Holistic Interdisciplinary Software Systems Engineering

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Introduction

- Presentation framework
  - software engineering of unmanned-aerial-vehicle system through modeling, simulation, visualization, and analysis
  - emphases
    - S software engineering: testing, evaluation, analysis
    - V virtual worlds and gaming
    - M mechatronics
    - P pedagogy
- Project serves as surrogate for many others and shows…

  … what I do

  … how I include students in teaching, research, and service

more details at shelby.wnmu.edu/uav and shelby.wnmu.edu/cmps450

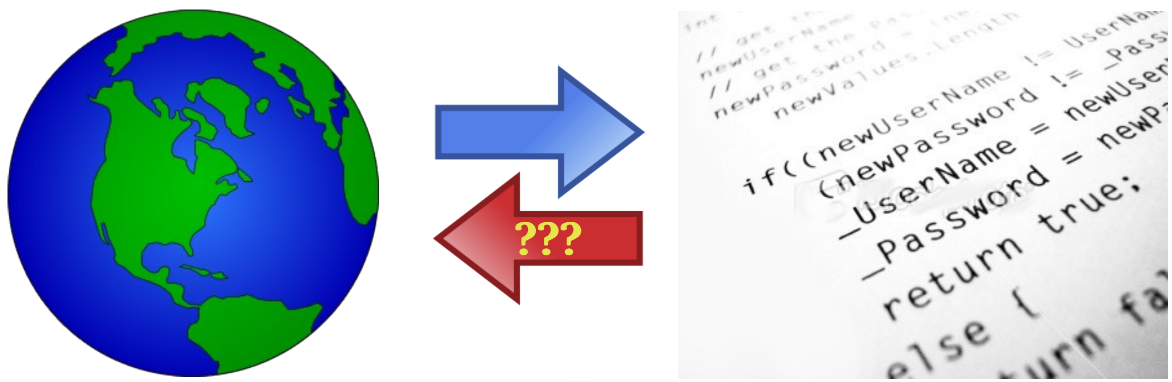
Background

- Army Future Combat Systems program
  - modeling and simulation of virtual worlds, agents, and systems of systems
  - serious software quality assurance

source: defenseindustrydaily.com

Pedagogical Framework • Goal

- *Bidirectional* correspondence between real world and model
  - does what it is supposed to do
  - does not do what it is not supposed to do



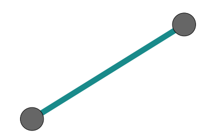
If builders built buildings the way programmers wrote programs, then the first woodpecker that came along would destroy civilization.

Harry Weinberger

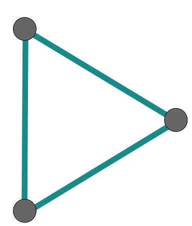
Pedagogical Framework • Approach

- Critical thinking
  - holistic, multi-perspective, systems view
    - *who*, *what*, *when*, *where*, *why*, *how*: W^{5}H
    - *data*, *information*, *knowledge*, *wisdom*: DIKW

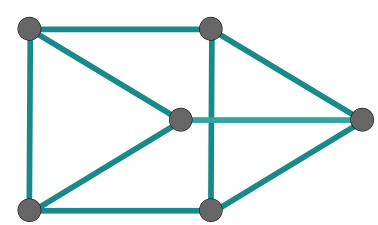
Data
no associativity



Information
associativity within one context

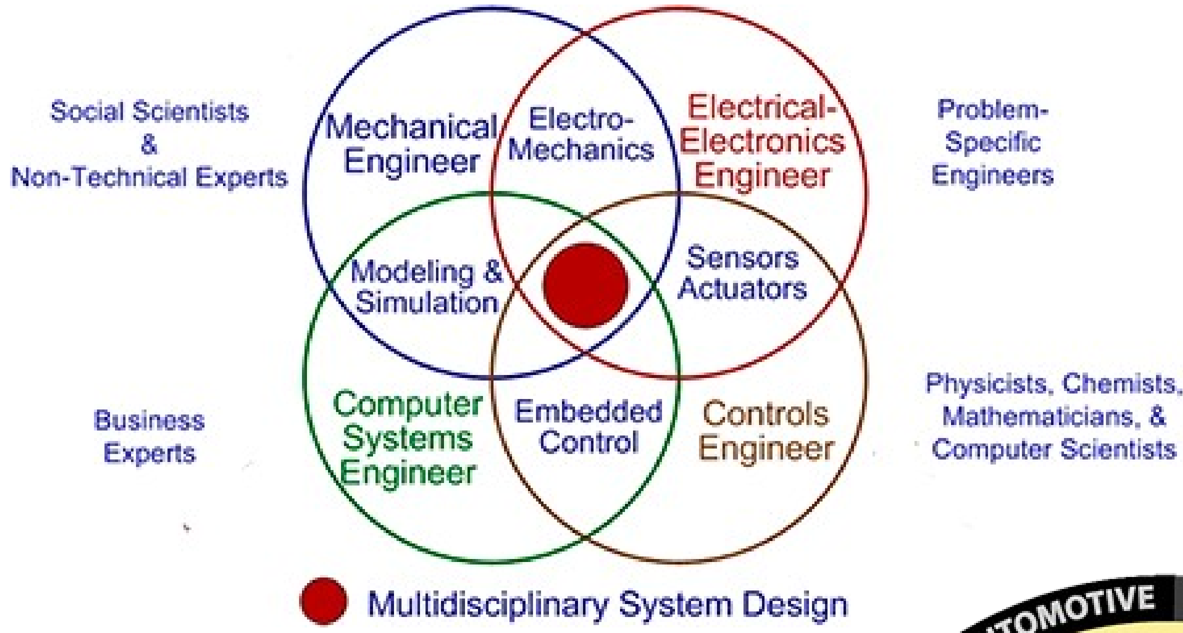


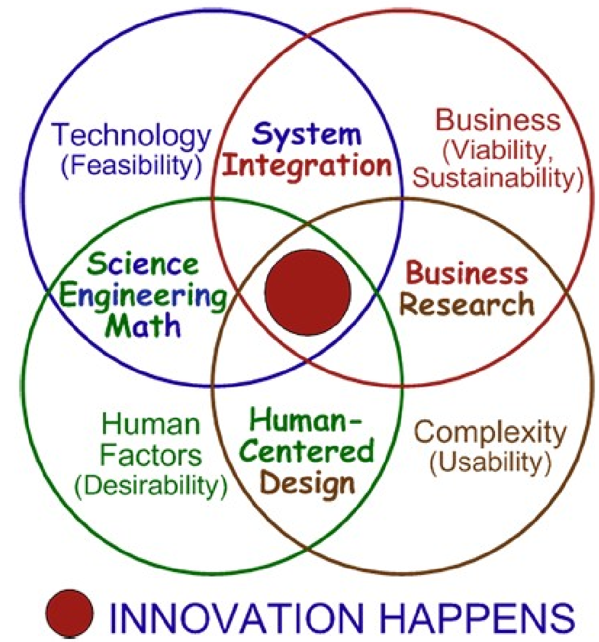
Knowledge
associativity within multiple contexts

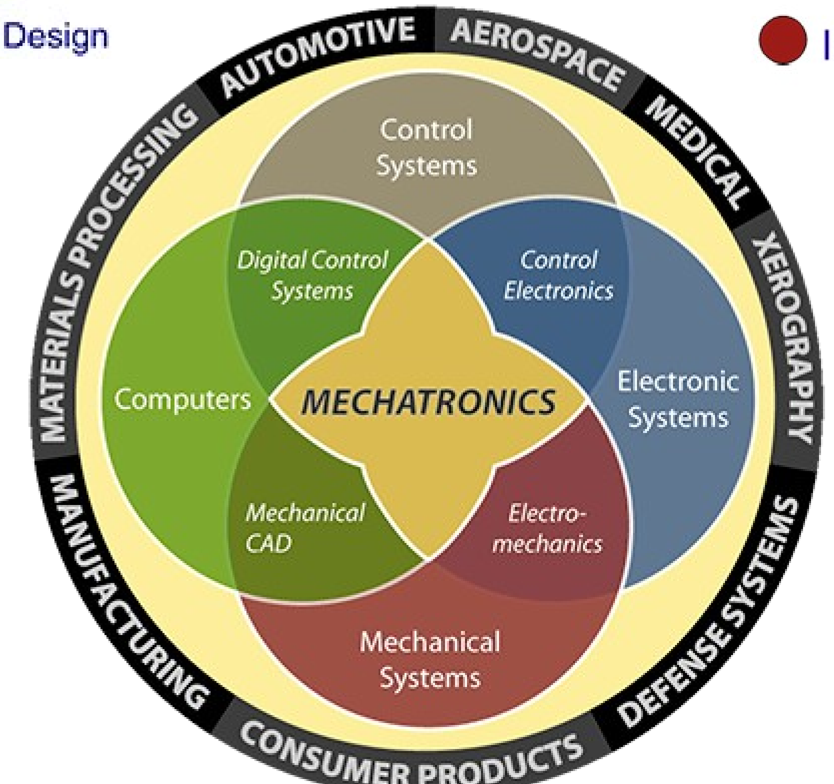


Wisdom
creation of generalized principles based on existing knowledge from different sources

Pedagogical Framework • Approach



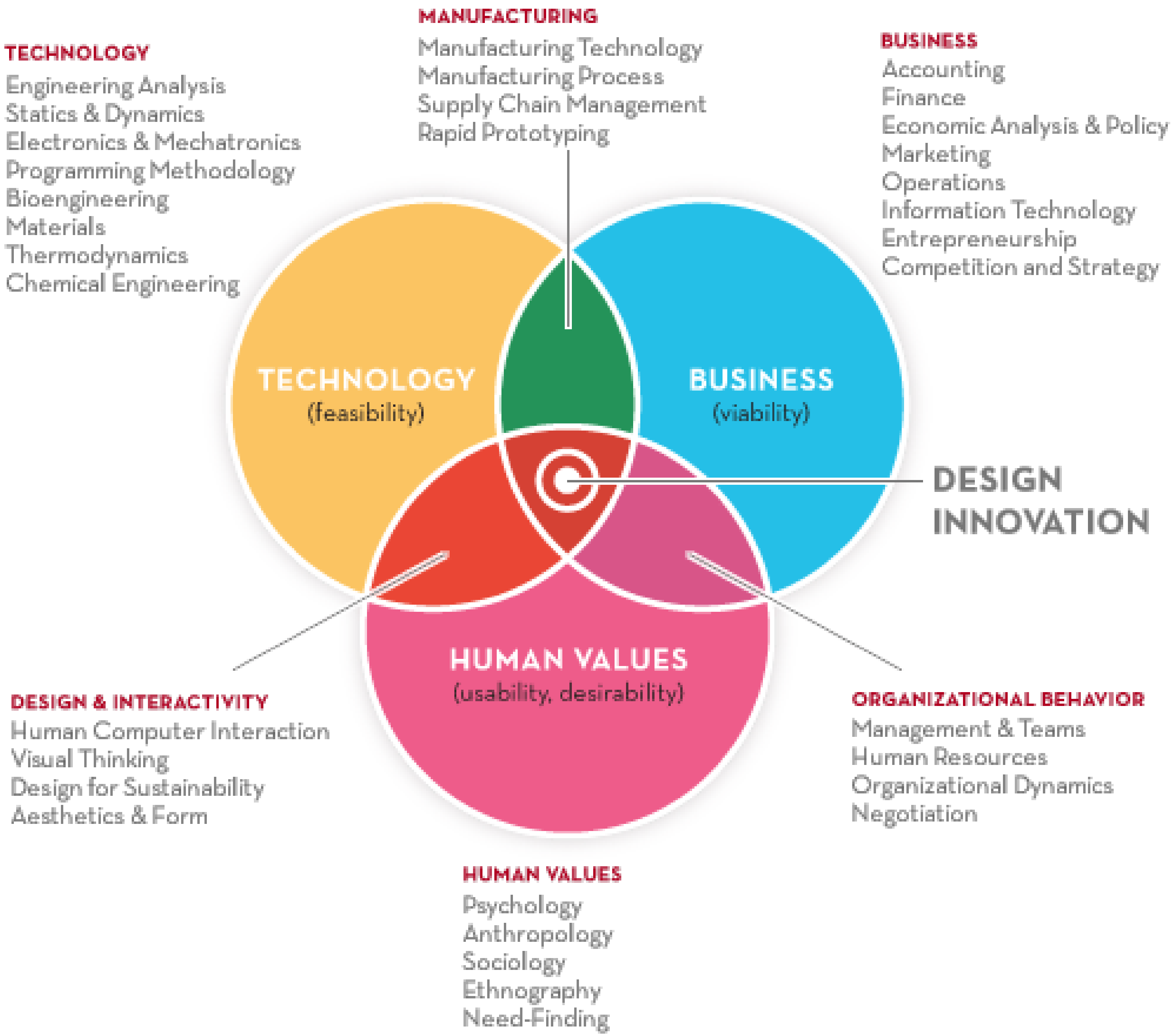




General aviation is an economic engine that pumps $150 billion in the U.S. economy each year and creates 1.3 million jobs.

AOPA Magazine, Sep. 2011

Pedagogical Framework • Approach

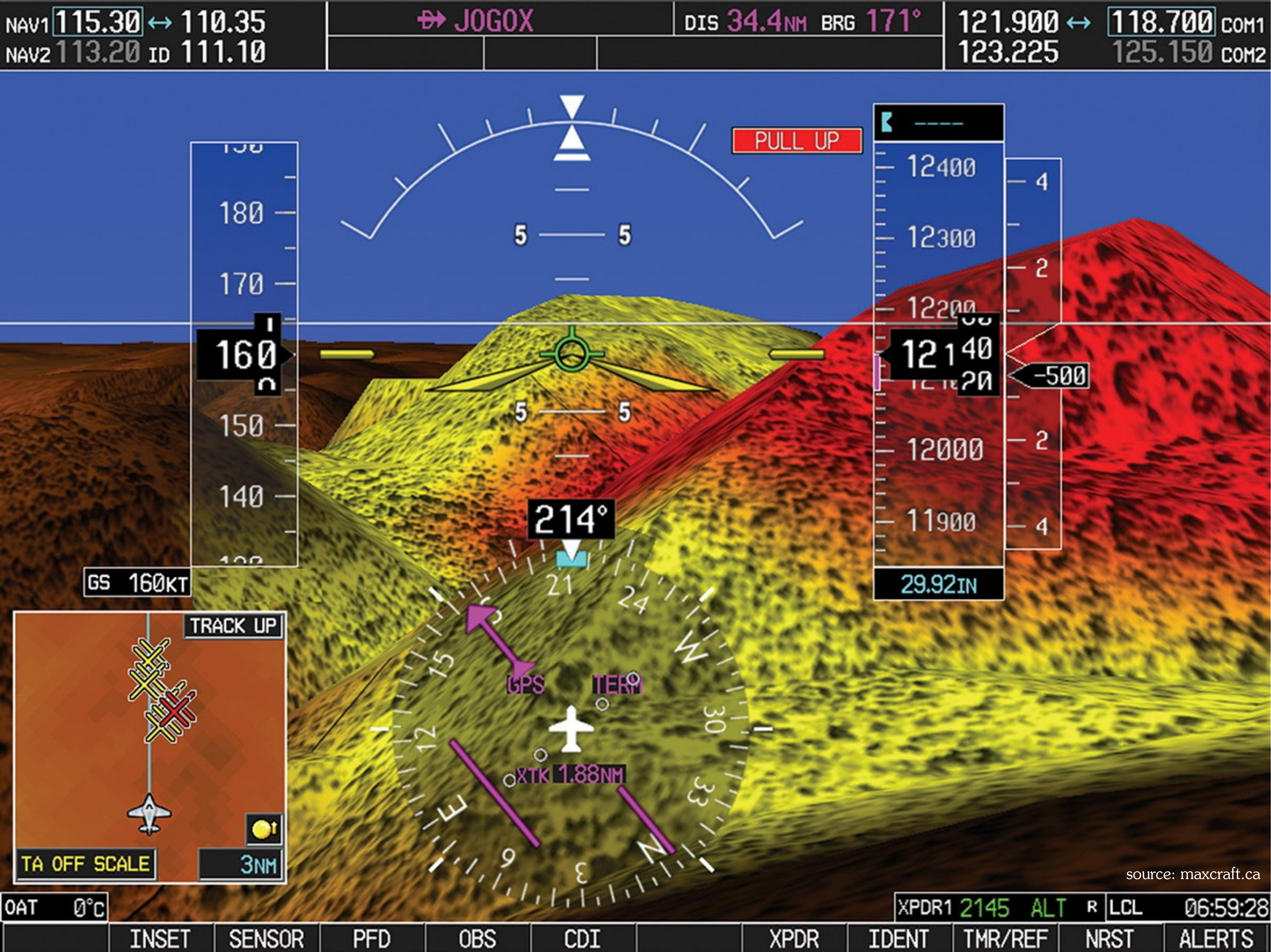


source: designinnovation.ie

Course Project

- Instrument-based flight simulator with human pilot

source: komanetskyaviation.com


NAV1 115.30 ↔ 110.35
NAV2 113.20 ID 111.10
JOGOX
DIS 34.4NM BRG 171°
121.900 ↔ 118.700 COM1
123.225 125.150 COM2
PULL UP
180
170
160
150
140
12400
12300
12200
12140
12000
11900
-500
29.92IN
214°
GS 160KT
TRACK UP
GPS
TERM
XTK 1.88NM
TA OFF SCALE
3NM
source: maxcraft.ca
OAT 0°C
XPDR1 2145 ALT R LCL 06:59:28
INSET
SENSOR
PFD
OBS
CDI
XPDR
IDENT
TMR/REF
NRST
ALERTS

Data Acquisition • Virtual

source: x-plane.com

Data Acquisition • Actual

- Data collection from flight-test regimen

Cessna 172XP

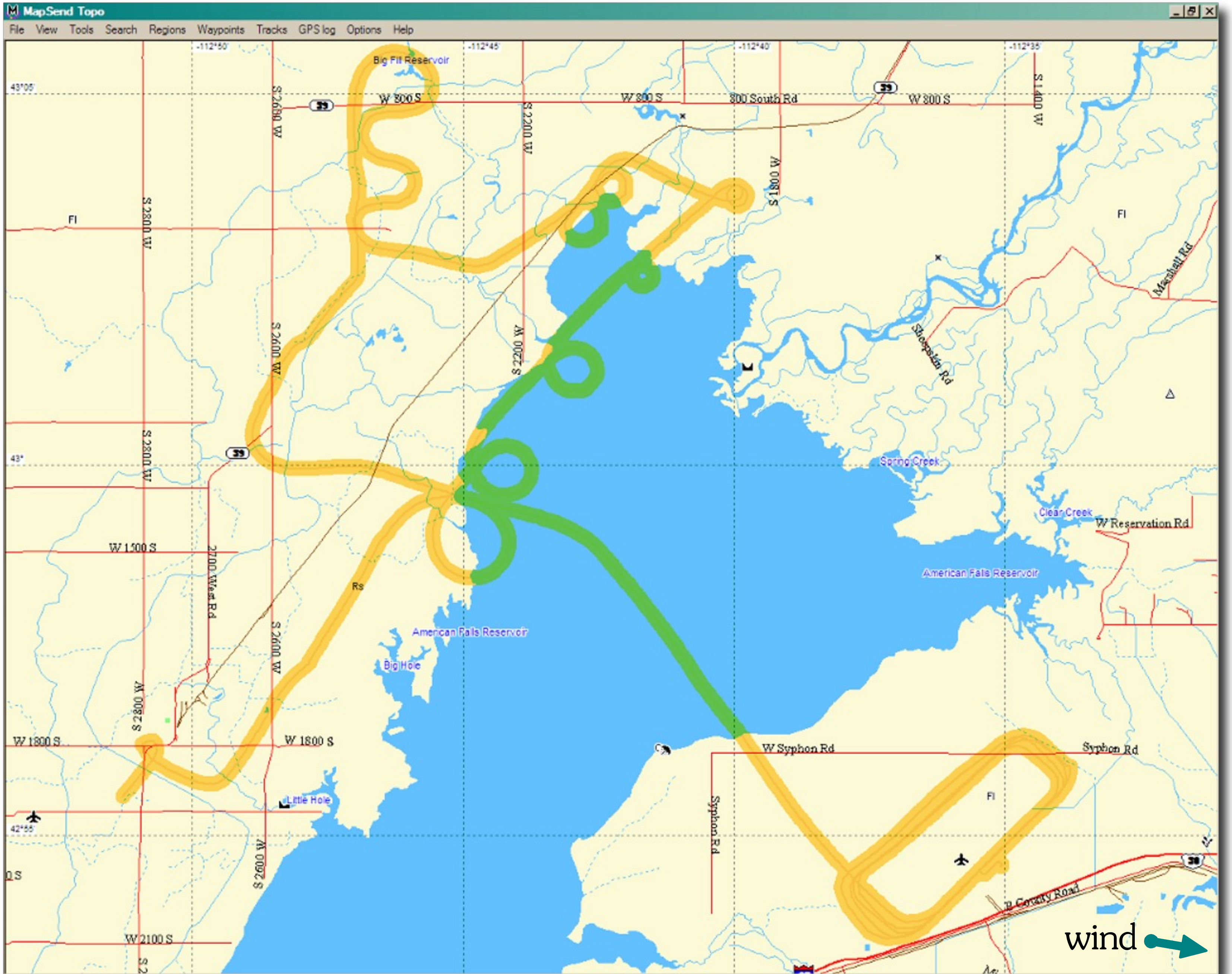
Robinson R22

see shelby.wnmu.edu/logger and shelby.wnmu.edu/yellowstone

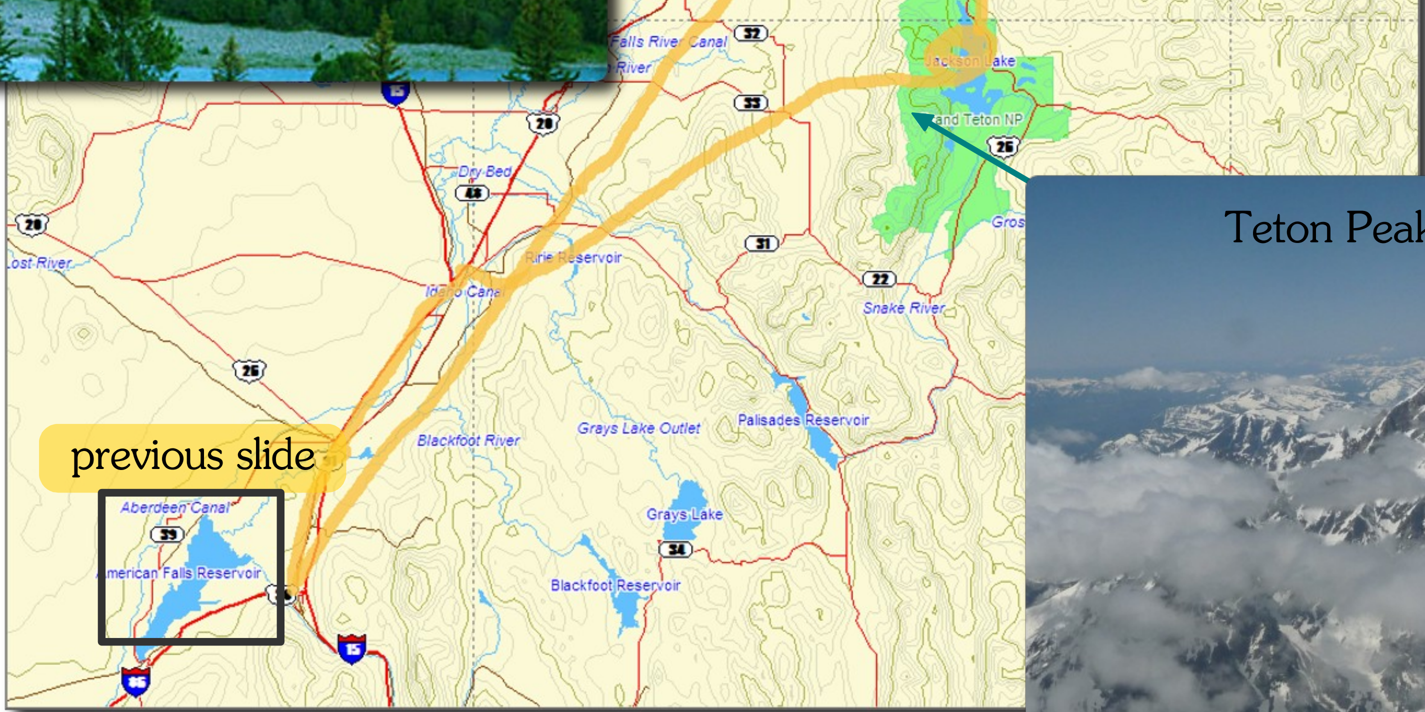
S V M P

source (right): everettaero.com

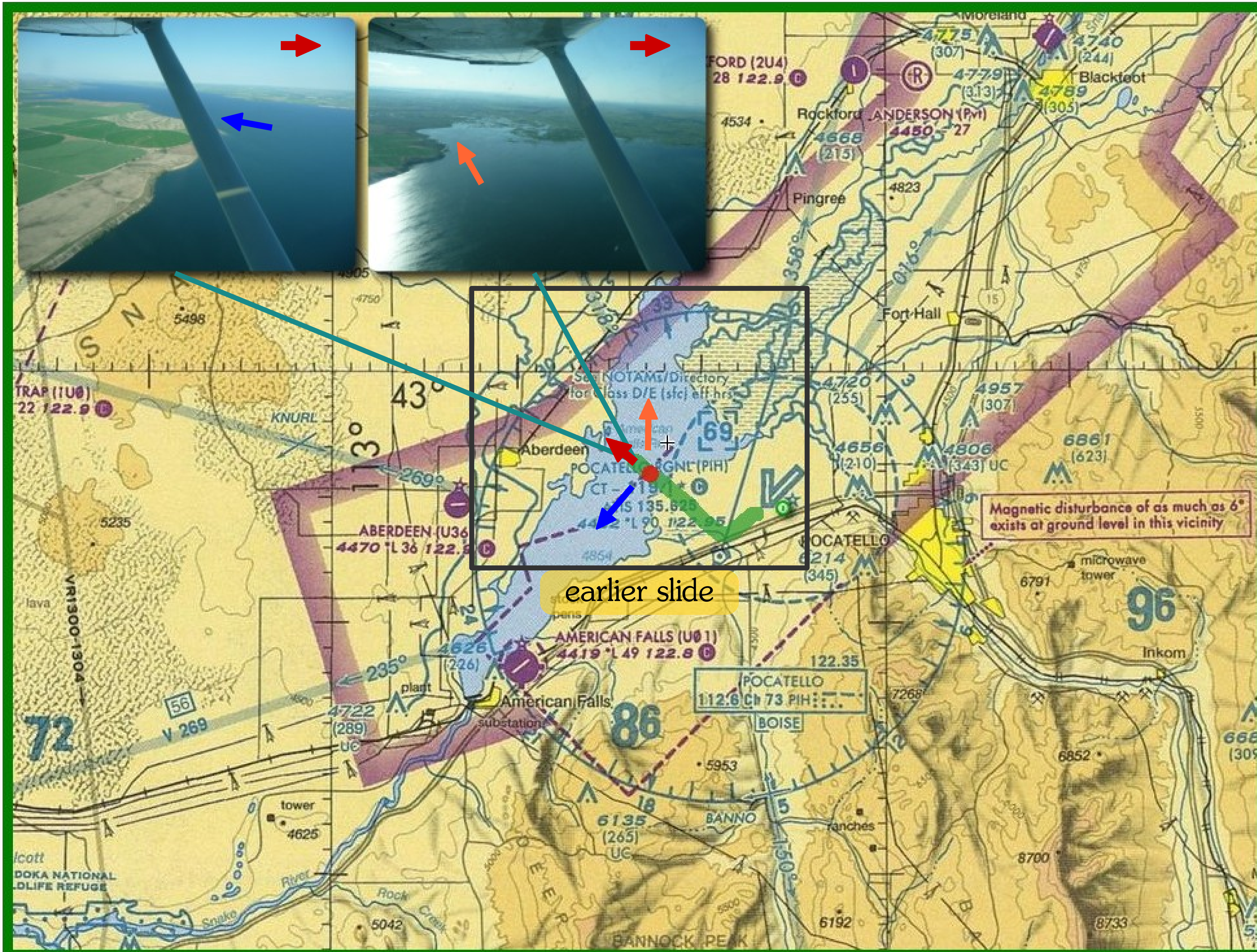
Data Acquisition • Actual



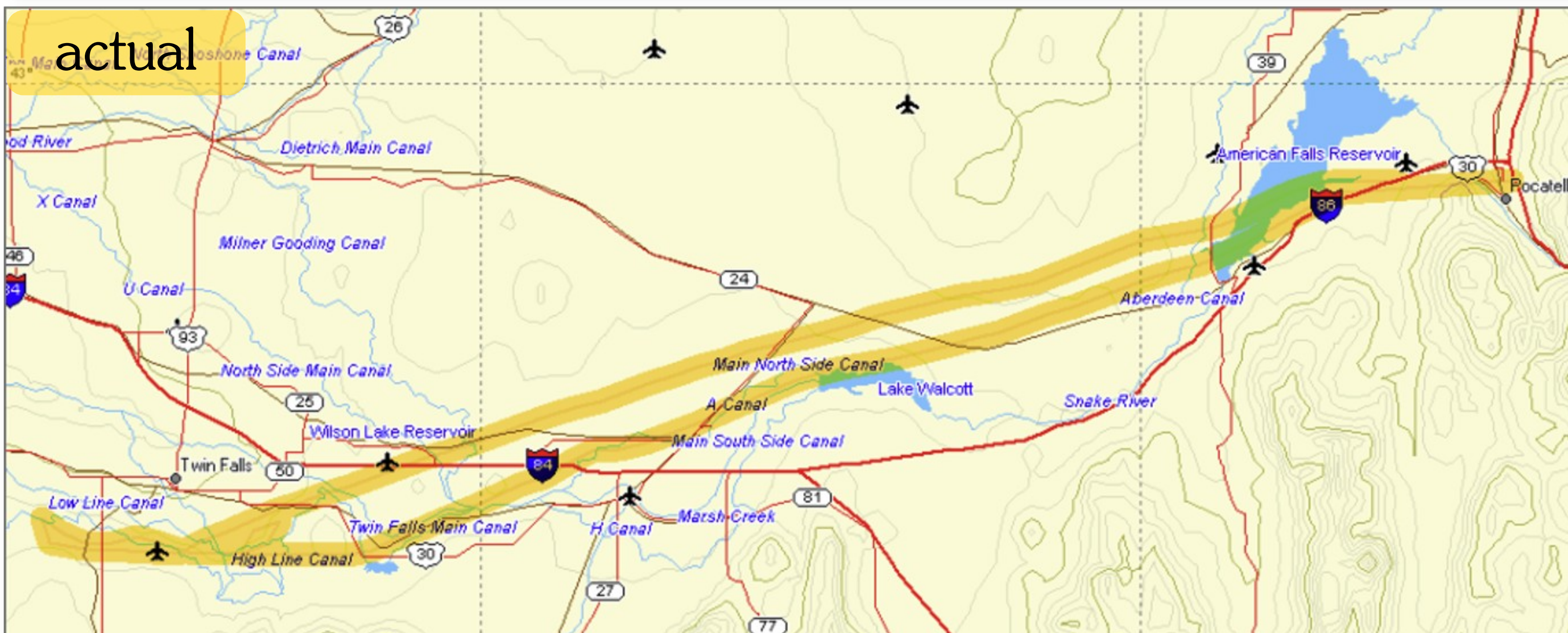
Data Acquisition • Actual



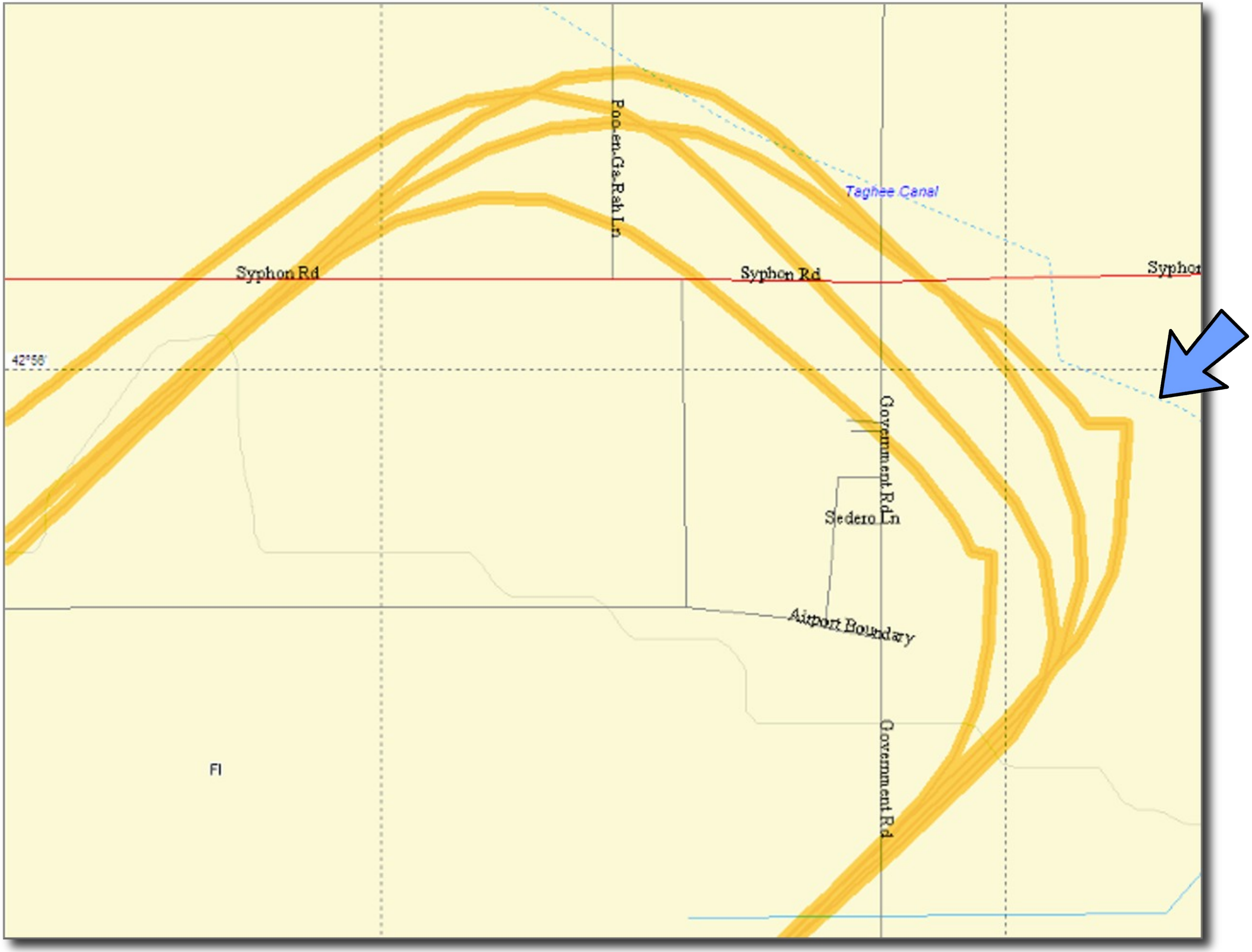
source (left): destination360.com


earlier slide
Aberdeen
American Falls
Pocatello
Blackfoot
Fort Hall
Pingree
Rockford
Inkom
Moreland
AMERICAN FALLS (U01)
ABERDEEN (U36)
ANDERSON (Pvt)
POCATELLO
112.6 Ch 73 PIH
BOISE
Magnetic disturbance of as much as 6° exists at ground level in this vicinity
See NOTAMS/Directory for Class D/E (sfc) eff hrs
KNURL
V 269
microwave tower
tower
plant
substation
ranches
BANNOCK PEAK
BANNO
lava
Snake River
Rock Creek


expected
previous slide
43°
114°
113°
51
54
72
86
91
238° 85nm

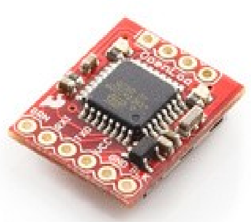

actual
Dietrich Main Canal
X Canal
Milner Gooding Canal
U Canal
North Side Main Canal
Wilson Lake Reservoir
Twin Falls
Low Line Canal
Twin Falls Main Canal
High Line Canal
H Canal
Marsh Creek
Main North Side Canal
A Canal
Main South Side Canal
Lake Walcott
Snake River
Aberdeen Canal
American Falls Reservoir
Pocatello
26
39
24
93
25
50
84
30
27
77
81
86

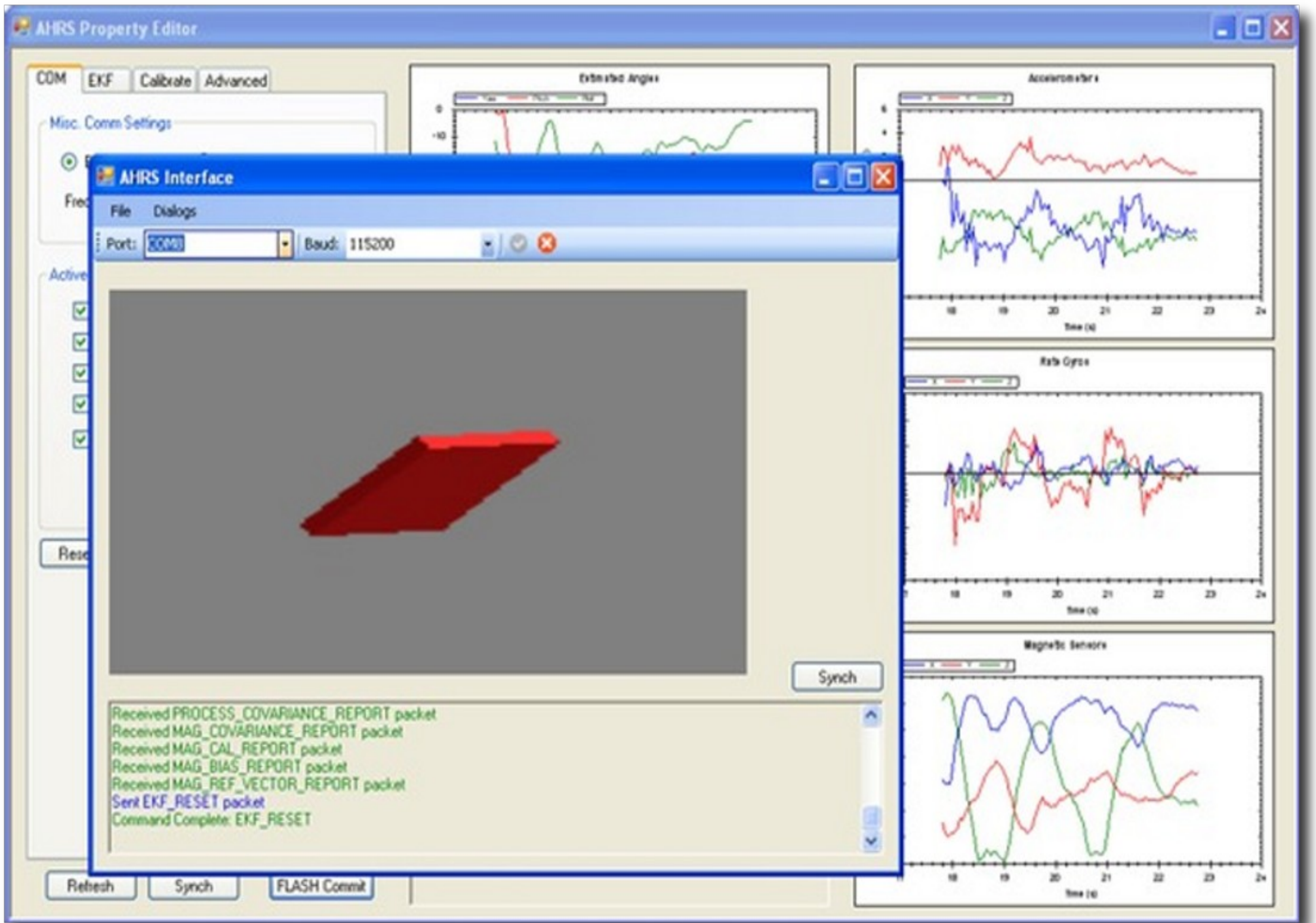
Data Acquisition • Actual



Data Acquisition • Actual

- Repurposeable logged sensors with innovative applications



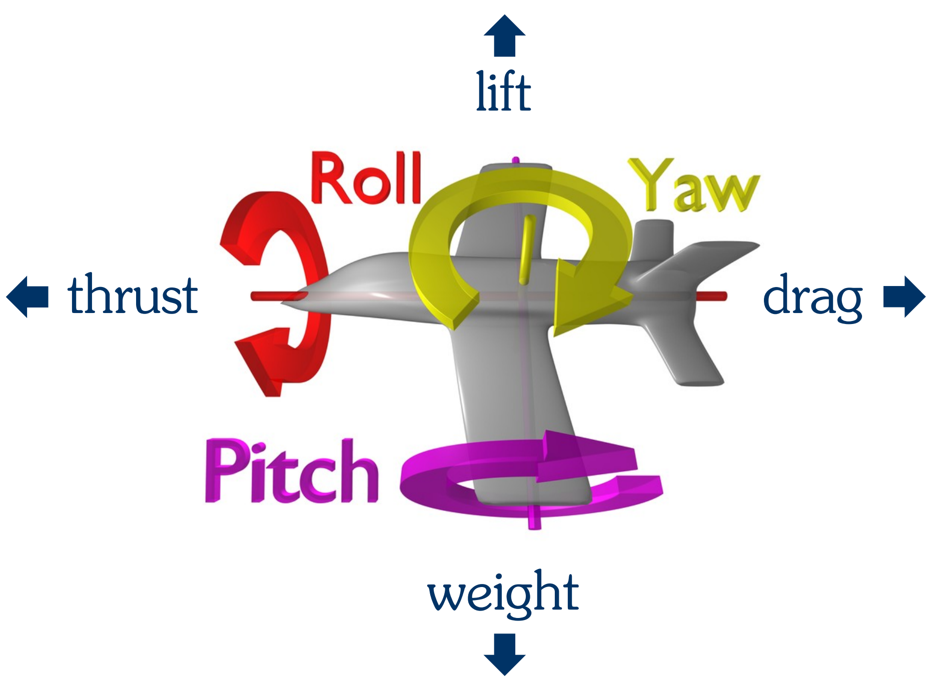


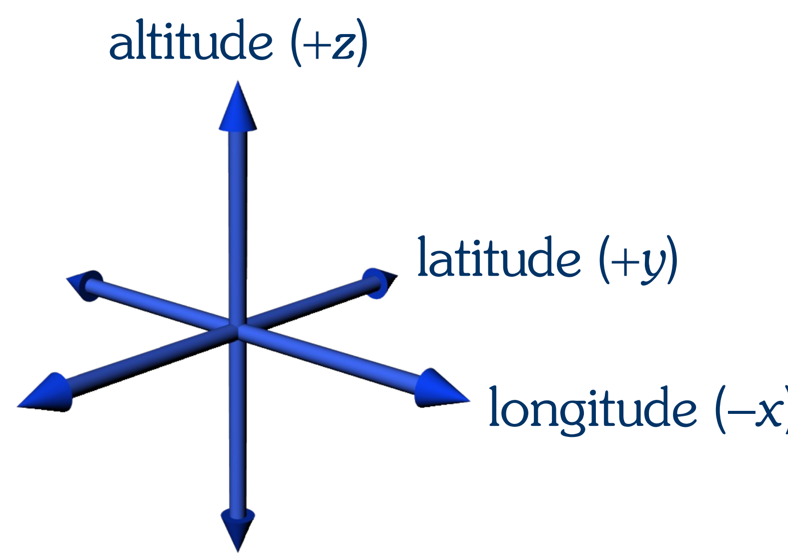
Game Engine

- Flight-dynamics model, instrumentation, graphics engine, etc.
- Student-friendly API and Javadoc with no magic

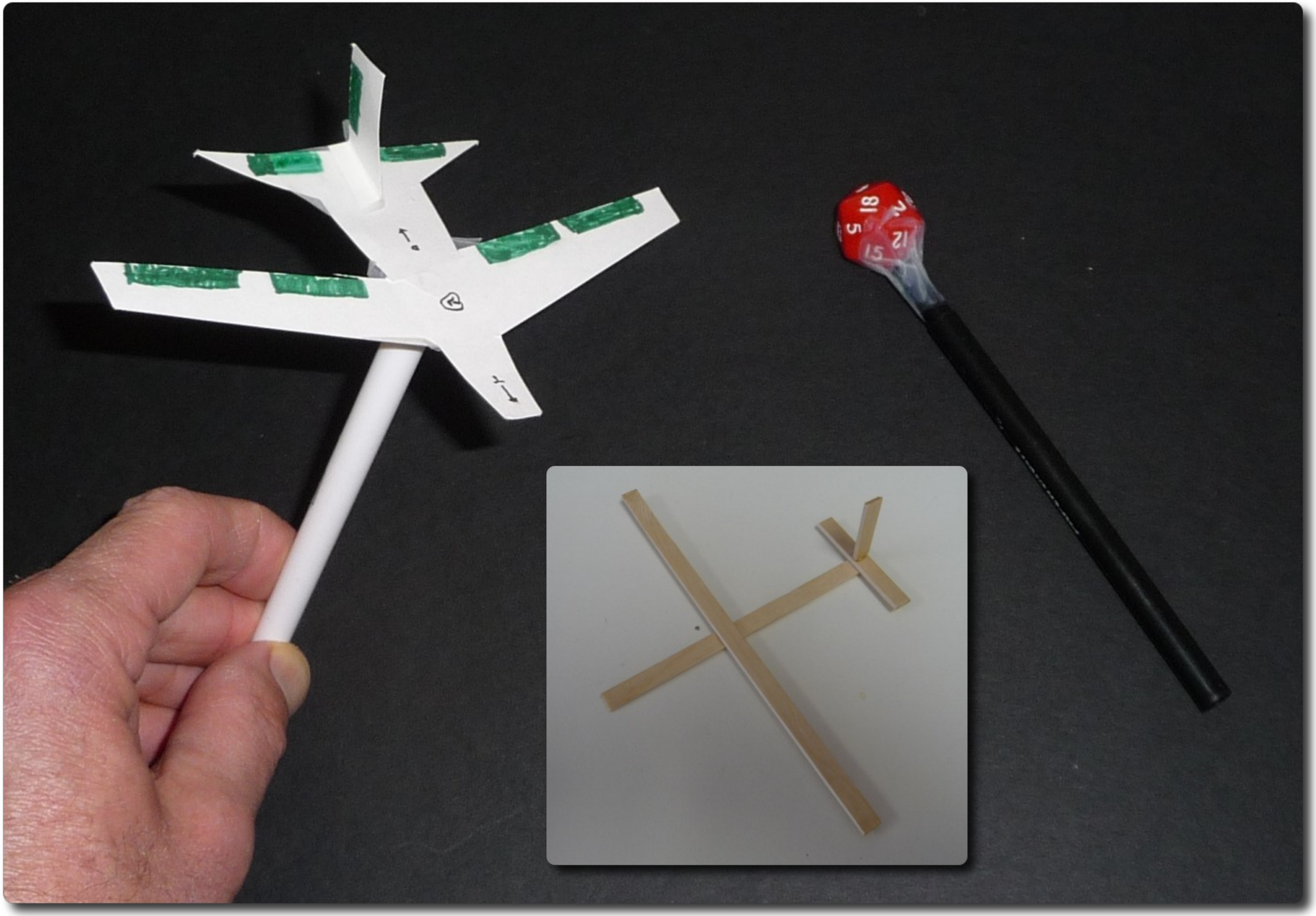
Conceptualization and Analysis

- Familiarization with subject matter
  - coordinate systems and units
  - input, processing, output
  - interrelationships, cause and effect, correlations
- Software errors are *our* fault in understanding and thinking



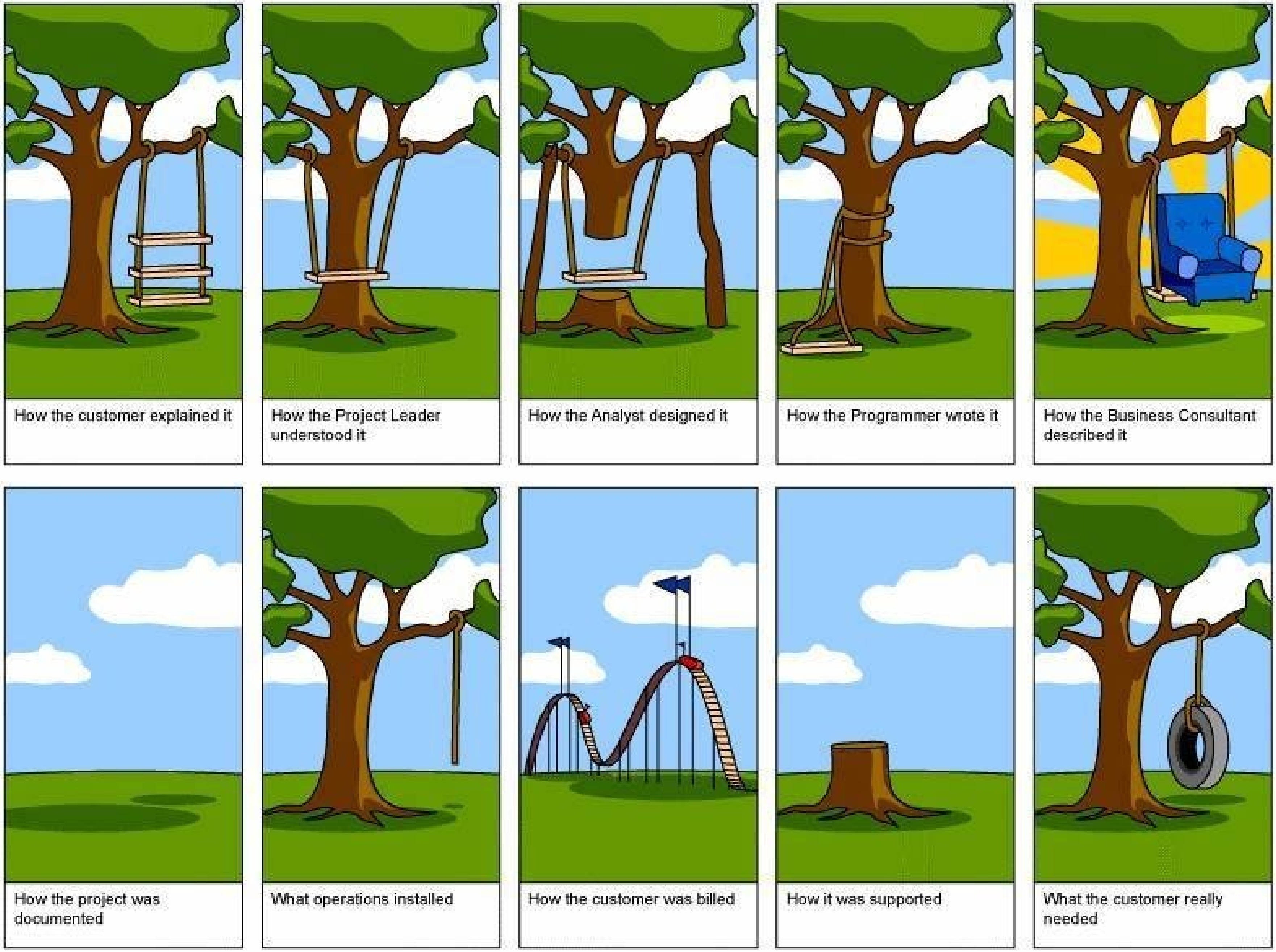


Conceptualization and Analysis



Conceptualization and Analysis

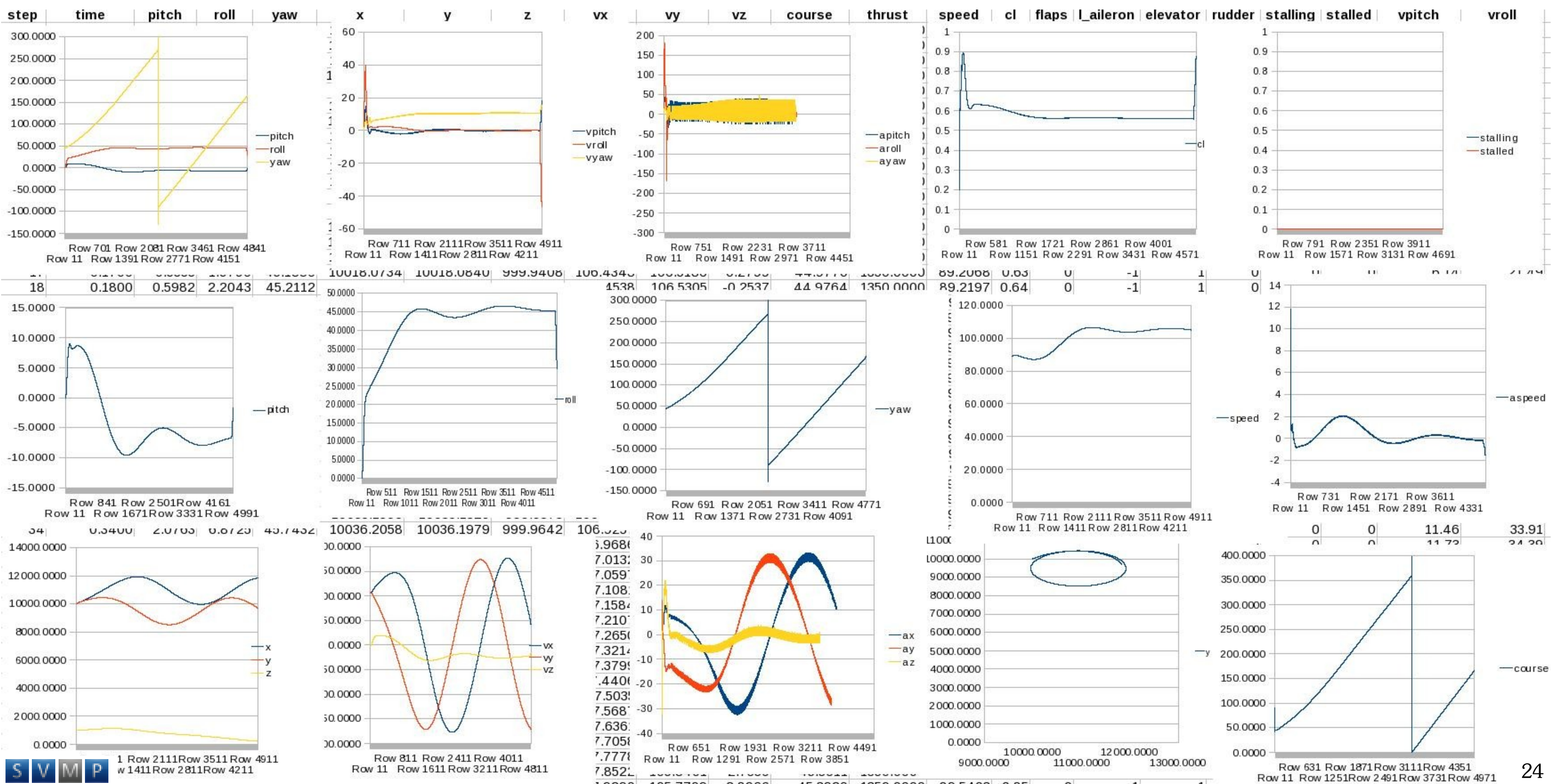
Conceptualization and Analysis



source: crossthebreeze.com

Analysis • Black-Box Programmatic

- Investigative reasoning by trial and error, kid-style
  - input: programmatic manipulation of flight-control surfaces
  - output: change in 30+ flight parameters in log



Analysis • Black-Box Interactive

- Learning to fly by trial and error given list of basic maneuvers

anybody can learn to fly if you think like a kid again!

Analysis • Black-Box Interactive

- Cross-references with reality
  - I flew, logged, videorecorded, and compared solutions with…

    … this simulator

    … X-Plane simulator

    … real plane

45° right turn

shelby.wnmu.edu/research/project-flying/right45.mov

stall

shelby.wnmu.edu/research/project-flying/stall.mov

landing

shelby.wnmu.edu/research/project-flying/landing.mov

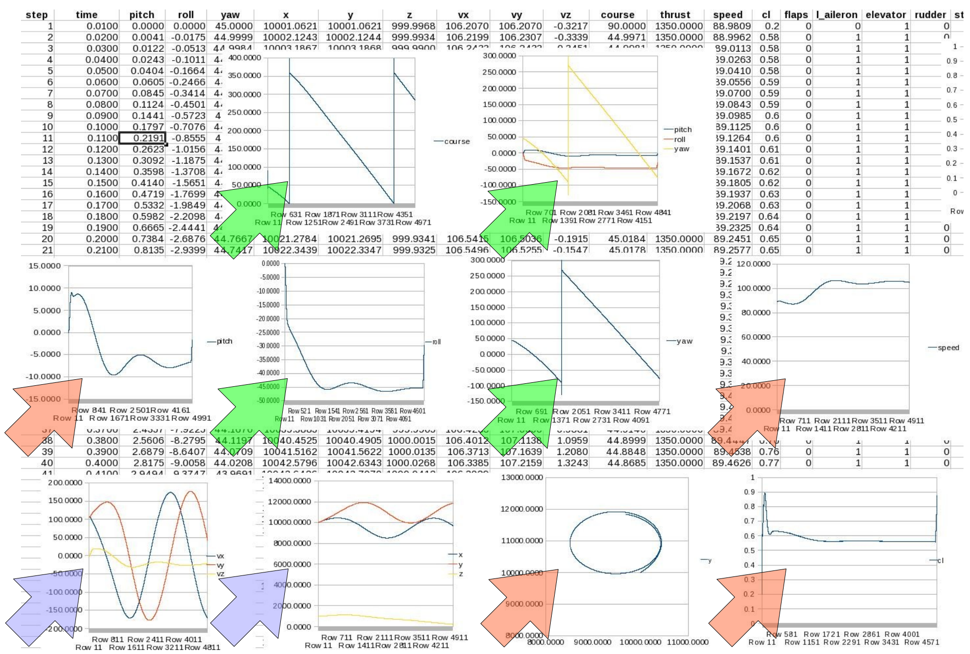
SVMP

Analysis • Black-Box Interactive

Analysis • Formal Experiments

- Controlled experiments via scientific method
  - claim/hypothesis: *turning right is "harder" than turning left*

left | right



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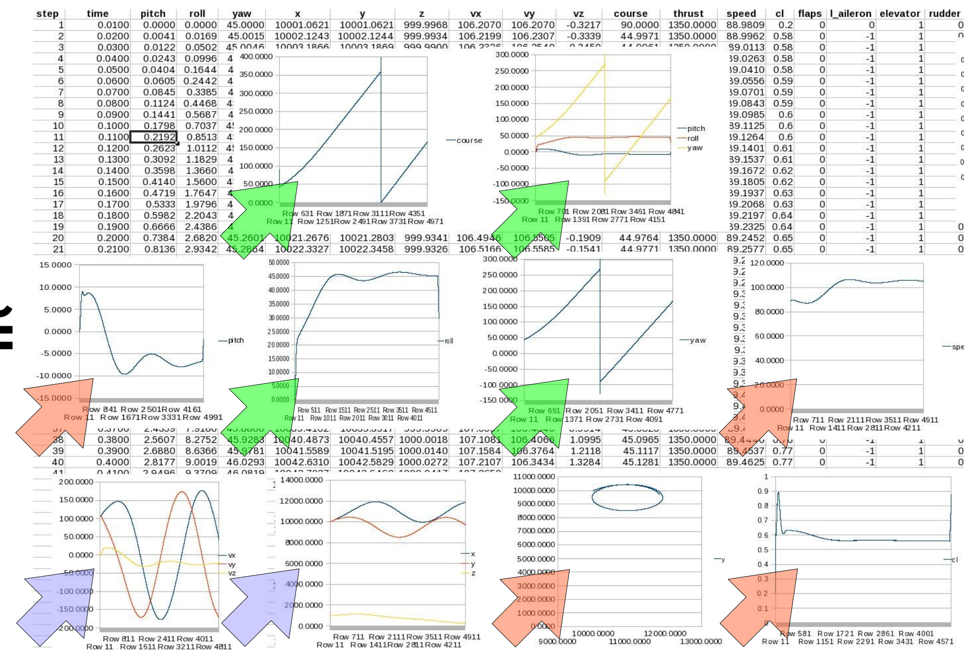
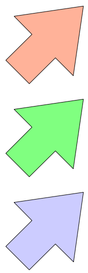


(scaling issue in plot)

key: 
identical

mirror image

swapped

Conclusion: no difference at all

Synthesis • Instrumentation

- Student-ranked subset of instruments to implement
  - required holistic understanding of how they work…

    … as instruments in real flight and model/simulation

    … as code via API

airspeed indicator

altimeter

clock

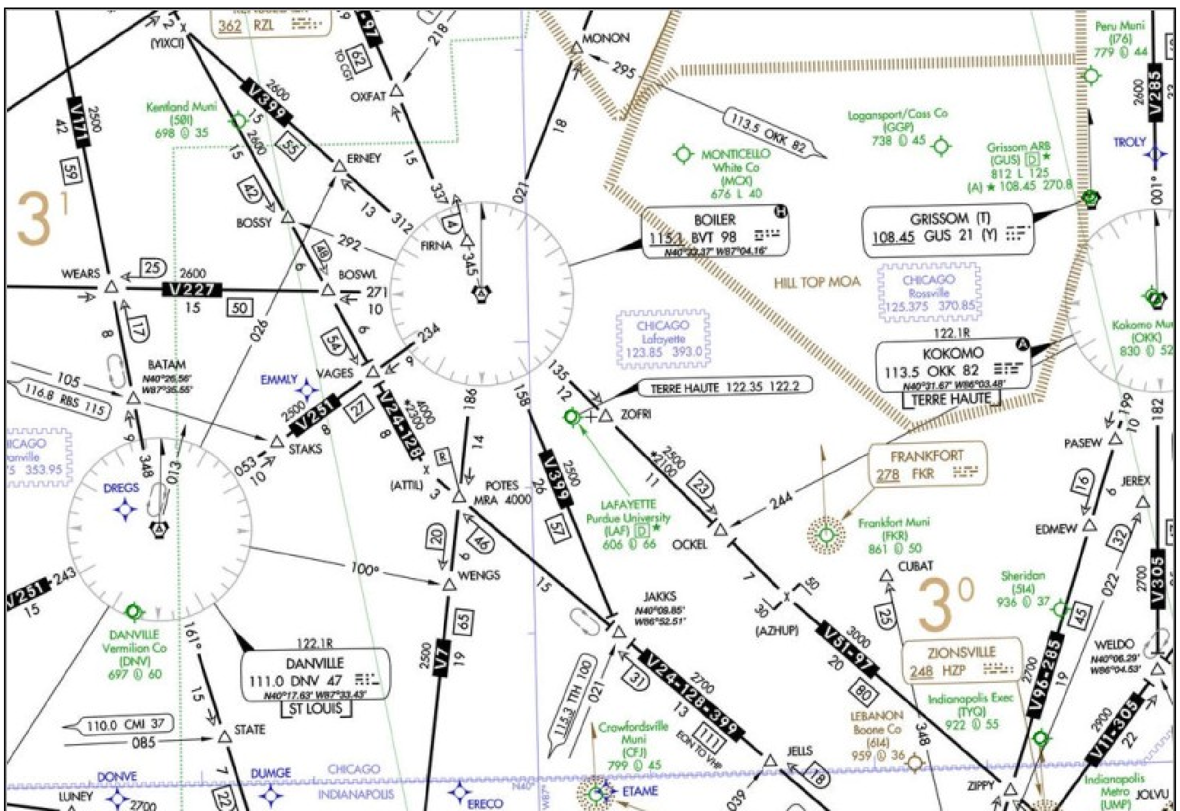
turn coordinator

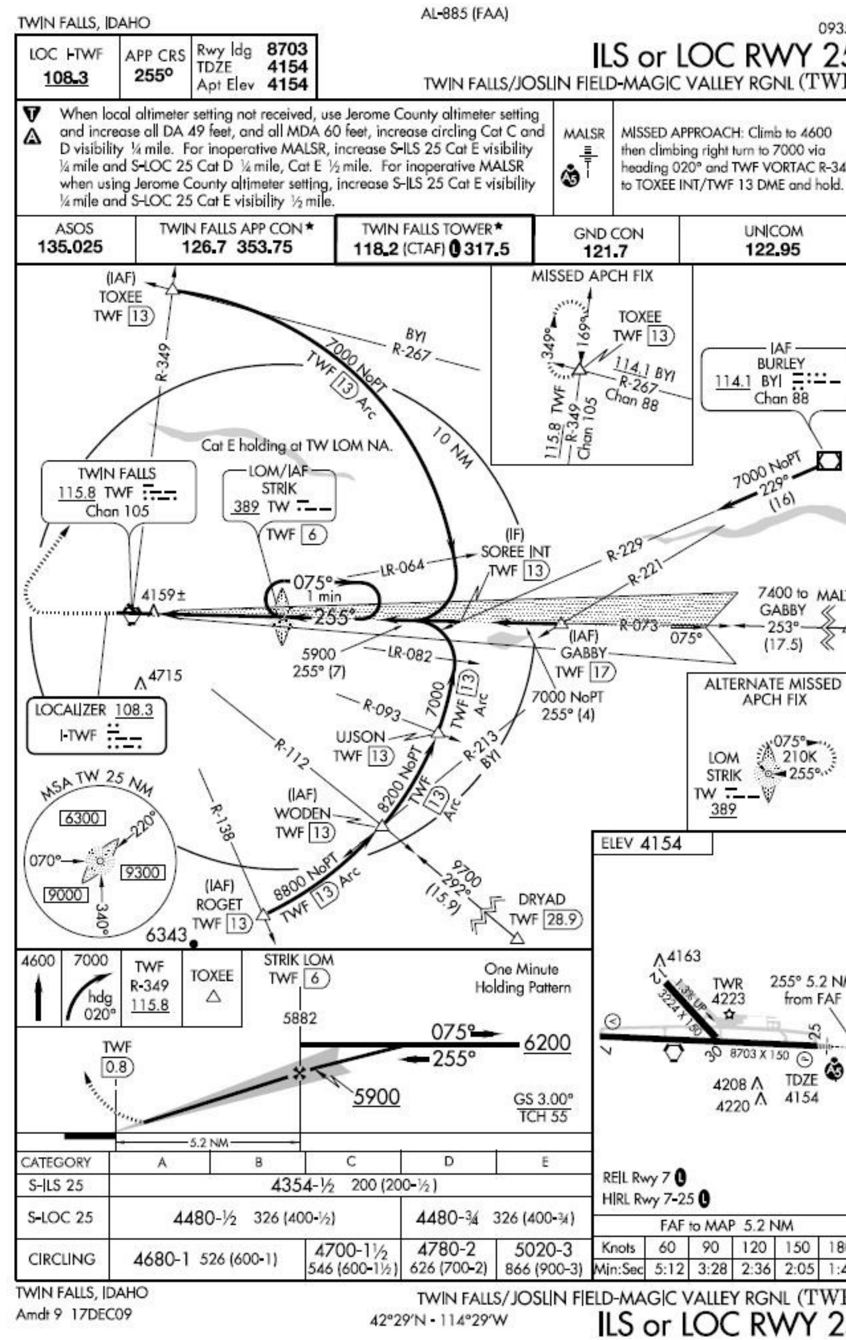
vertical speed indicator

tachometer

Synthesis • Radio-Navigation

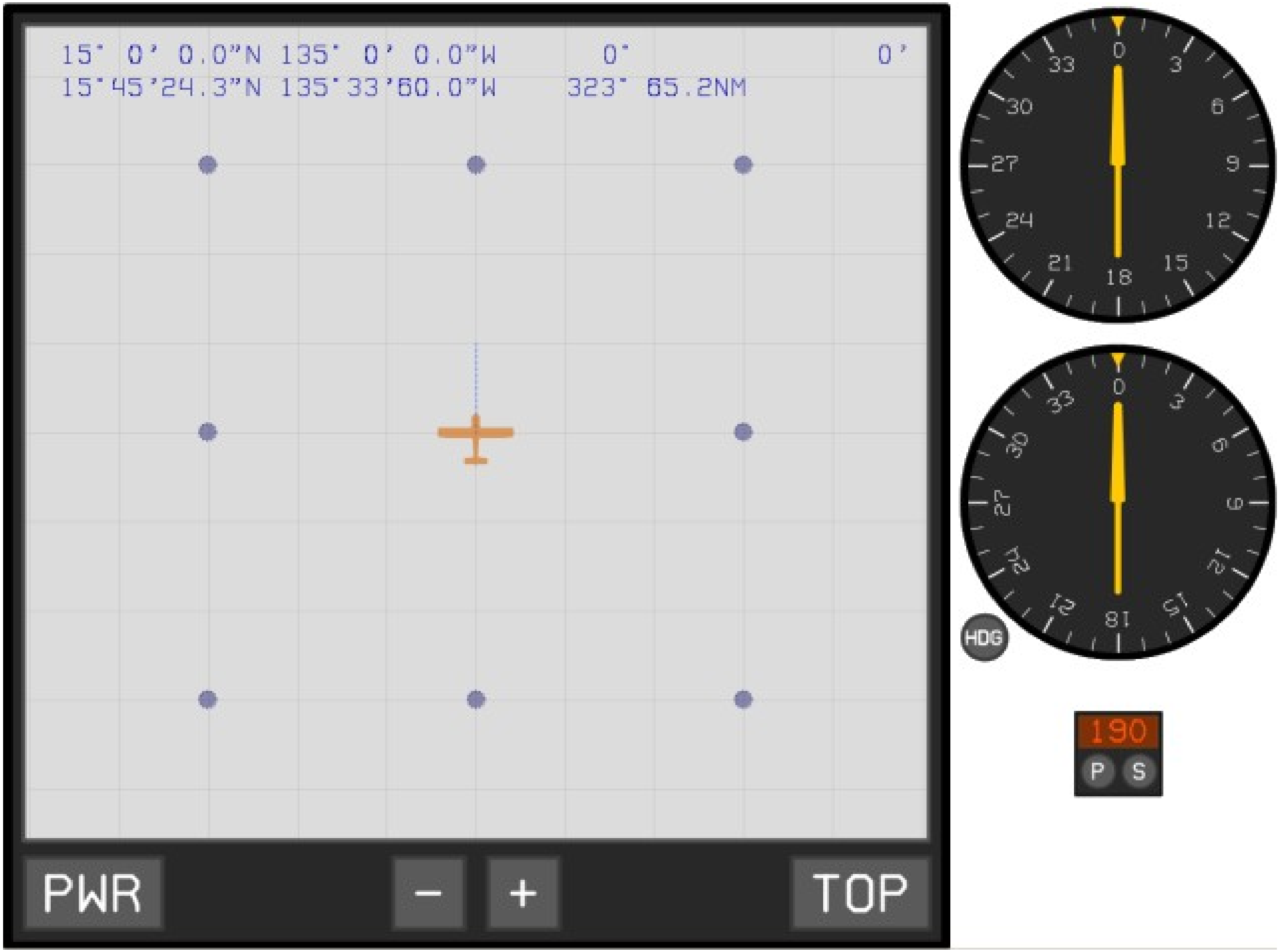
- Four navigational flight computers



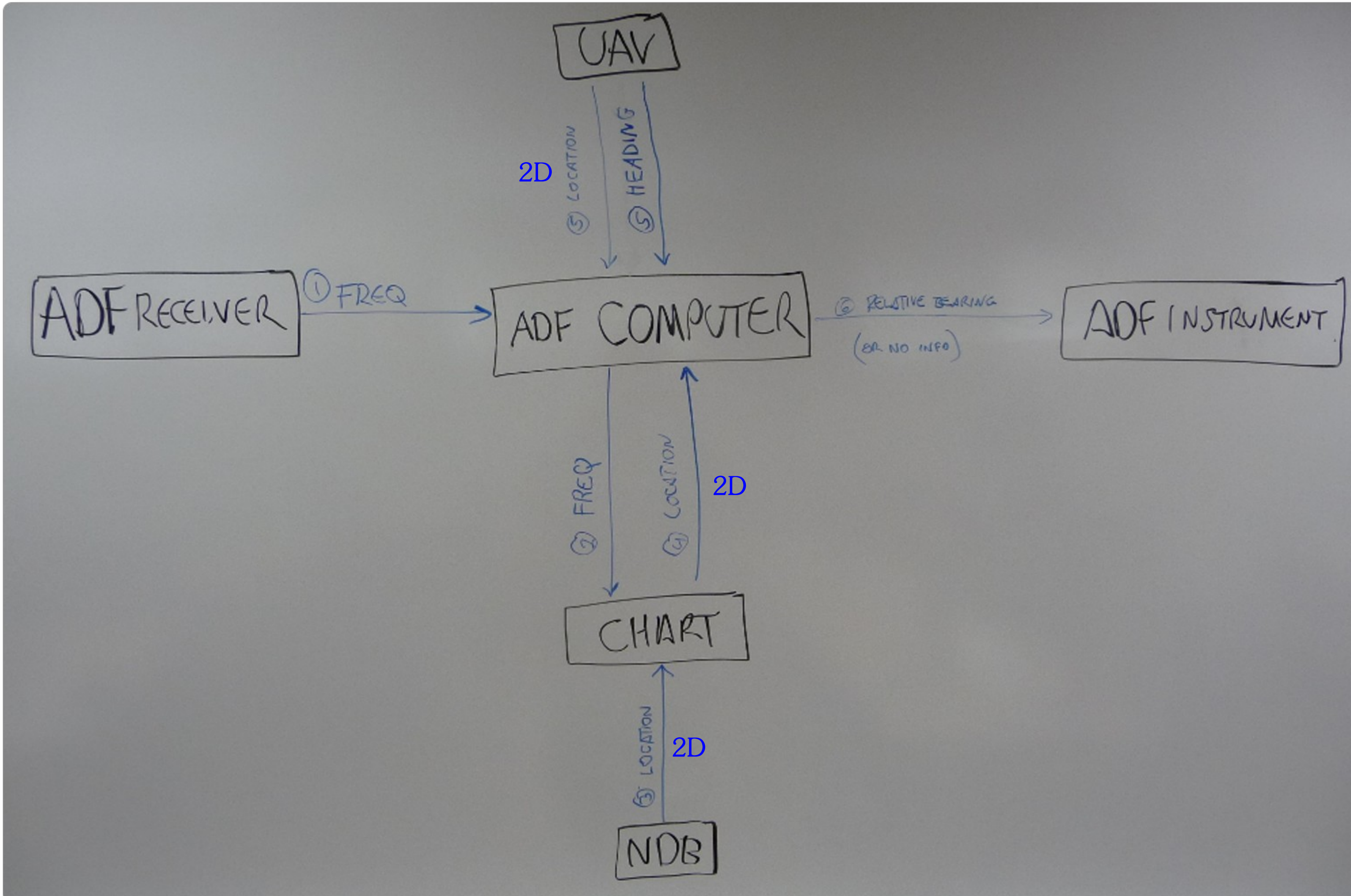


Radio-Navigation • ADF

- Homing beacons

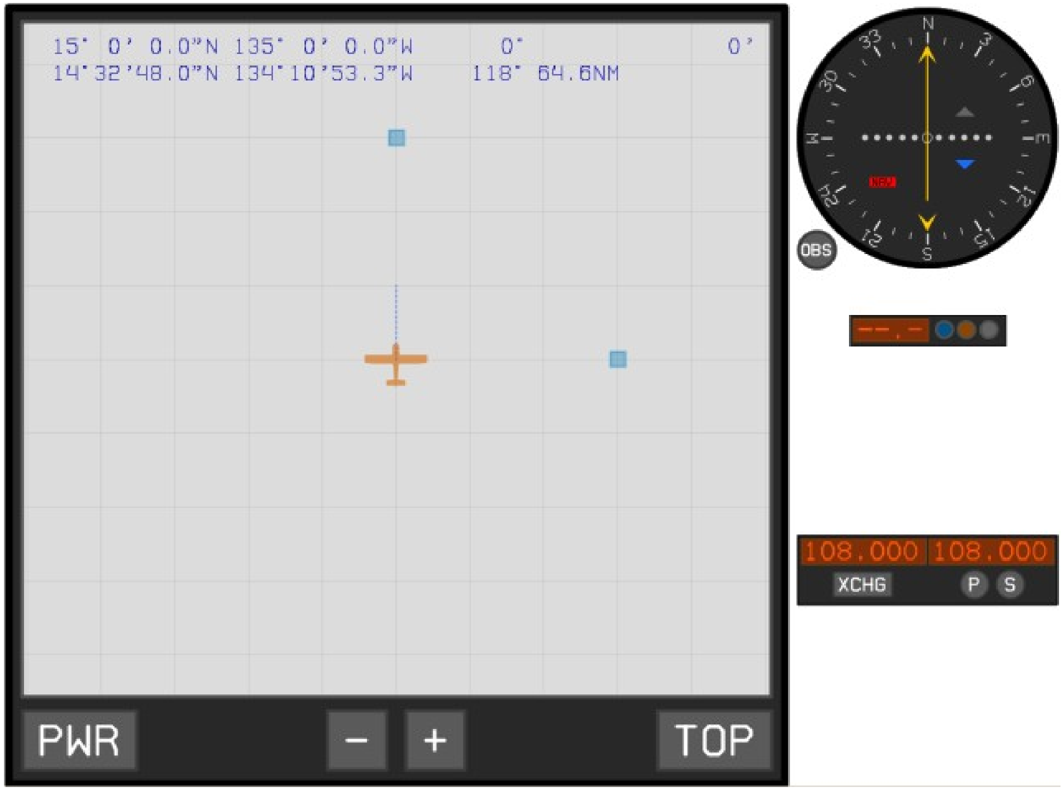


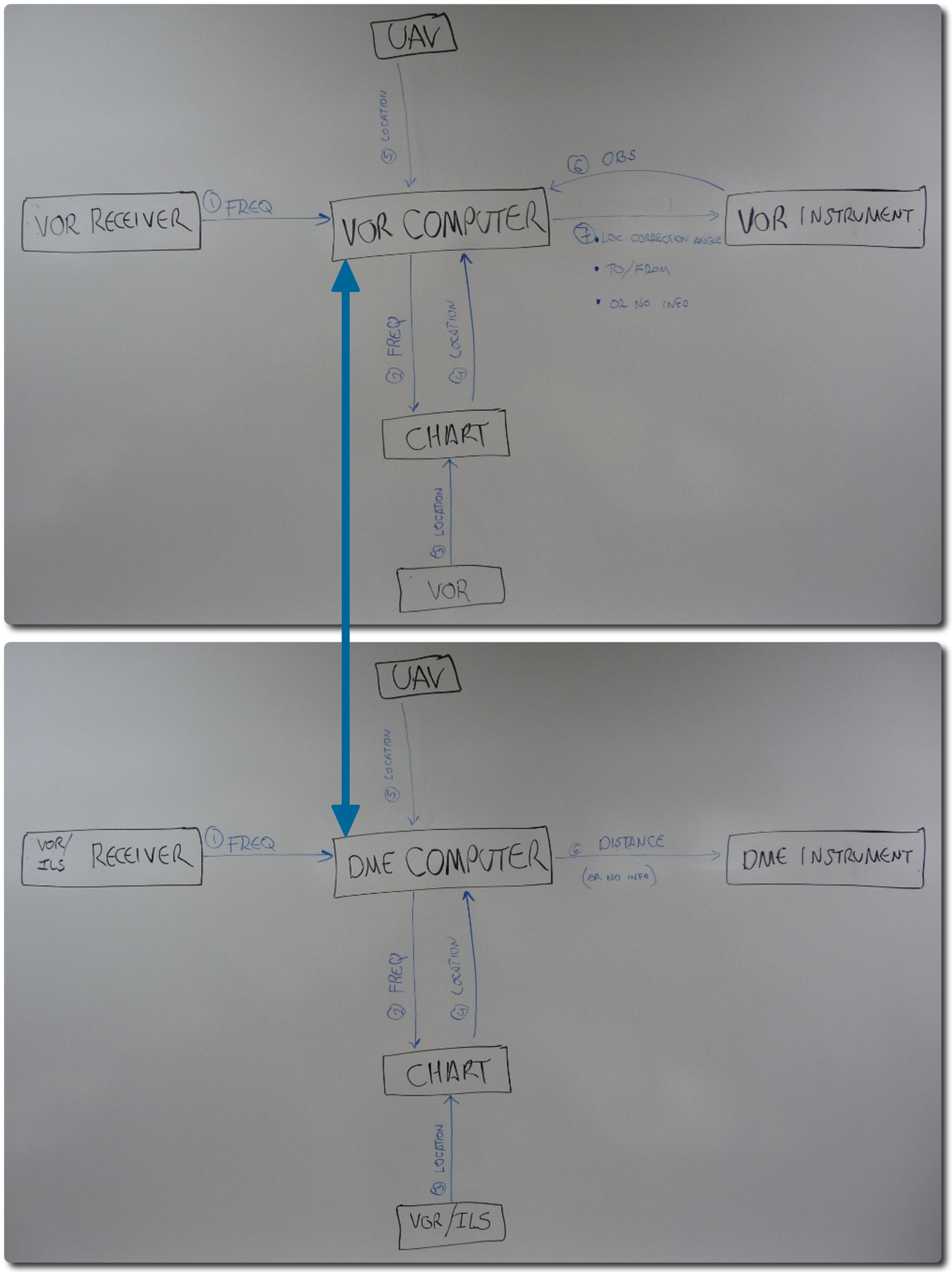
Radio-Navigation • ADF



Radio-Navigation • VOR/DME

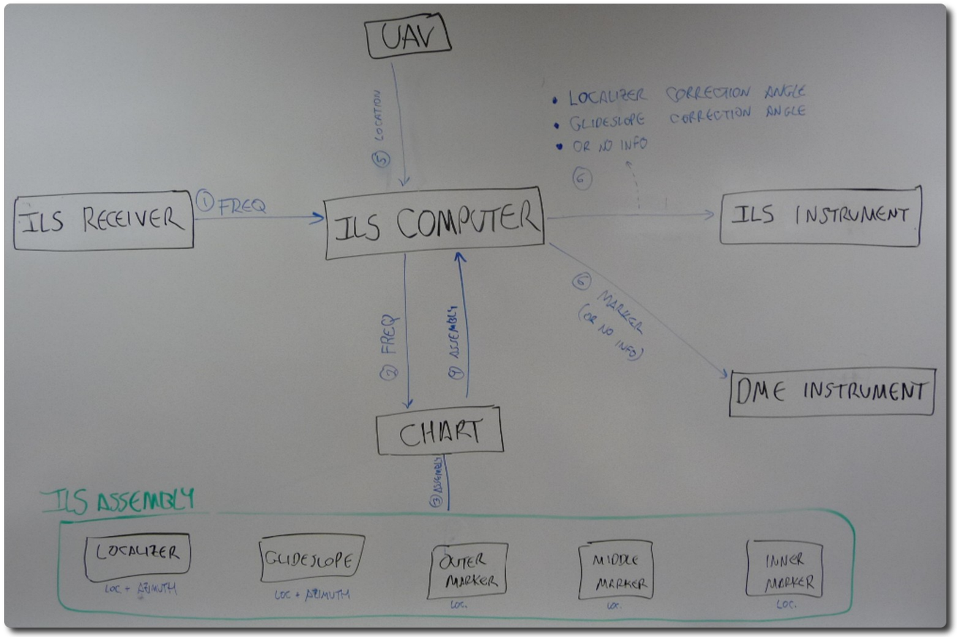
- Aerial highways





Radio-Navigation • ILS

- Instrument Landing System



Wind Model

- Optional text-based plug-in
  - 3D interpolation on winds-aloft vectors
  - strong connection with system architecture and concurrent courses

```
135,15
a..a...R.... m........... y........... K....sdfgs.. .......DG... .......dh...
b.....SDG... n..SDFGDFG.. z.......w... L..DGFD...sg .....f...... ..GS....fh..
c.....S..... o..T.T...... A....aXC.... M.......g.s. ............ ............
d...aS..G... p........DFG B.......w... N.s..bsd.... xcb...sdfee. ....WTE...df
e.SDFG..DFG. q....D..DFG. C.....bgh... ...g..m..... ...xcd...e.. F.JH.....ds.
f...FGSDF... r........... D...g....... .......ukui. ......b..g.. ....H.....f.
g....a..a... s...d....... E......CAS.. ....suk.g... ..DG.dfsdfg. ....GFGHJ...
h......M.G.. t......a..DF F..d..Csdf.. .........sd. ....s....... ....E...fg..
i.......C... u...D.D..... G......Cds.. .s.....dfg.. .....cdb.DFs ..SG...sSDF.
j...ZaZa.... v........... H........... .......t.... ...af.ssd.g. .D..FGHJDF..
k........... w.....SDF... I.....sdCx.. ..fghd...... .......DFGg. ........G...
l....a...SJ. x.....D..G.. J...C.C..... ............ ...DG....... n....fg.....
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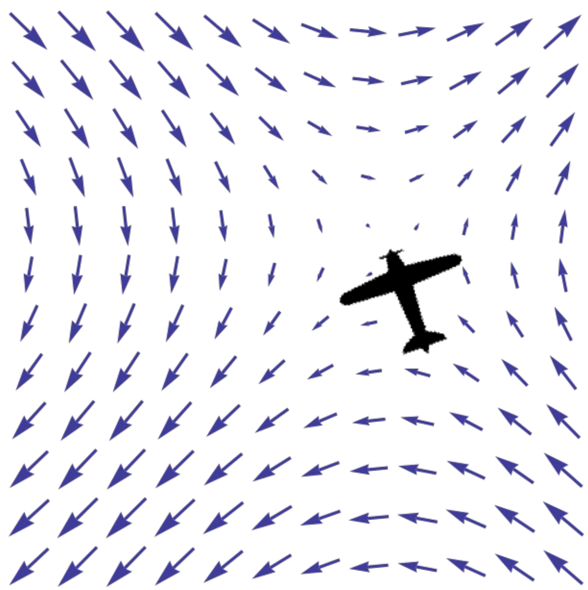
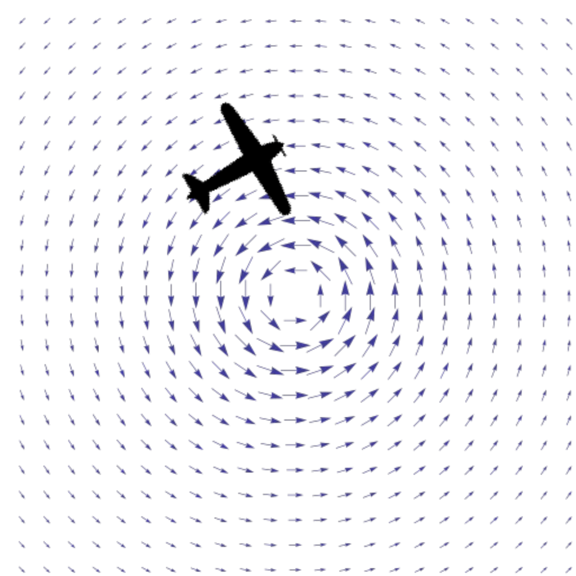
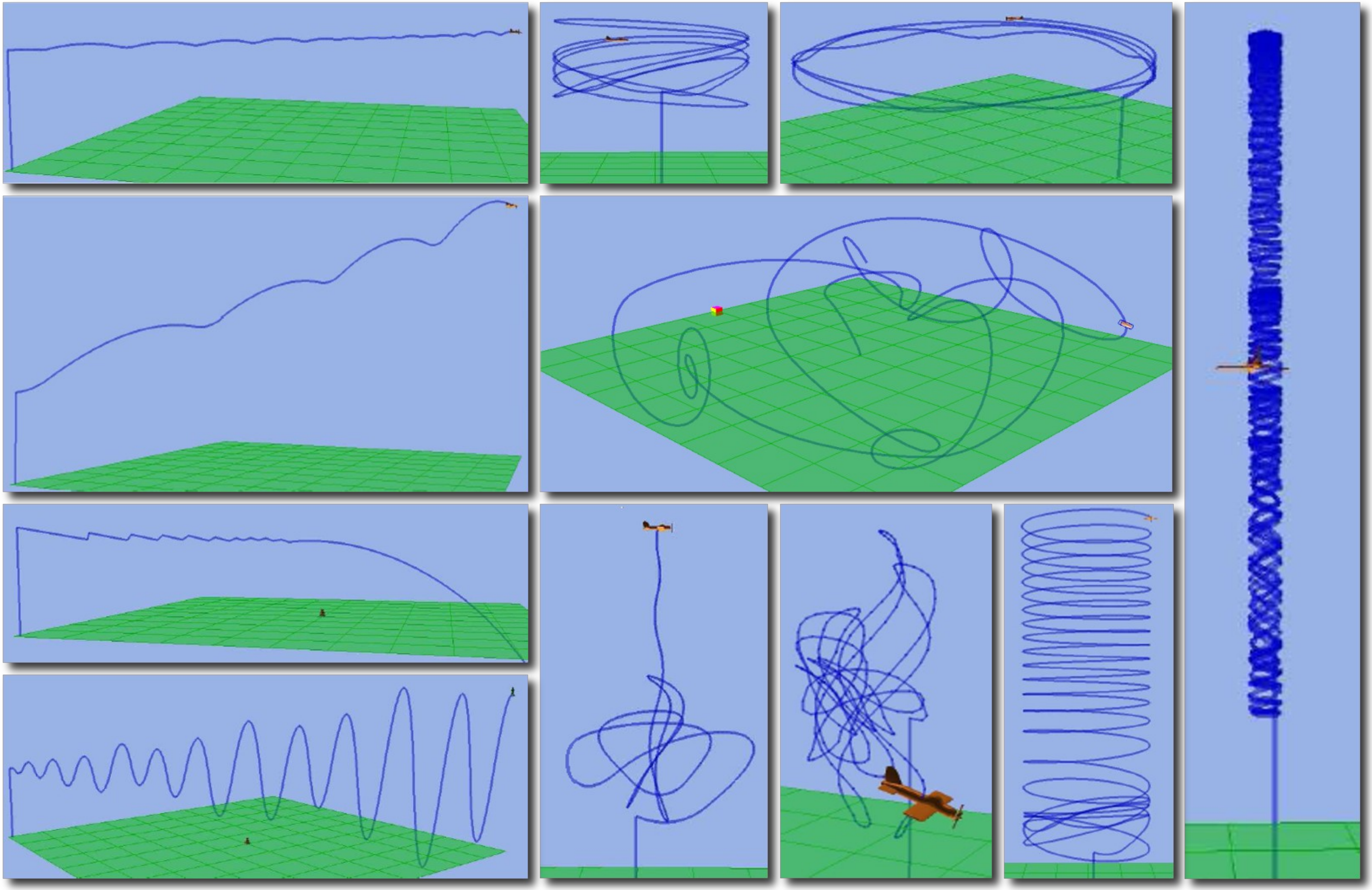


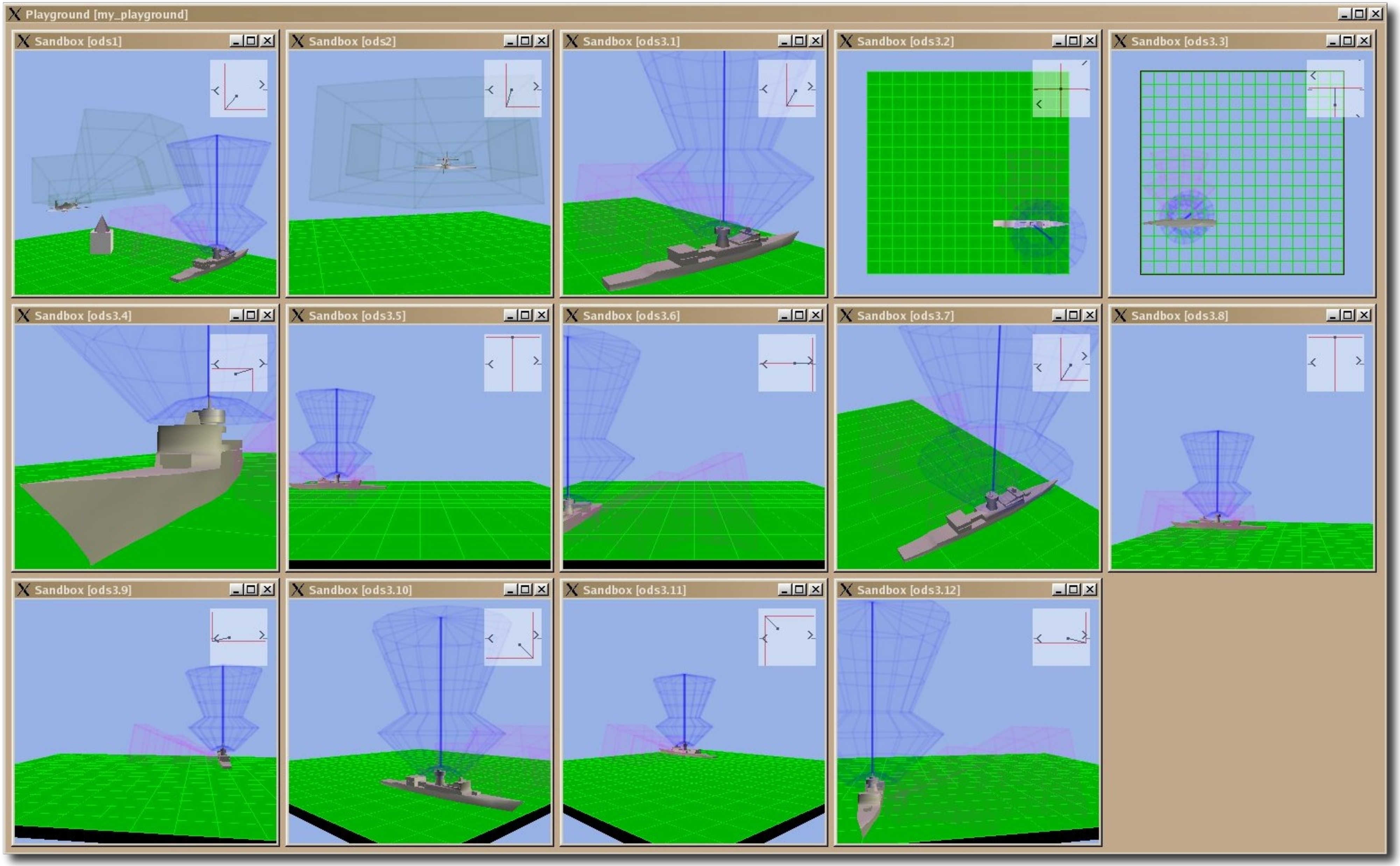


Visualization • Virtual

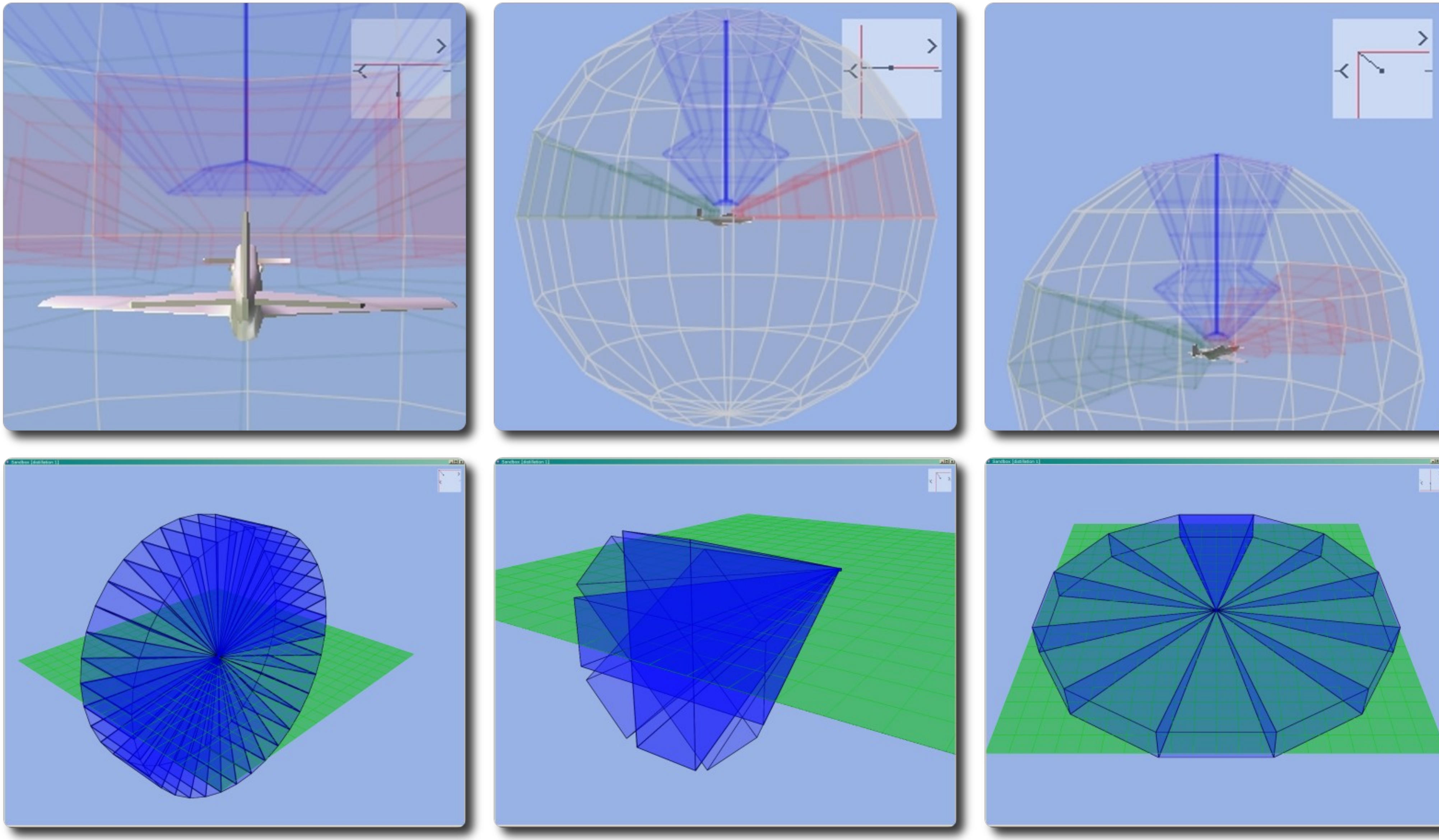


SVMP

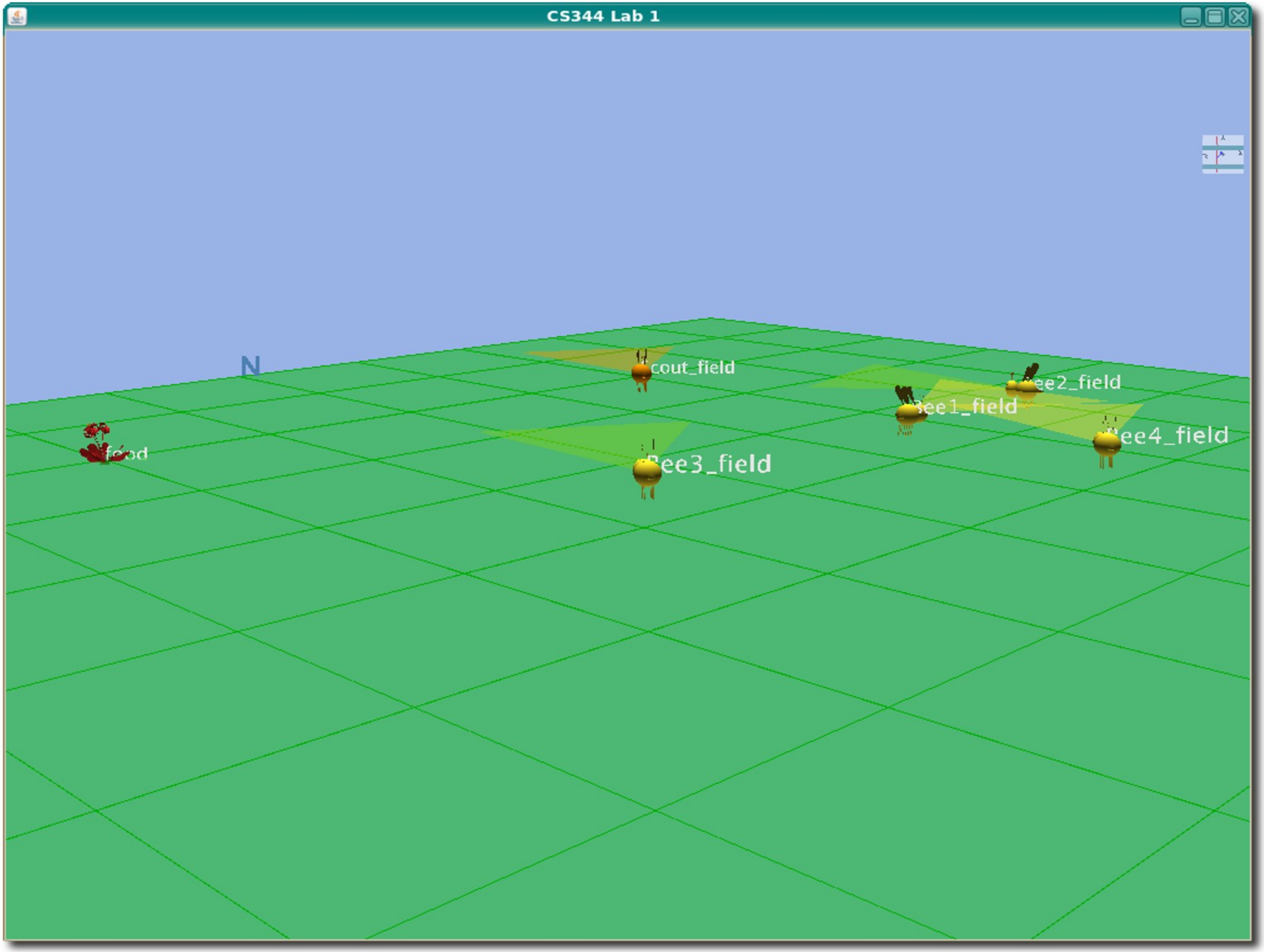
Visualization • Virtual



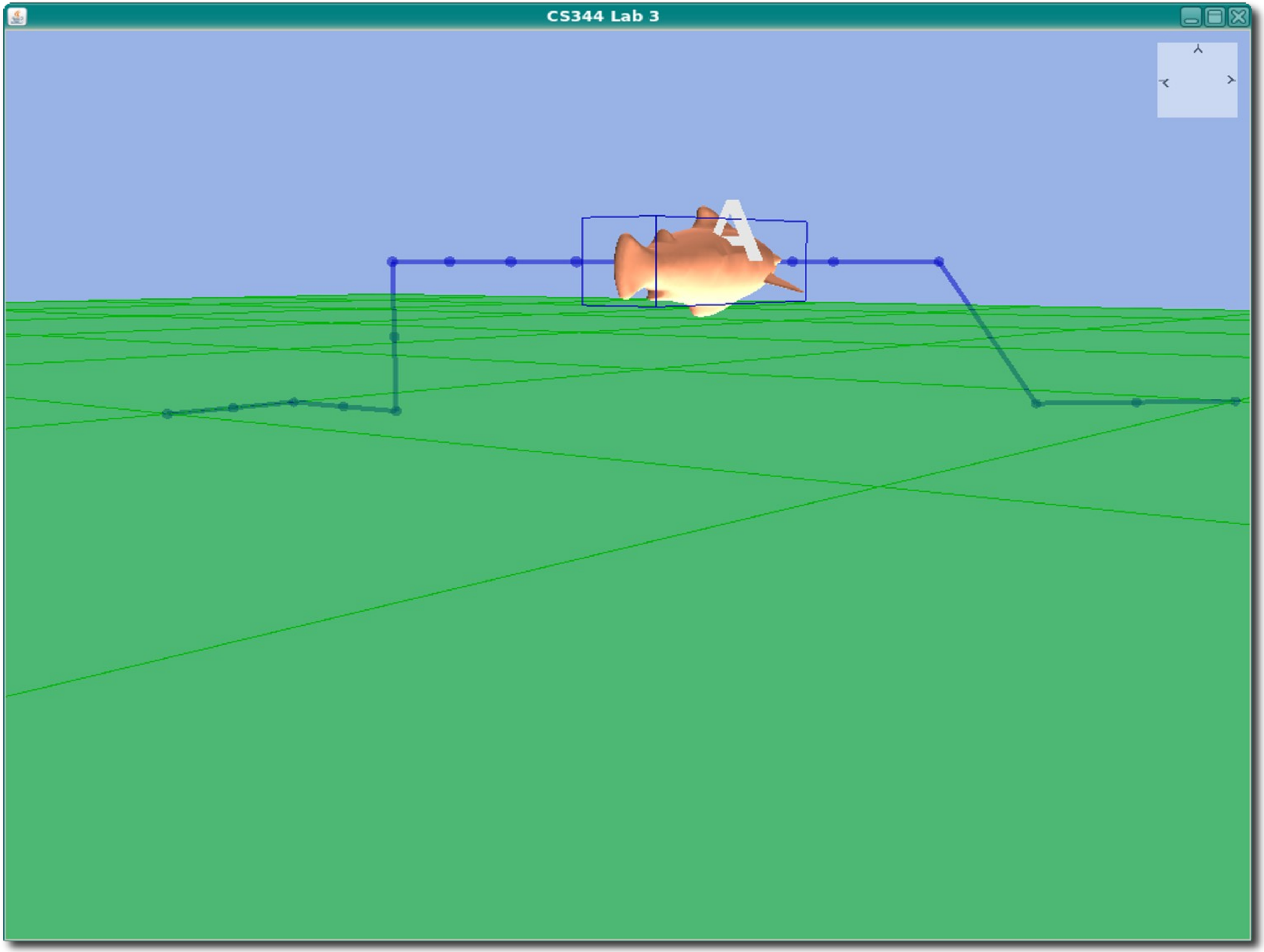
Visualization • Virtual



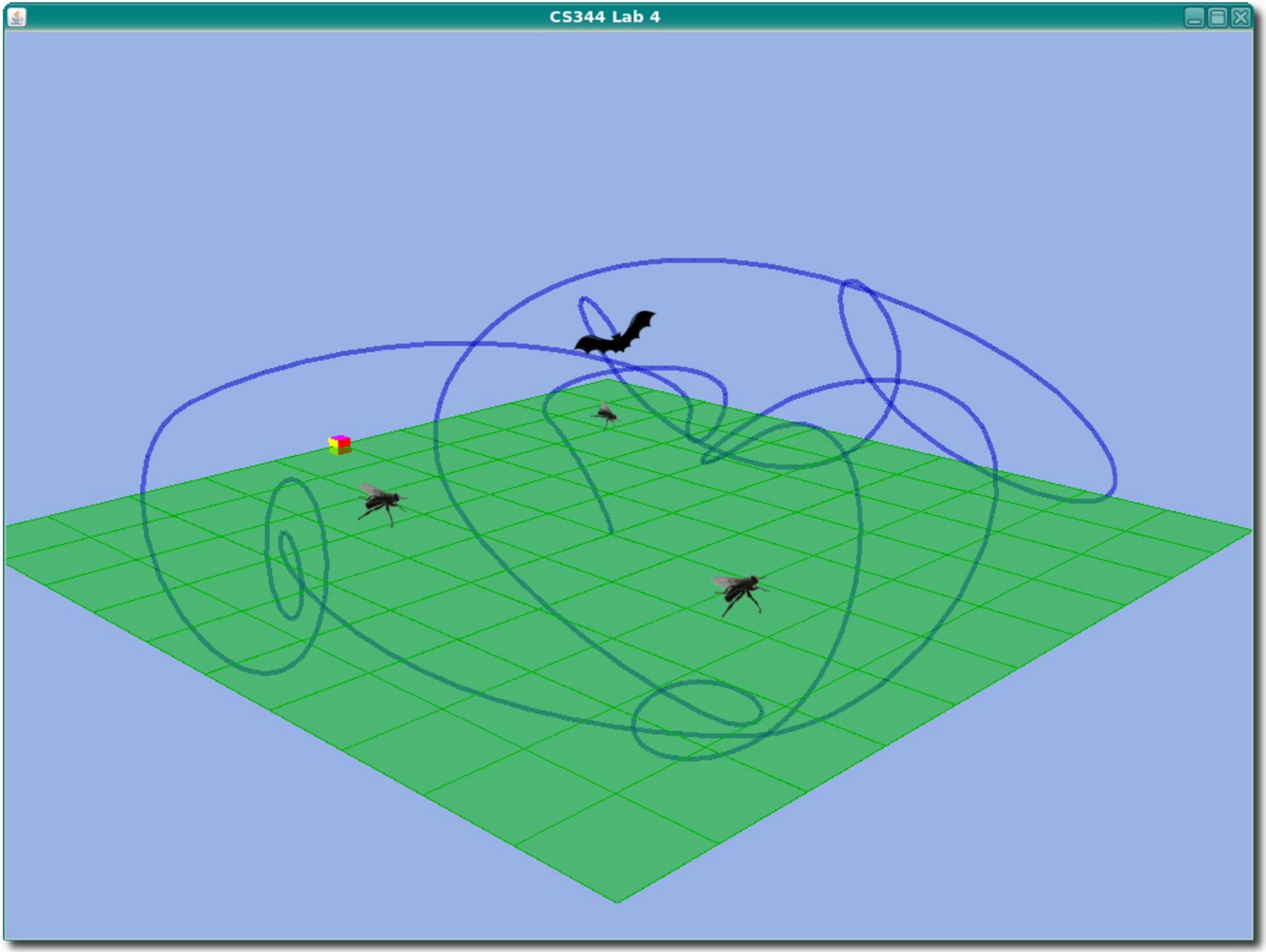
Visualization • Virtual



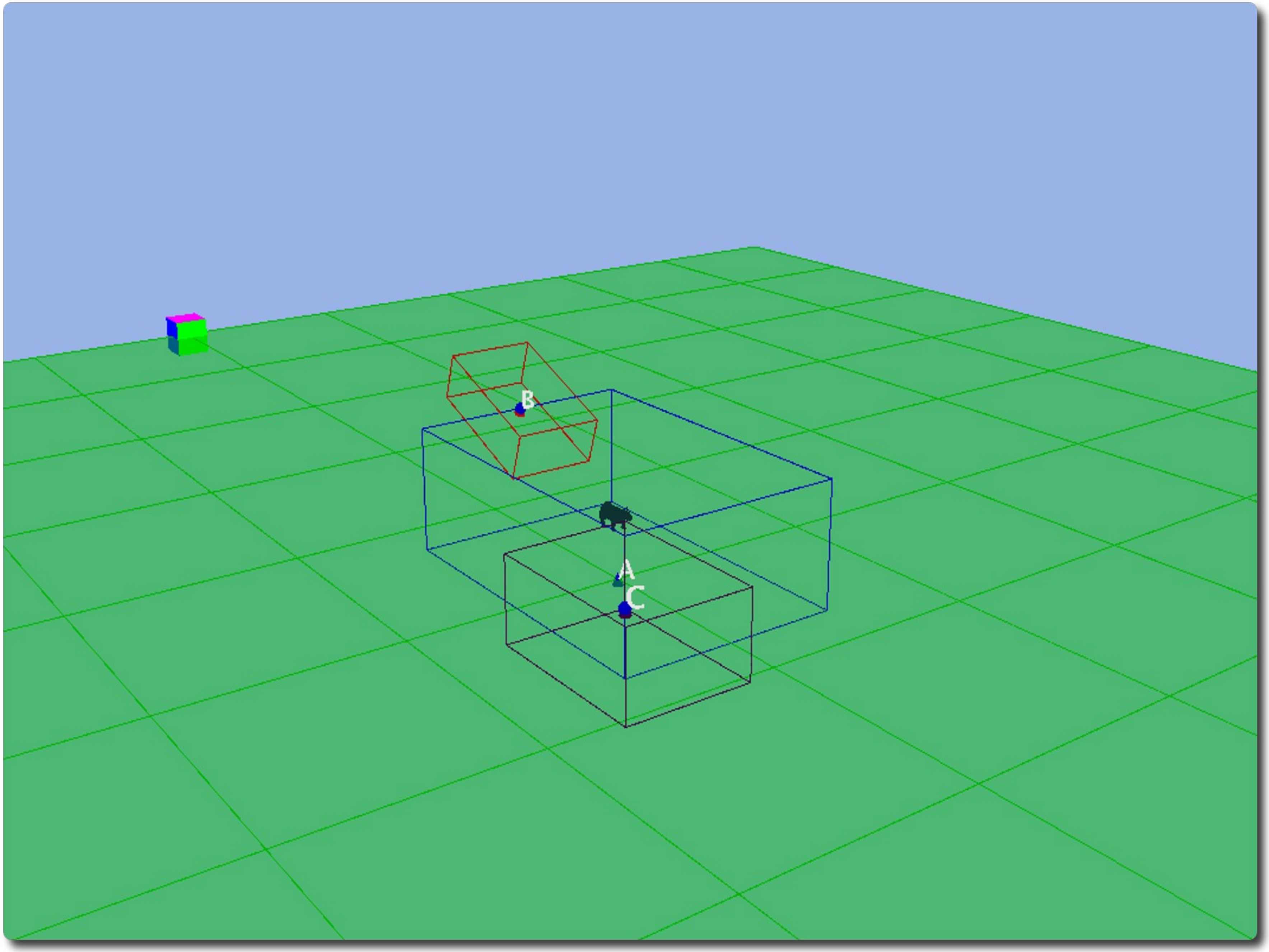
Visualization • Virtual



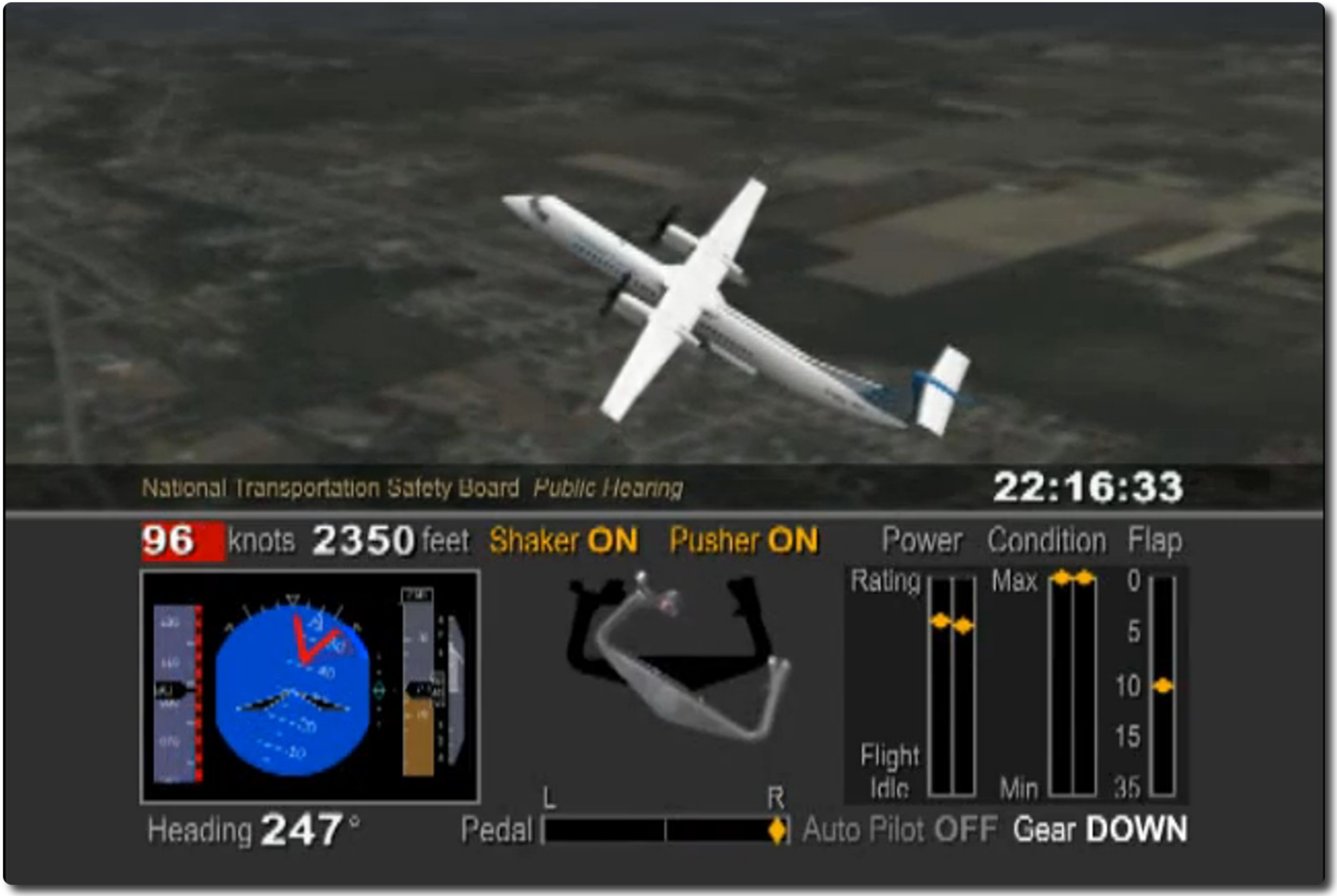
Visualization • Virtual



Visualization • Virtual

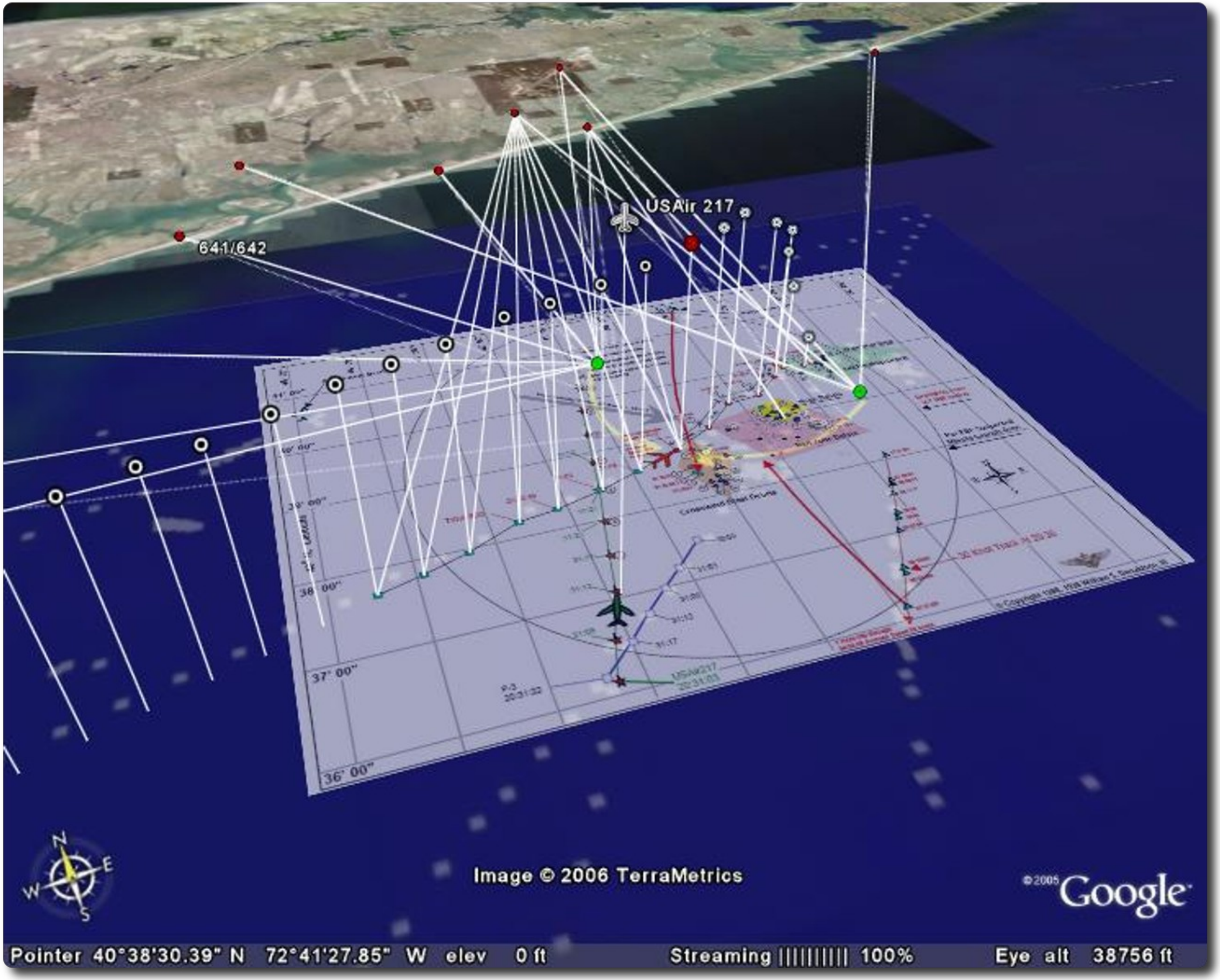


Visualization • Virtual



source: www.youtube.com/watch?v=vMy8kZ2_TMs

Visualization • Virtual



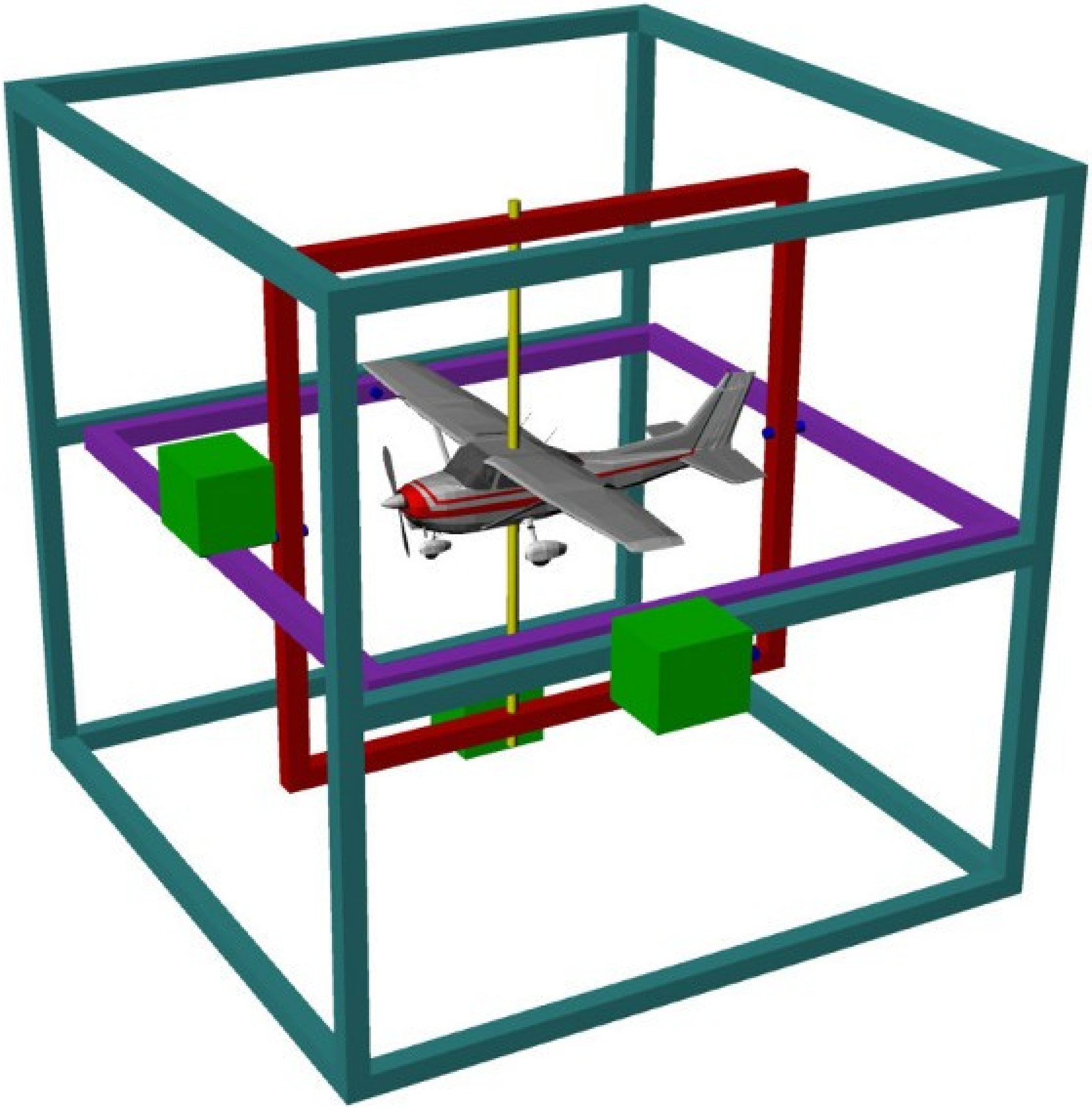
Visualization • Actual

- Three-axis model-controlled electromechanical gimbal
  - computer science (software and hardware)
  - electrical engineering
  - mechanical engineering
  - fabrication
- Useful in…

  … software engineering

  … embedded/game systems

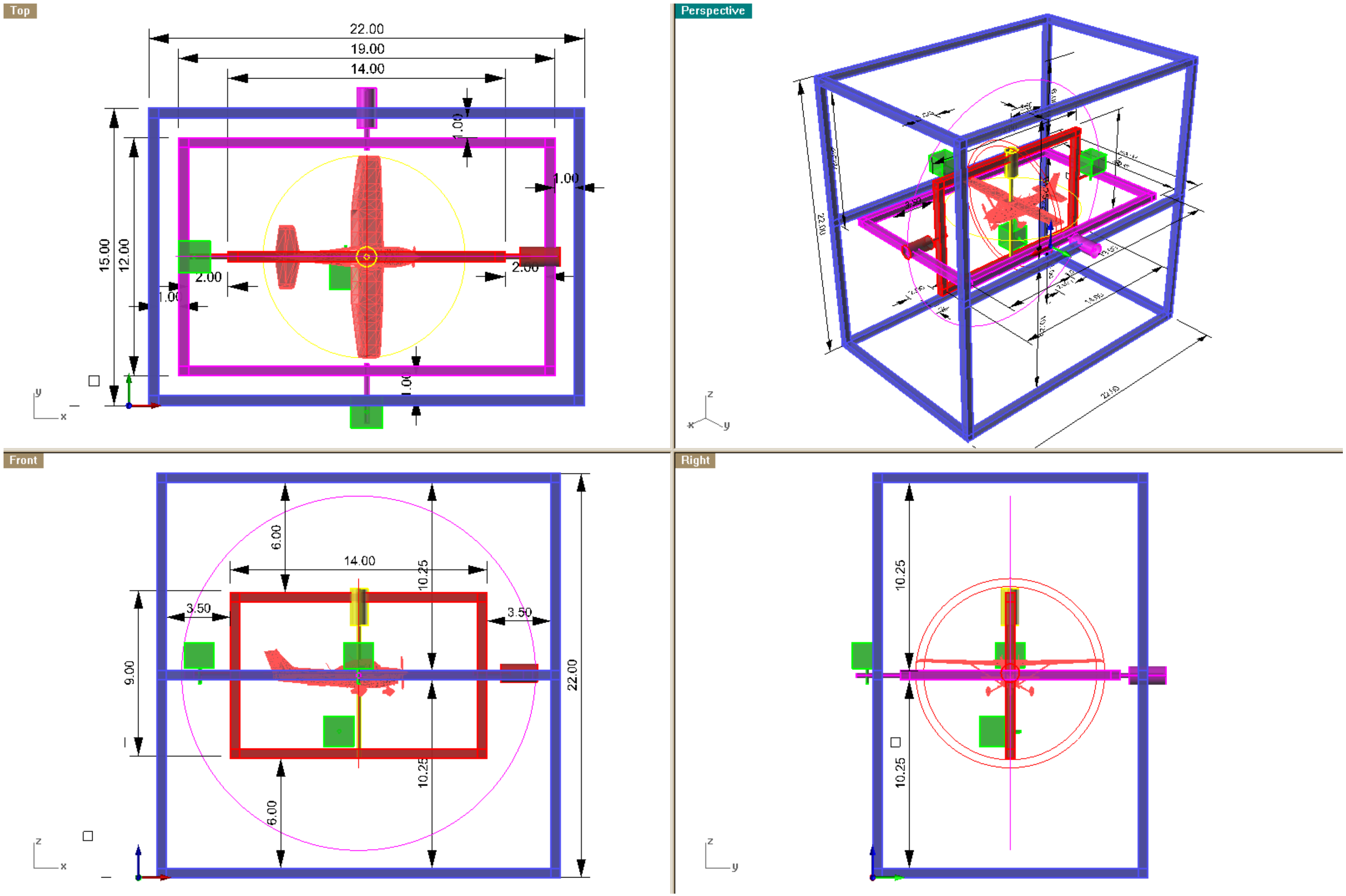
  … recruitment and science fairs



see shelby.wnmu.edu/gimbal

Visualization • Actual

- Crossover to computer-aided design (CAD) and manufacturing (CAM)

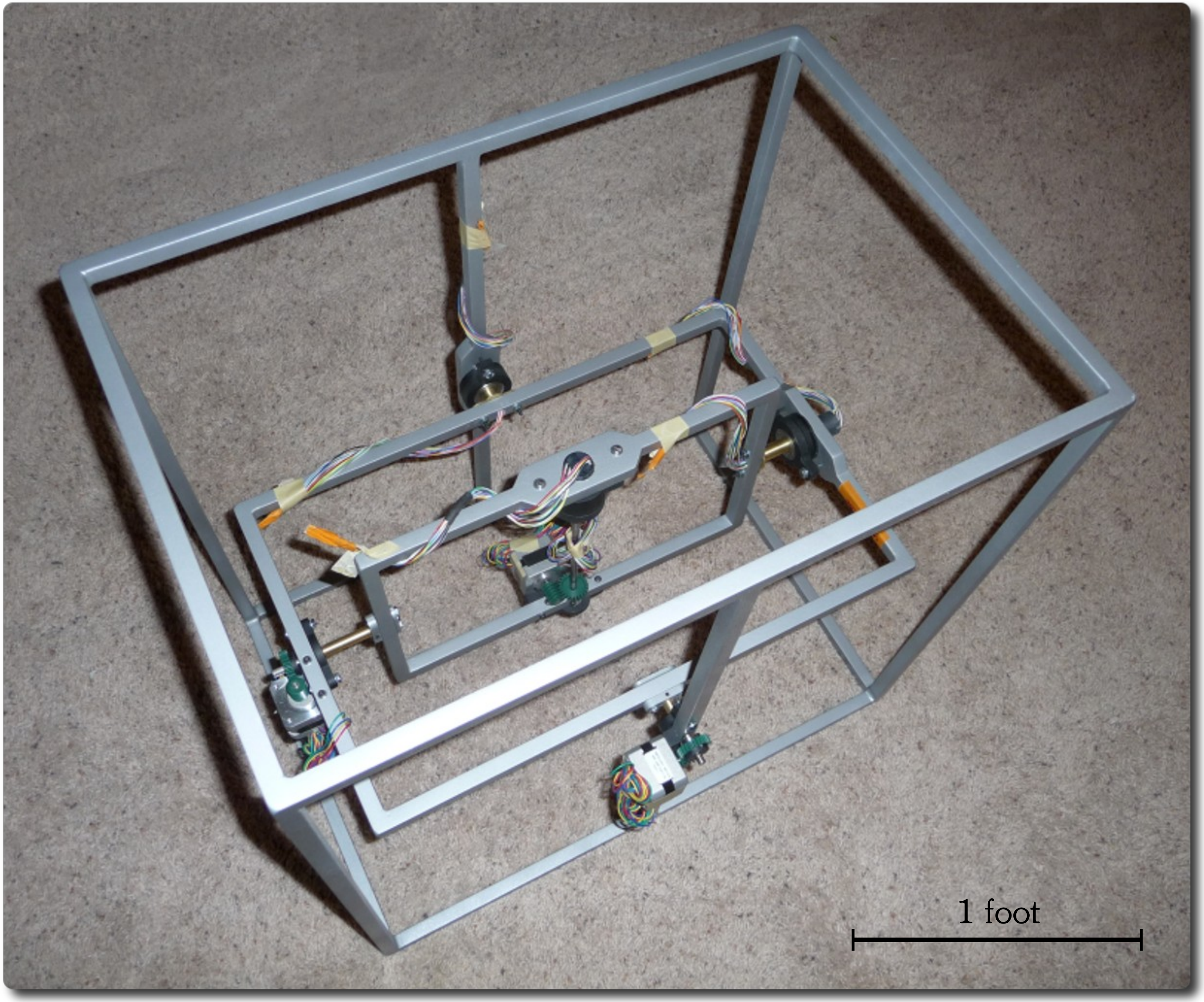


see shelby.wnmu.edu/mill and shelby.wnmu.edu/lathe

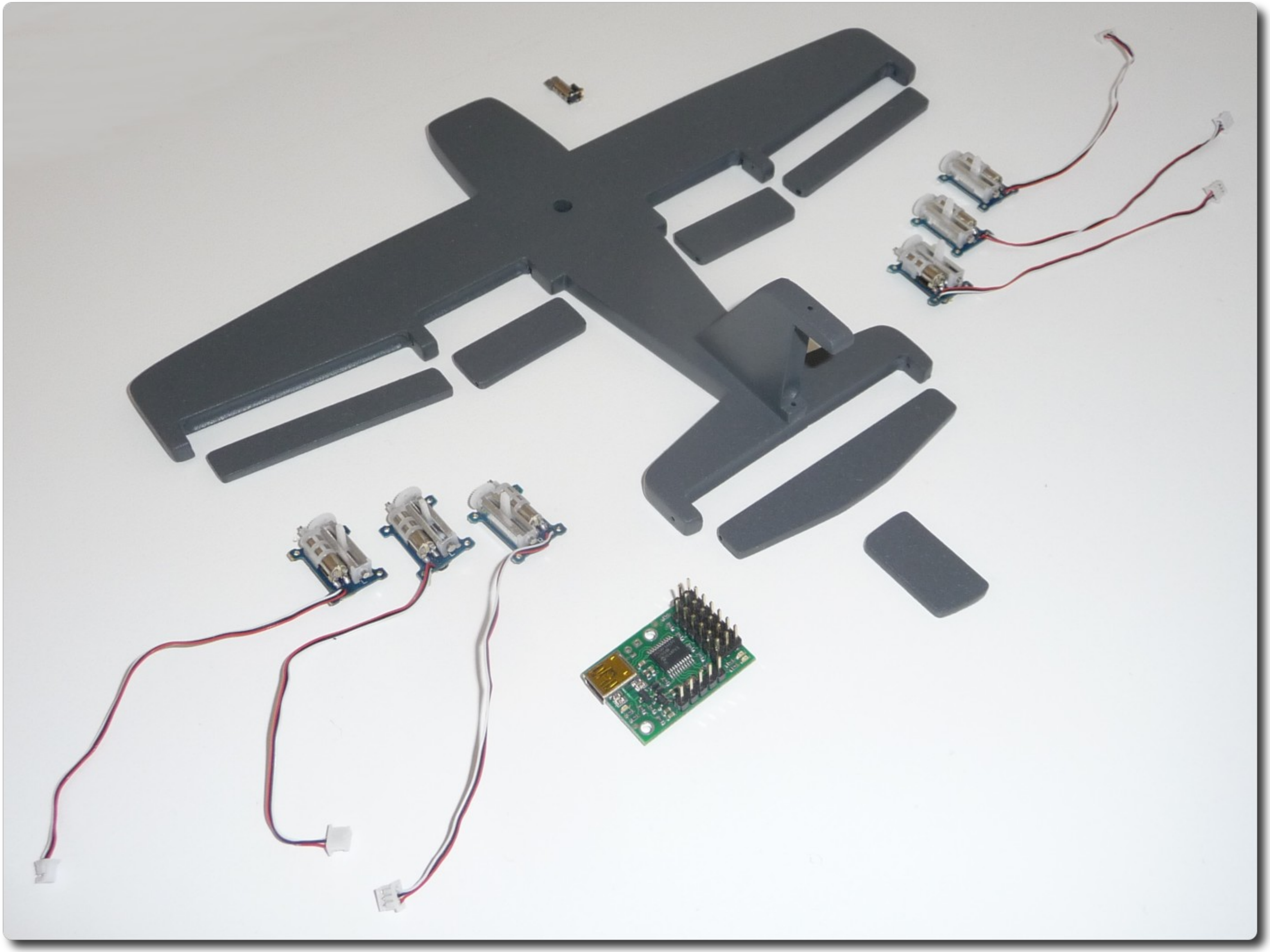
SVMP


SCORE 0000
HIGH SCORE 5000

Visualization • Actual



Visualization • Actual



Visualization • Actual

source: hotseat.com

Visualization • Actual

THEME BUILDING

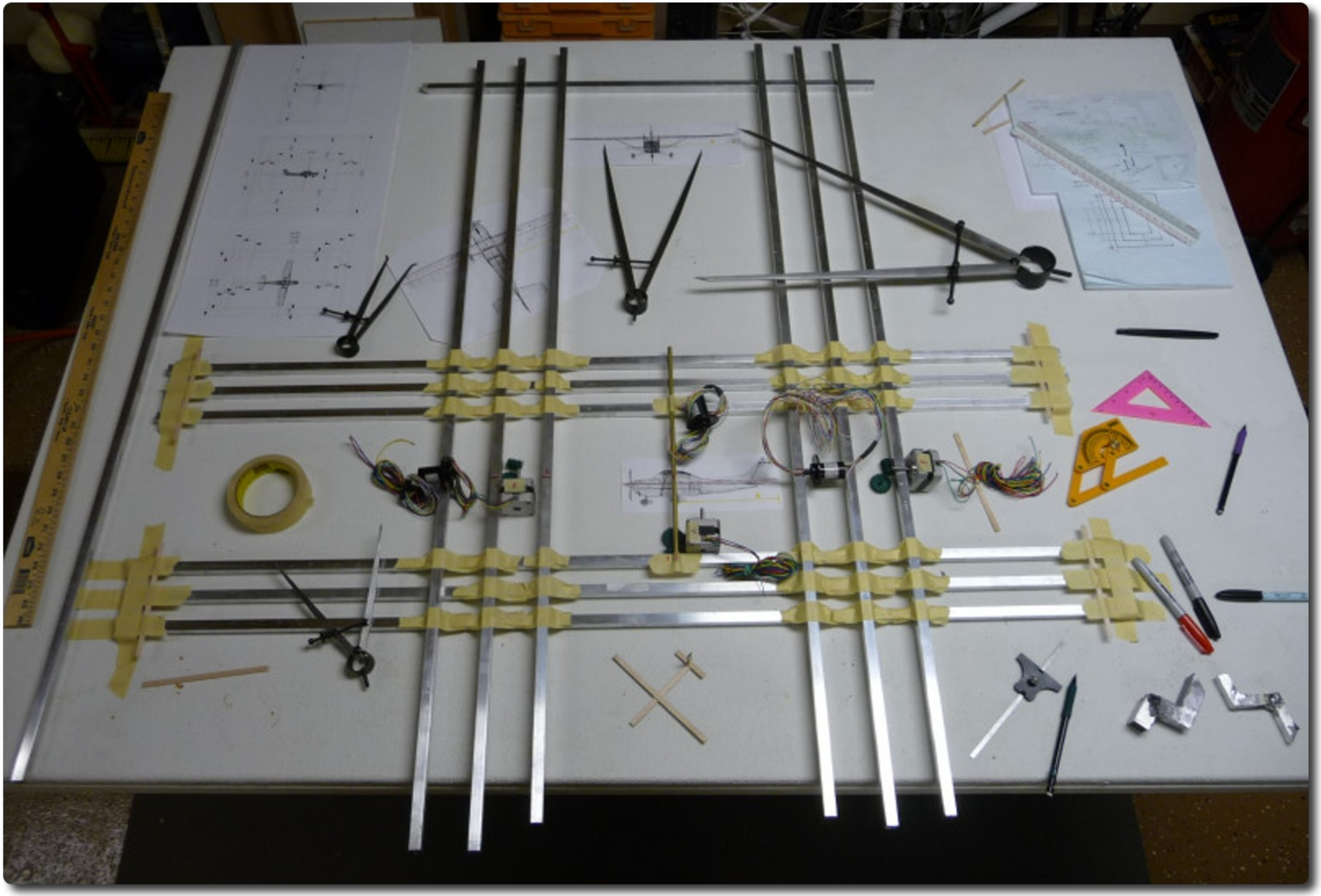
Rec-Room Cockpit

How one reader built his own flight simulator

STORY BY **Andrew Rosenblum**

Clint Fishburne, a regional-airline pilot based in Atlanta, wanted to help his children develop the body movement and muscle memory necessary to fly and land a plane. With the cost of commercial flight simulators starting at $25,000, though, Fishburne, a longtime PopSci reader, decided to make one from scratch. Building the plywood-and-PVC plane, frame and control stick was relatively easy. The challenge was making a platform that could mimic a plane's motion and that was strong enough to support and move a 75-pound child. After some experimentation, Fishburne built four custom airbags made of PVC-coated fabric and, to inflate them, connected them to 457-air-watt central vacuum motor. The amount of air in the four bags varies, allowing the simulator to bank or pitch up to 25 degrees on either axis. When the pilot pushes the stick left, a valve increases airflow to the right airbag and vents air from the left. An accelerometer sends spatial-position data to a laptop by USB, and an LCD projector beams the imagery from Microsoft's Flight Simulator software onto a wall. Fishburne is now trying to commercialize a kit version of his simulator, in part to inspire more young gamers to become pilots.

Fabrication

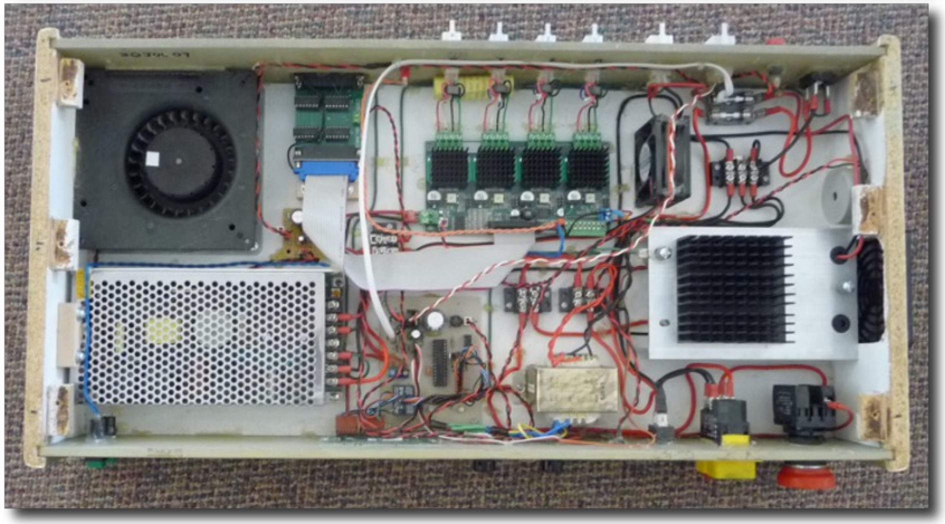


see shelby.wnmu.edu/welder

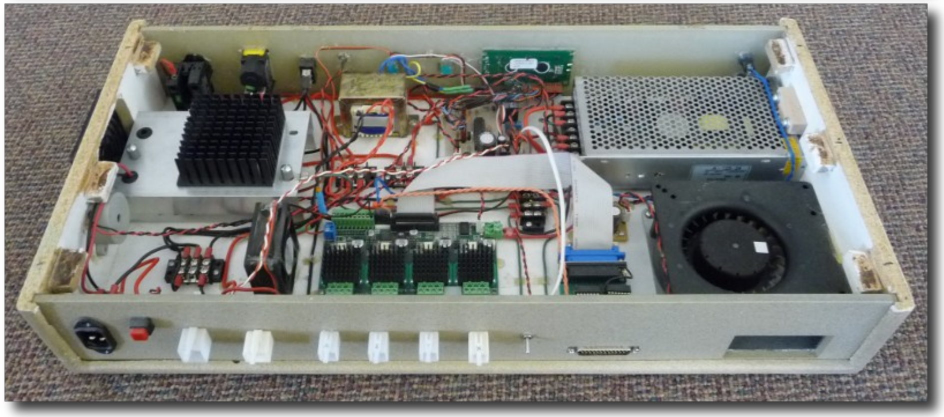
Fabrication

input

processing



output



Data Analysis and Machine Learning

- Metrics for data analysis
  - Army Future Combat Systems
  - DanStat Half-Life Statistics Engine
- Machine learning
  - landing and hovering
  - air traffic self-organization
  - self-adapting software

Accelerating Software Modernization with Artificial Intelligence

AI is radically transforming the way organizations evolve their software assets to achieve competitive advantage.

Artificial Intelligence (AI) is the quest to achieve computers that equal or exceed human performance on complex intellectual tasks. A phenomenal development in AI is the recent emergence of automated computer language translation programs, driven by the need to modernize the nearly half trillion lines of legacy software developed during the latter half of the 20th century.

Early software translators of the 1960s, like the earliest chess programs, were disappointing and limited. Leveraging AI technologies that evolved from the 1980s era USAF's Knowledge Based Software Assistant and emerging standards, computers can now understand and translate software applications with levels of proficiency that vastly exceed human performance. This technology is revolutionizing the way industries, such as finance, insurance, manufacturing, and healthcare as well as military and governments are modernizing their legacy systems.

Leading this field is The Software Re[illegible]ution, Inc (TSRI), a Kirkland, Washington [illegible] company. Building upon 32 y[illegible] R&D, TSRI's robust JANUS[illegible] provides large-scale, error-f[illegible] modernizations at 100% levels of auto[illegible]. By applying AI to abstract software [illegible]odels, TSRI delivers automated code conversion with unprecedented target code quality, economies of scale and schedule compression, accomplishing with small teams in months what would take years by other means. The following list of brief case studies represents five recent TSRI legacy system modernization projects.

- **European Air Traffic Management System (EATMS), Thales Air Systems:** This realtime system manages over 10 million passenger flights annually. Thales engaged TSRI to transform EUROCAT's 2 million lines of legacy Ada into Java. The result was a perfect functional replica of EUROCAT in its new language. TSRI's 100% automation eliminated the risk of errors inherent in a manual rewrite. EUROCAT will commence operation in significant airports across Europe and Asia at the end of 2011.
- **Patriot Missile, Fire Platoon Simulation & Battalion Simulation Support Systems, Raytheon:** TSRI used the JANUS Studio® tool suite to modernize four different Patriot systems including Patriot Japan. These modernizations included the transformation of nearly 200 thousand source lines of Fortran code to C++, re-factoring and documentation.
- **Major Healthcare Insurance Company:** This system consisted of over 180 thousand source lines of PowerBuilder and nearly 3 million lines of COBOL. In modernizing this system TSRI provided transformation, re-factoring and supported system integration. This project was completed in only 16 months.
- **Major US Bank:** This legacy application contained over 3 million source lines of Fortran and over 160 thousand lines of DCL. TSRI automatically generated a *Transformation Blueprint™* to assist in the systems design architecture, performed the code documentation and provided engineering support.
- **Advanced Field Artillery Tactical Data System (AFATDS), Stanley and Associates (Now CGI Federal):** A version of the US Army's legacy AFATDS system consisting of over 5 million source lines of ADA-83. TSRI employed JANUS Studio® to transform this system into Java in only 10 months. TSRI delivered the modern system to Stanley in August 2010.

Information Systems Transformation: Architecture-Driven Modernization Case Studies provides more detailed information on these case studies.

For more information visit **www.tsri.com**

Information Systems Transformation:
Architecture-Driven Modernization Case Studies
By William M. Ulrich and Philip Newcomb
ISBN: 978-0123749130

About the book:
Architecture-Driven Modernization (ADM) gives you everything you need to know to update costly obsolete systems, transform data, and save millions of dollars.

Philip Newcomb
Founder and CEO of TSRI

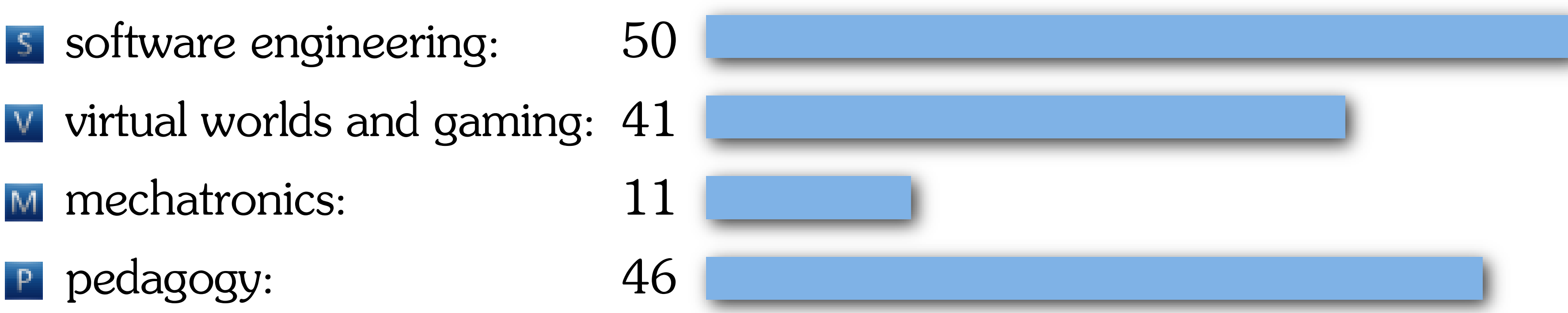
Mr. Newcomb is an internationally recognized expert in the application of AI and formal methods to software engineering. After leaving Boeing he led a team of software engineers to develop TSRI's JANUS Studio® tool suite. Mr. Newcomb is the author of numerous papers, books and industry standards.

TSRI is a Platform Member of the OMG and leading contributor to the ADM Task Force (ADMTF) standards. TSRI's services and JANUS Studio® tool suite have served as the leading exemplar for the OMG's emerging ADMTF standards.

source: ammodel.wordpress.com

Conclusion

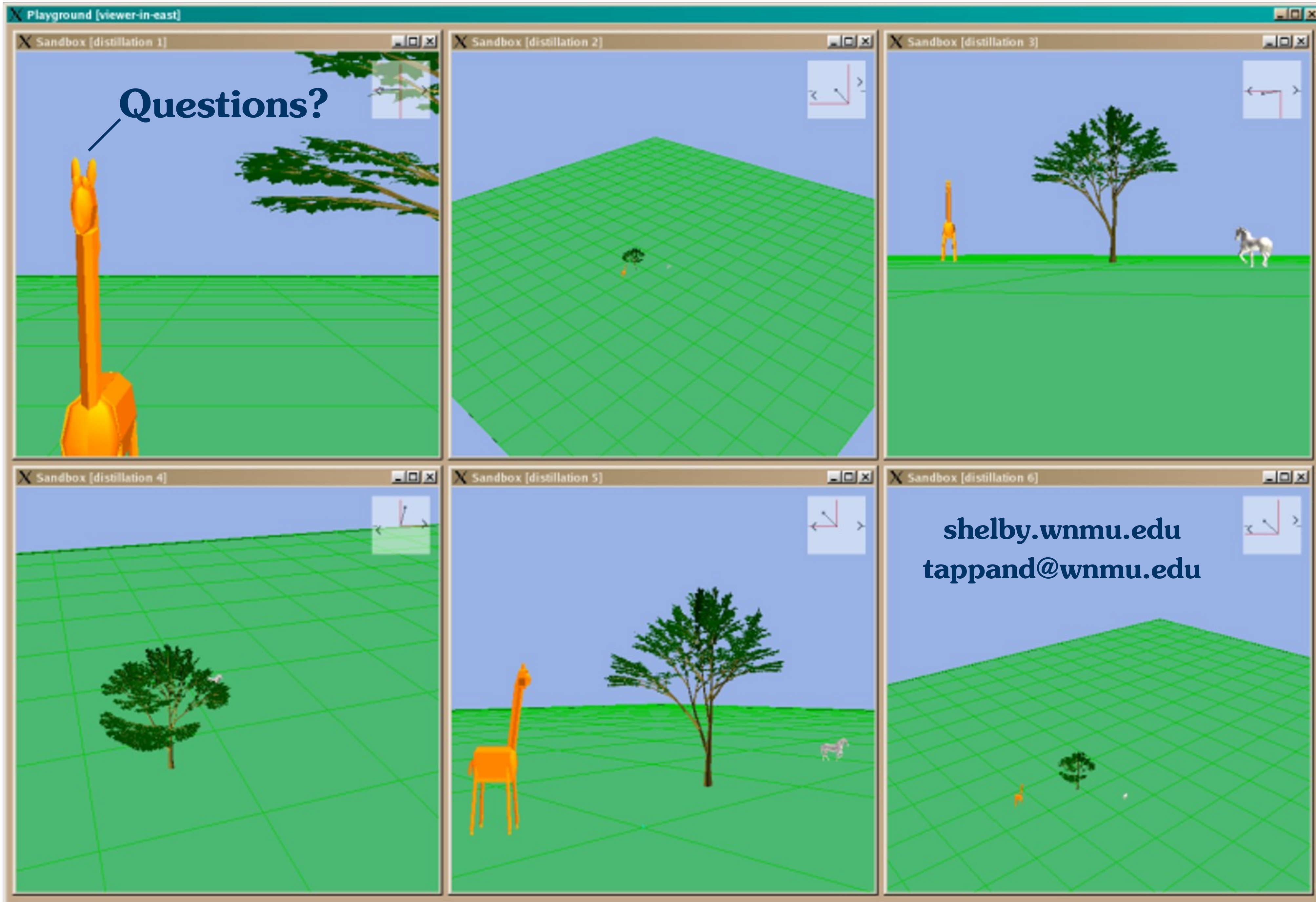
- On-going end-to-end software-engineering project
  - real-world example by real-world practitioner using real-world tools
  - interdisciplinary computer science with computer, electrical, and mechanical engineering, fabrication, and aviation
  - broad student involvement
  - award-winning teaching philosophy
  - great funded research potential



MACGYVER

All he needed was a ball-point pen and a paper clip.

source: de-motivational-posters.com



this talk available at shelby.wnmu.edu/uav-talk