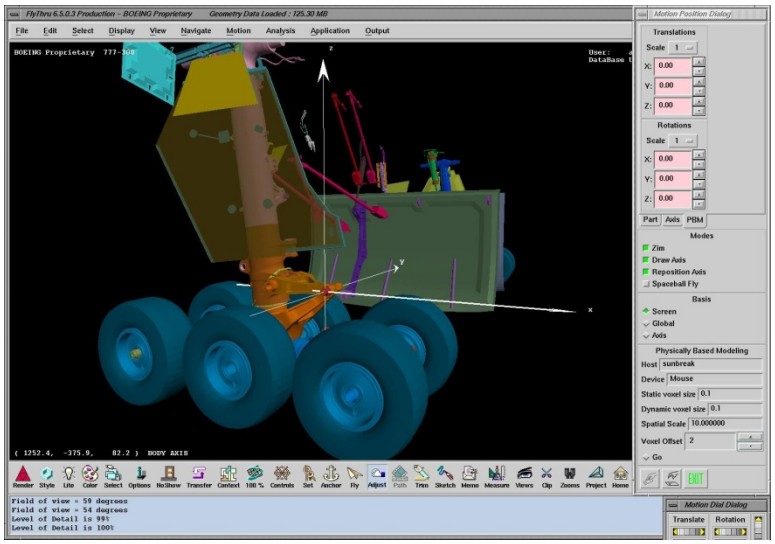
Voxmap PointShell (VPS)

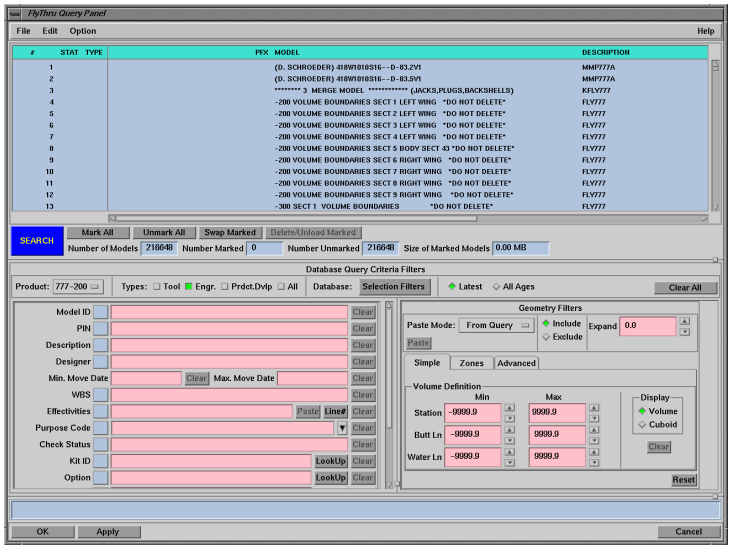
- **VPS supports real-time collision detection for haptics**
- **Speed is essential**
  - Visualization requires at least 10Hz
  - Touch requires at least 1000 Hz
- **Developed in 1997, by Bill McNeely, Jim Troy, Jeff Heisserman, Kevin Puterbaugh, Karel Zikan, et al.**
- **VPS met speed and accuracy requirements for Boeing maintenance removal tasks and interference checking**
- **Published at SIGGRAPH'99**



FlyThru

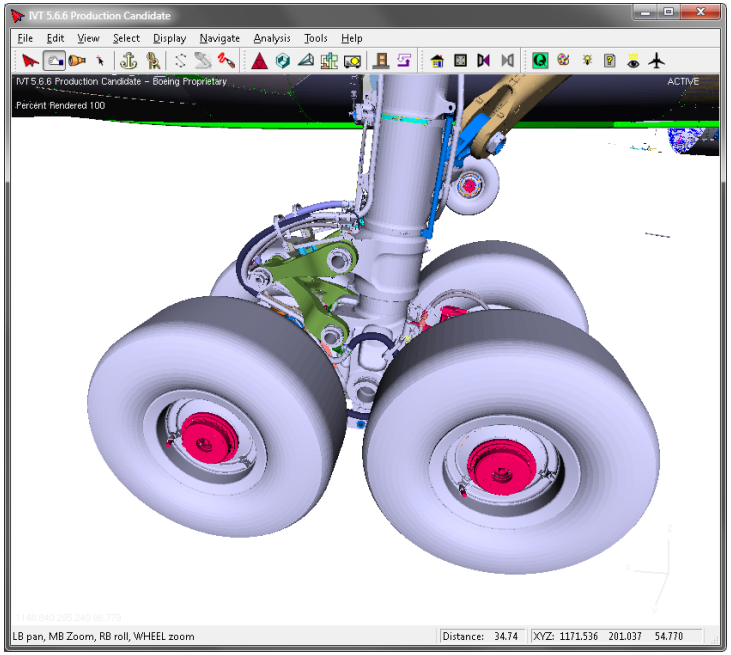
- Implemented in early 1990's to support design reviews for the 777 (Bob Abarbanel, Eric Brechner, Bill McNeely, et al.)
- Published by Abarbanel at SIGGRAPH'96
- Sucked all possible performance from SGI hardware
- Linked to geometry configuration management systems (EPIC/DIRRECT)
- Eventually implemented on IBM RS6000s
- Preferred visualization tool in BCA and some BDS

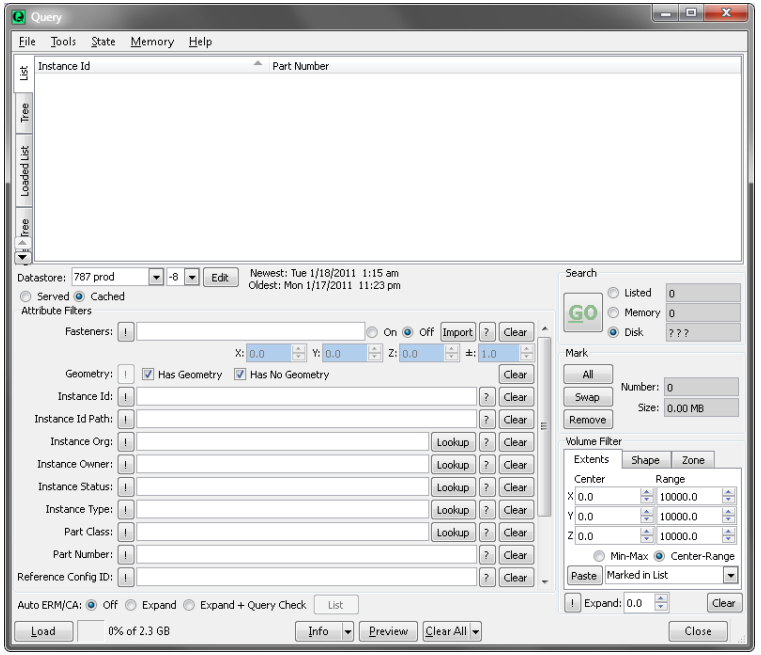




IVT

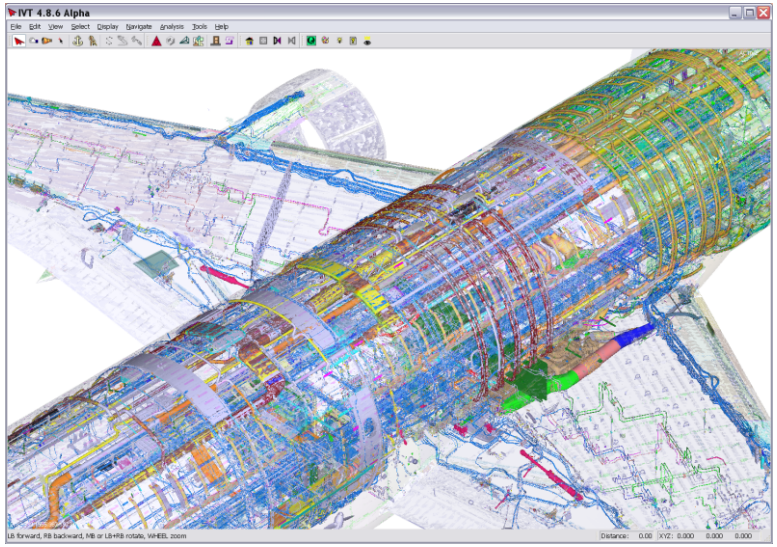
- **FlyThru transitioned to IVT (Interim -> Integration Visualization Tool) and PCs for the 787 in early 2000's (John Gass, Bill McGarry, Nik Prazak, Richard Clark, et al.)**
- **Linked to geometry configuration management systems (EPIC/DIRRECT, Enovia)**
- **20,000 registered users across BCA/BDS programs**

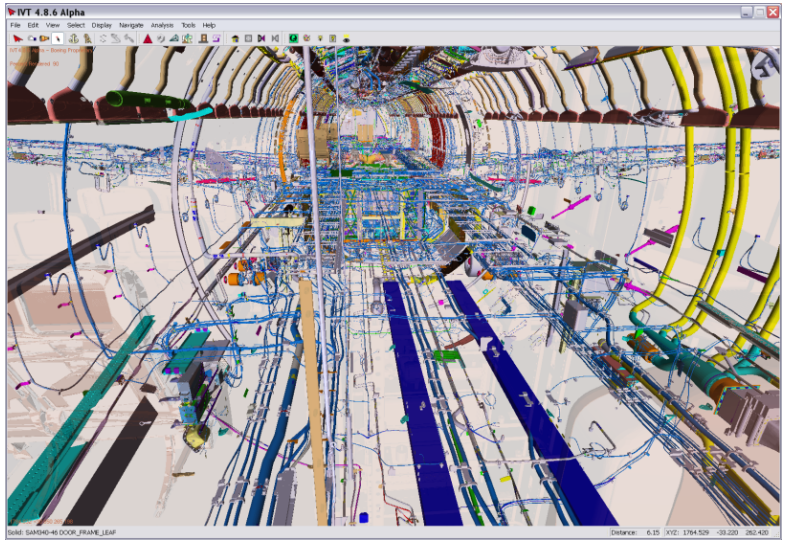




Massive Model Visualization

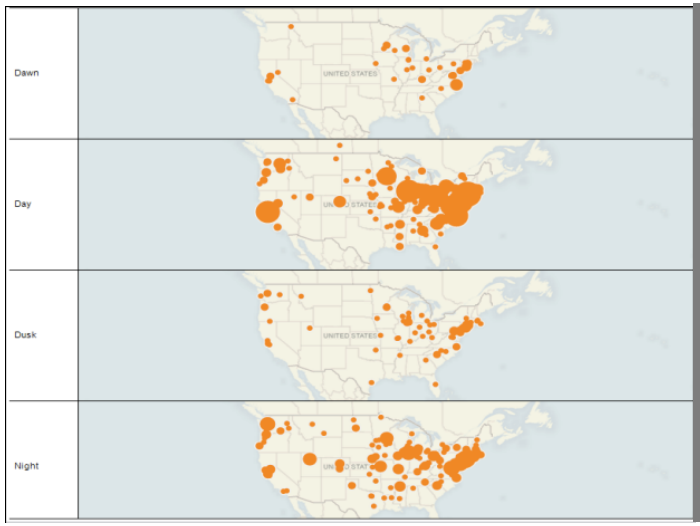
- **Dave Kasik started investigating ways to visualize entire aerospace products in 2004 in collaboration with organizations around the world**
- **Monograph ‘Real-Time Massive Model Rendering’ (Yoon, et al.) 2008**



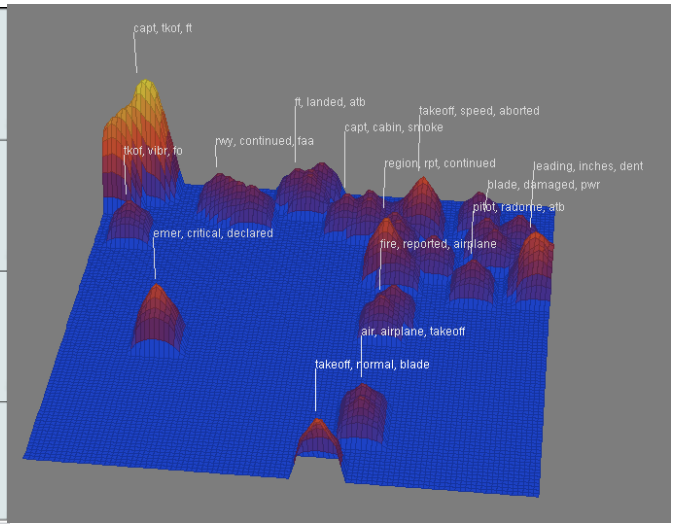


Visual Analytics

- All previous topics addressed geometry visualization
- Visual analytics, defined as the science of analytical reasoning facilitated by interactive visual interfaces, allows dynamic exploration of non-geometric data
- In 2005, Dave Kasik helped define the national research agenda (*Illuminating the Path*, free download from nvac.pnl.gov)
- Boeing is an early adopter and funding Canadian visual analytics research via offset programs
- Value: early investigations affected design and training for bird strikes, industrial safety, and BCA marketing



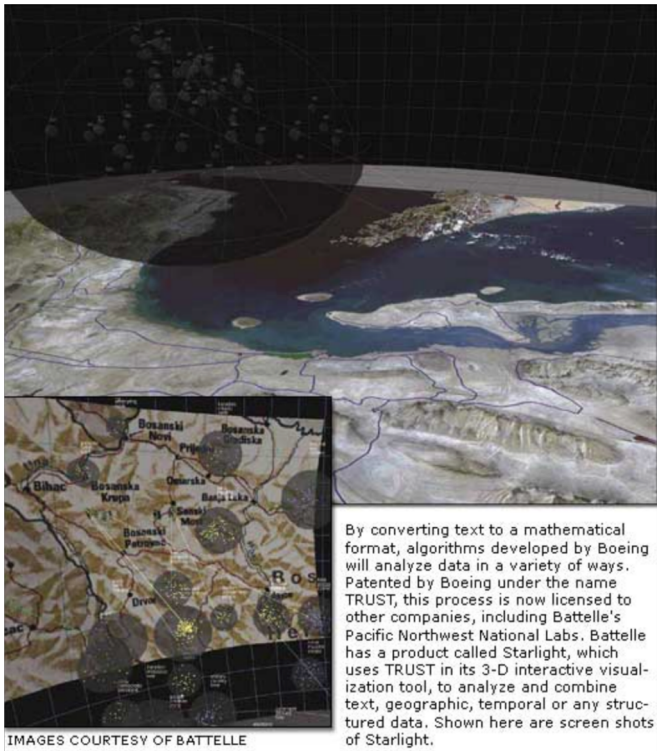
Output from Tableau



Output from INSPIRE

Text Analysis

- **Developed Simplified English Checker, 1990's**
- **Early text cluster analysis algorithm development (Anne Kao, TRUST).**
  - Licensed outside Boeing



IMAGES COURTESY OF BATTELLE

By converting text to a mathematical format, algorithms developed by Boeing will analyze data in a variety of ways. Patented by Boeing under the name TRUST, this process is now licensed to other companies, including Battelle's Pacific Northwest National Labs. Battelle has a product called Starlight, which uses TRUST in its 3-D interactive visualization tool, to analyze and combine text, geographic, temporal or any structured data. Shown here are screen shots of Starlight.

Lessons Learned

- **Boeing has a long tradition in computing**
- **Visualization has specific value for**
  - Highly complex products
  - Processing huge amounts of data
  - Widest path into brain
  - Complex system integration
  - Complex non-geometric data exploration and analysis tasks
  - Actual usage is highly unpredictable
- **Internal business model changed in early 1990's**
  - Boeing and other industrial companies dominated computing advances until mid-1990's
  - Decided to use commercial-off-the-shelf (COTS). Going alone too costly
  - Industry now influences computing indirectly
- **Fewer and fewer high-powered industrial computing technologists**

Moving Forward

Technology	Boeing start	Evolution
Computer graphics	1960	CAD (1980's) -> entertainment (late 1990's). Now everywhere.
Man-model	1964	2 internal systems until late 1990's. Mostly COTS today
B-spline surface rendering	1980	NURBS started dominating CAD geometry in mid-to-late 1990's
Fractals & animation	1980	Fractals became commonplace in mid-1990s
User interface management systems	1981	Precursor published in 1976. Became COTS in 1980's and fizzled in mid-1990's
NURBS Algorithms	1981-1982	NURBS started dominating CAD geometry in mid-to-late 1990's
IGES	1982	Dominant interchange format until late 1990's. Gradually giving way to STEP.
Augmented Reality	1990	Lots of academic research through late 2000's. Finally becoming 'real' with mobile maps.
FlyThru/IVT	1992	CAD vendors built/acquired similar systems in the early 2000's
VoxMap PointShell	1997	Collision detection embedded in many electronic games, surgical trainers, etc. Boeing has sold a few VPS licenses.
Massive model visualization	2004	Full production in Superviewer. One COTS package (Right Hemisphere), no CAD vendors.
Visual analytics	2004	Primary use in intelligence community. Early experimental use in Boeing.

Technology Transition Duration

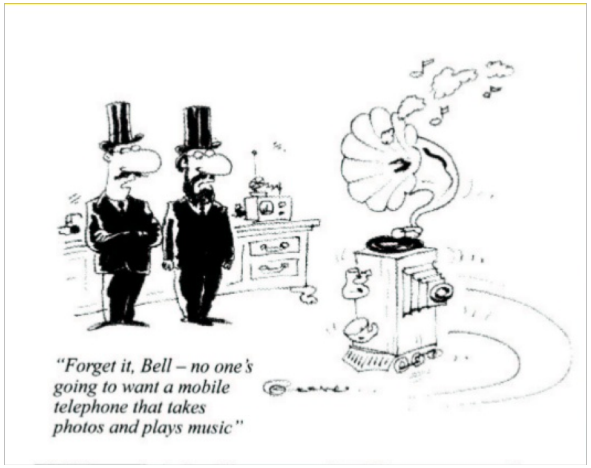
Technology	Boeing start	Evolution
Computer gra	20 yrs to CAD, 10 to games, 20 to commonplace	s) -> entertainment (late 1990's). Now .
Man-model	45 yrs to reasonable use 1964	2 internal systems until late 1990's. Mostly COTS today
B-spline surfa	20 yrs to commonplace 1980	NURBS started dominating CAD geometry in mid-to-late 1990's
Fractals & ani	15 yrs to commonplace 1980	Fractals became commonplace in mid-1990s
User interface	15 yrs to reasonable use, little use in 2011	ecursor published in 1976. Became COTS in 80's and fizzled in mid-1990's
NURBS Algori	20 yrs to commonplace 1981-1982	NURBS started dominating CAD geometry in mid-to-late 1990's
IGES	5 yrs to reasonable use, some use in 2011	ominant interchange format until late 1990's. adually giving way to STEP.
Augmented R	20 yrs to some use 1990	Lots of academic research through late 2000's. Finally becoming 'real' with mobile maps.
FlyThru/IVT	20 yrs to reasonable use 1992	CAD vendors built/acquired similar systems in the early 2000's
VoxMap Point	20 yrs to reasonable use 1997	Collision detection embedded in many electronic games, surgical trainers, etc. Boeing has sold a few VPS licenses.
Massive model visualizat	10 yrs to 5,000 users 04	Full production in Superviewer. One COTS package (Right Hemisphere), no CAD vendors.
Visual analytics	10 yrs to acceptance 04	Primary use in intelligence community. Early experimental use in Boeing.

Evolution Lessons

- **Boeing pushed the state-of-the-art to understand state-of-the-art products**
- **It takes a long time for state-of-the-art in aerospace and computing technology to become widespread**
  - Researchers must be aware of previous work

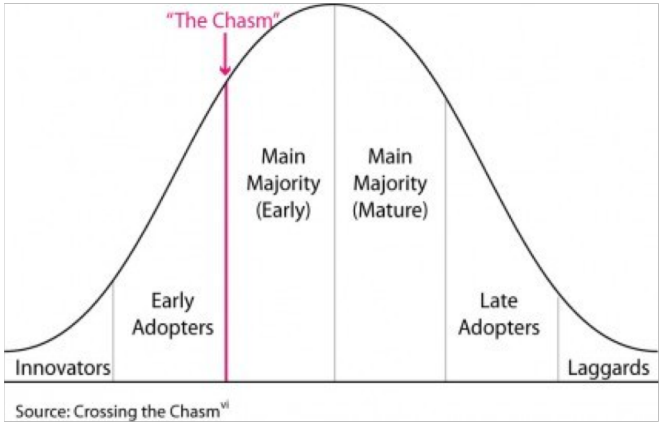
Why Discuss Technology Transition

- **What does success mean to you?**
  - Number of publications?
  - Student careers?
  - Having people use your ideas?
- **Personal motivation from others using your ideas**
  - Plagiarism sincerest form of flattery
- **Lots of success and failure**
  - Takes a long time



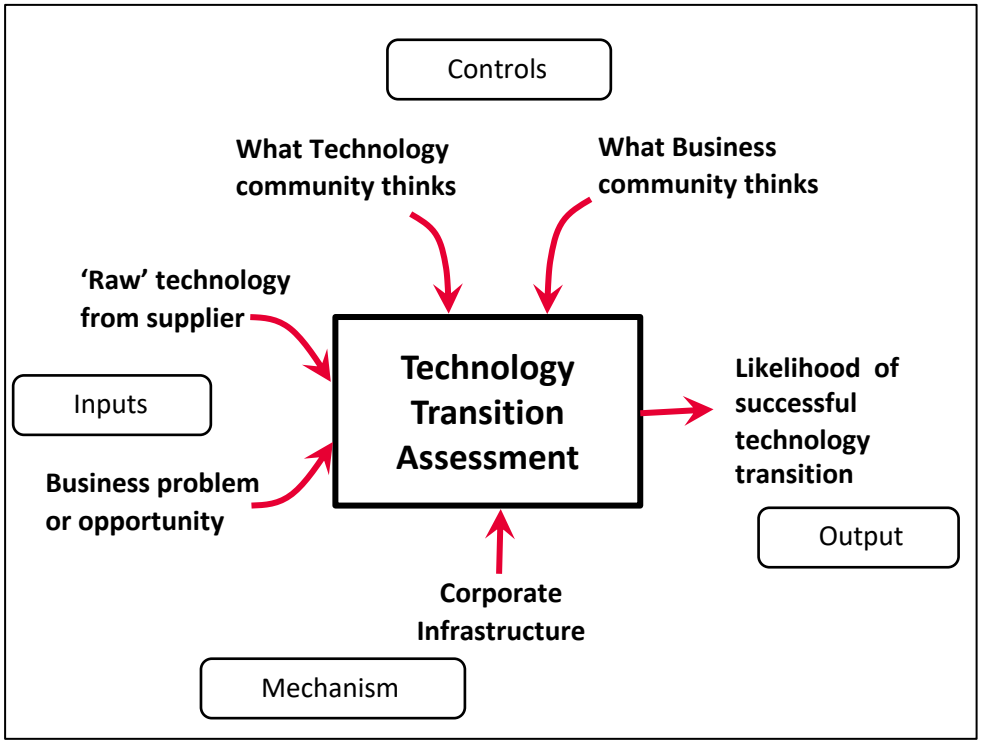
Background

- **What can researchers do to improve acceptance odds and shorten cycle?**
  - Hypothesis: Criteria can help tech researchers when applied early and throughout a project



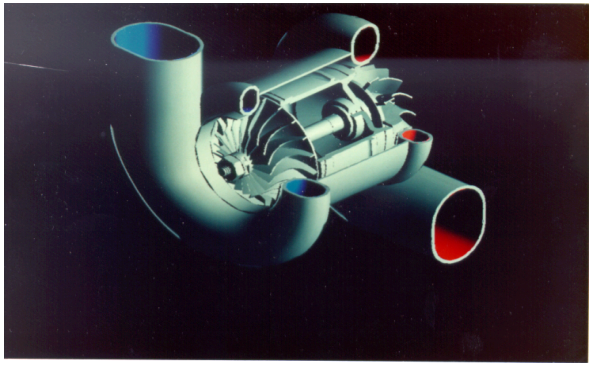
- **Ex post facto analysis of project success**

Transition Model

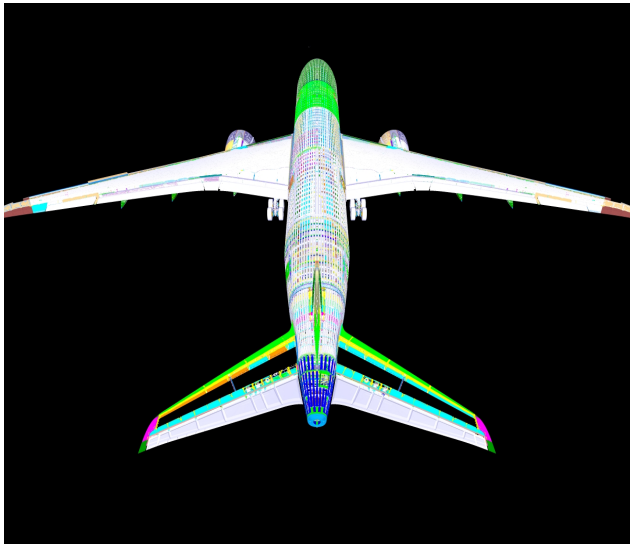


Boeing Examples

- **Not great**
  - Boeing CAD



- **Much better**
  - Massive model visualization



Transition Lessons

- Tech researchers tend to ignore transfer problems
- Even when problems are known, don't know all the 'gotchas'
- Criteria presented are direct result of authors' lessons learned

Summary

- **Lots of ways of validating innovation, including:**
  - Publish
  - Patent (use some caution: Fission-Fusion engine)
  - Prototype
- **Patience and confidence are virtues in tech transfer**
  - Many recipients will just say ‘not interested’
- **Have courage in your convictions**
- **Easier to seek forgiveness than ask permission**
- **Learn from both successes and failures**
- **Technology transition is a contact sport**
  - (credit: Tom Calvert, Simon Fraser University)
- **The last word: Scale kills**

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