MODEL CENTER IN THE CLASSROOM: LESSONS LEARNED AND BEST PRACTICES

Douglas L. Van Bossuyt, Joseph Piacenza, David Jensen, Irem Y. Tumer

Authors

- Douglas L. Van Bossuyt, Colorado School of Mines
  dvanboss@mines.edu, Corresponding Author
- **Joseph Piacenza**, Cal State Fullerton
  jpiacenza@fullerton.edu, ***Presenting Author***
- David Jensen, University of Arkansas
  dcjensen@uark.edu
- Irem Y. Tumer, Oregon State University
  irem.tumer@oregonstate.edu

Overview of Presentation

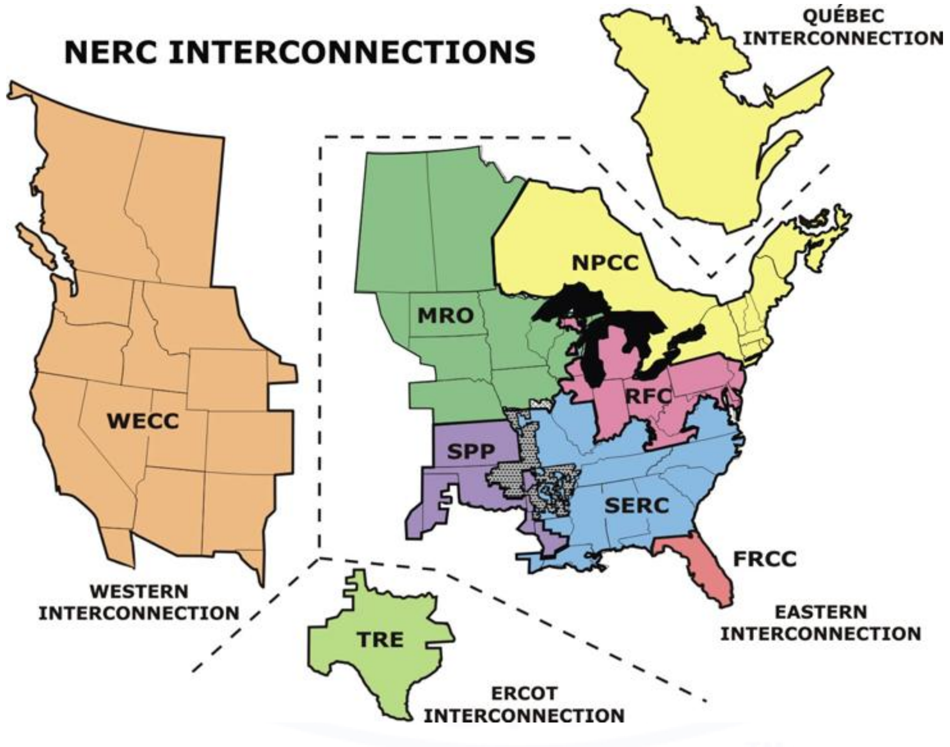
- Our experiences with Model Center in the classroom
- Lessons learned from implementing Model Center into the curriculum
- Best practices and guide for implementing Model Center into your curriculum
- Future efforts in using Model Center in the classroom

Background

- ModelCenter introduced in OSU complex system design course at in 2008 by Irem Tumer
- Steve Wall from JPL introduced the software to students
- Model Center has since been deployed to Colorado School of Mines and is in the process of deployment to University of Arkansas and CSUF

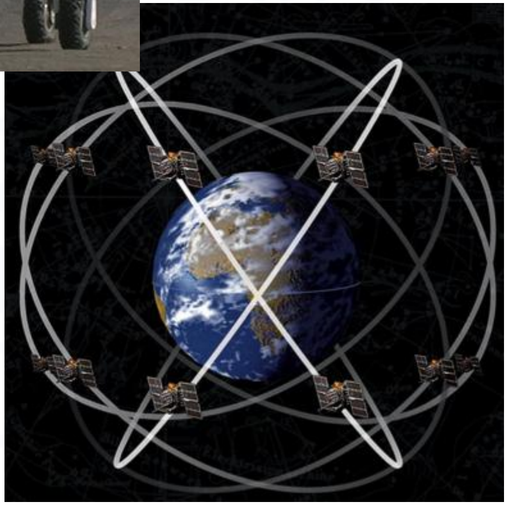
Model Center at Oregon State University

- Graduate course in Complex System Design
  - Teams of students develop models of complex systems
    - Space mission-related systems
    - Power grid interconnect modeling
  - Subsystems models developed by individual students and integrated in Model Center
  - Trade studies performed to identify preferred design solutions and understand design space



OSU Space Systems Example

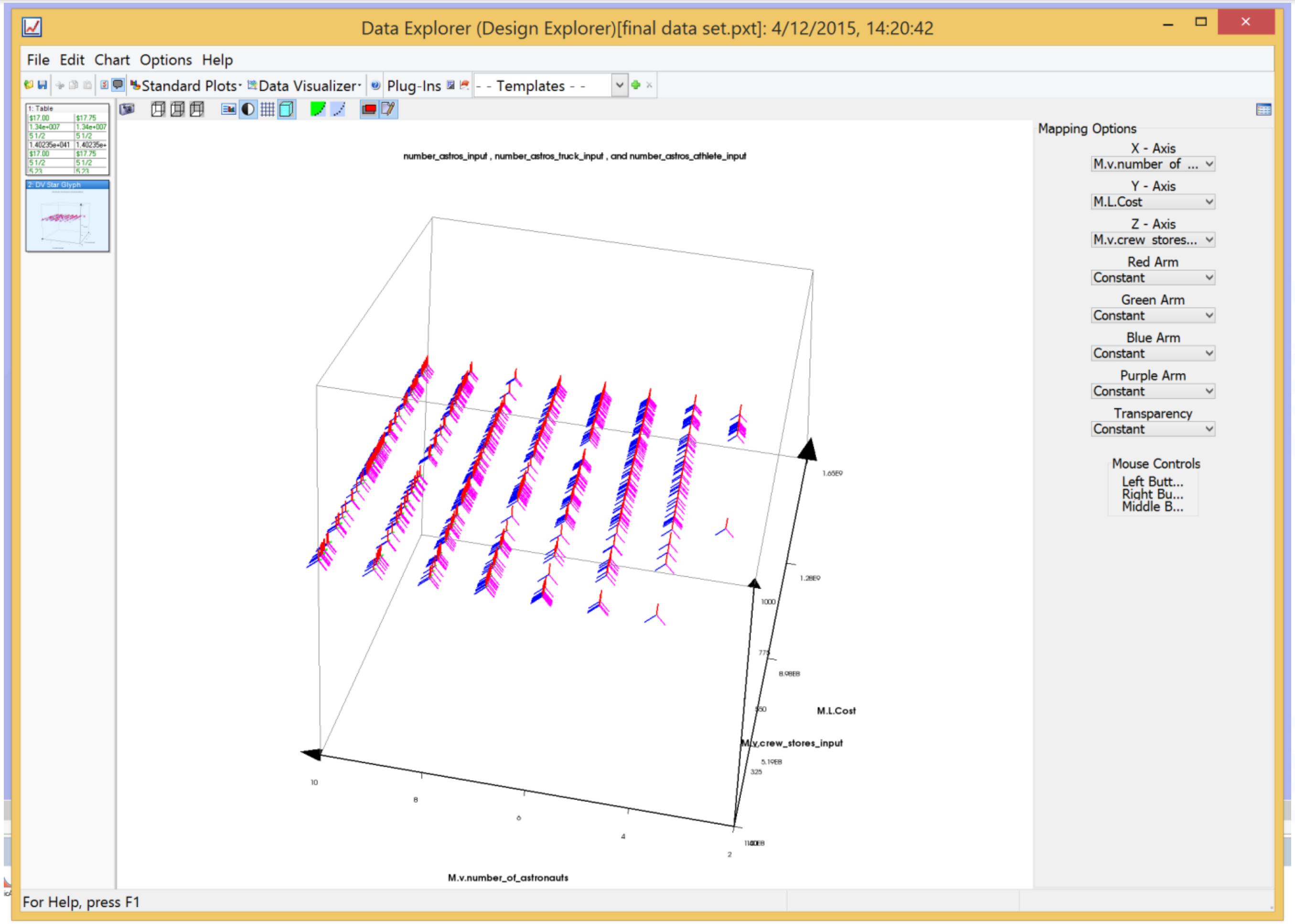
- Space System Models
  - Lunar crew transport system
  - Scientific satellite constellation
- Design Parameters and Constraints
  - Understand subsystem boundaries and import and export of energy, mass, and data
  - Used design space exploration tools to find optimal designs



Space Systems Example (Con't)

OUTPUTS	
Mass (kg)	100
Cost (USD)	100000
Power (kWatt)	5
Data Throughput (mBit/sec)	5
Volume (stowed) (m^3)	1
Volume (open for business) (m^3)	18
INPUTS	
Astronaut Mass	
VARIABLES	
Number of Astronauts to Carry	3
Cost per kg	1000
Power per kg carried	0.05
Equipment Mass (kg)	100
Samples to Return (kg)	100
Data Throughput	5
volume per kg	0.01
mass per kg carried	0.5
volume per astronaut	6

Space Systems Example (Con't)



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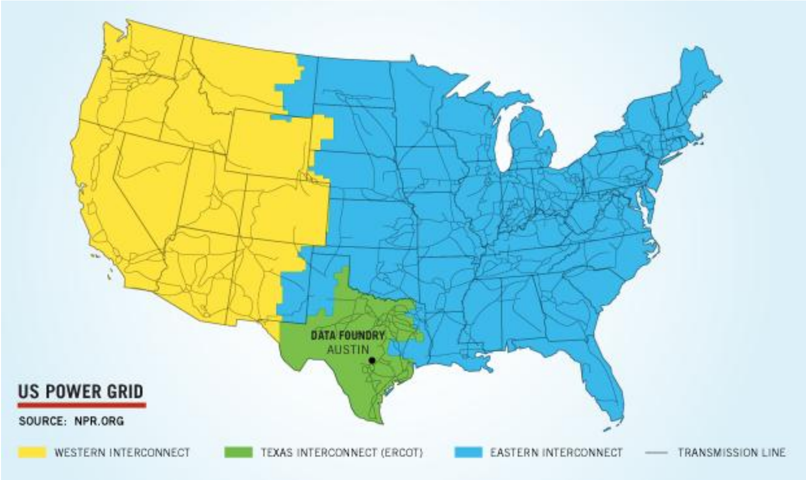
Electrical Power Grid Modeling Example

- Teams of students developed models of grid interconnects
  - Each team developed an interconnect model
    - Power generation, transmission, distribution, consumption
  - Modeled at a high level with varying time steps (hours to days)
- Students used trade space exploration to optimize each interconnect model



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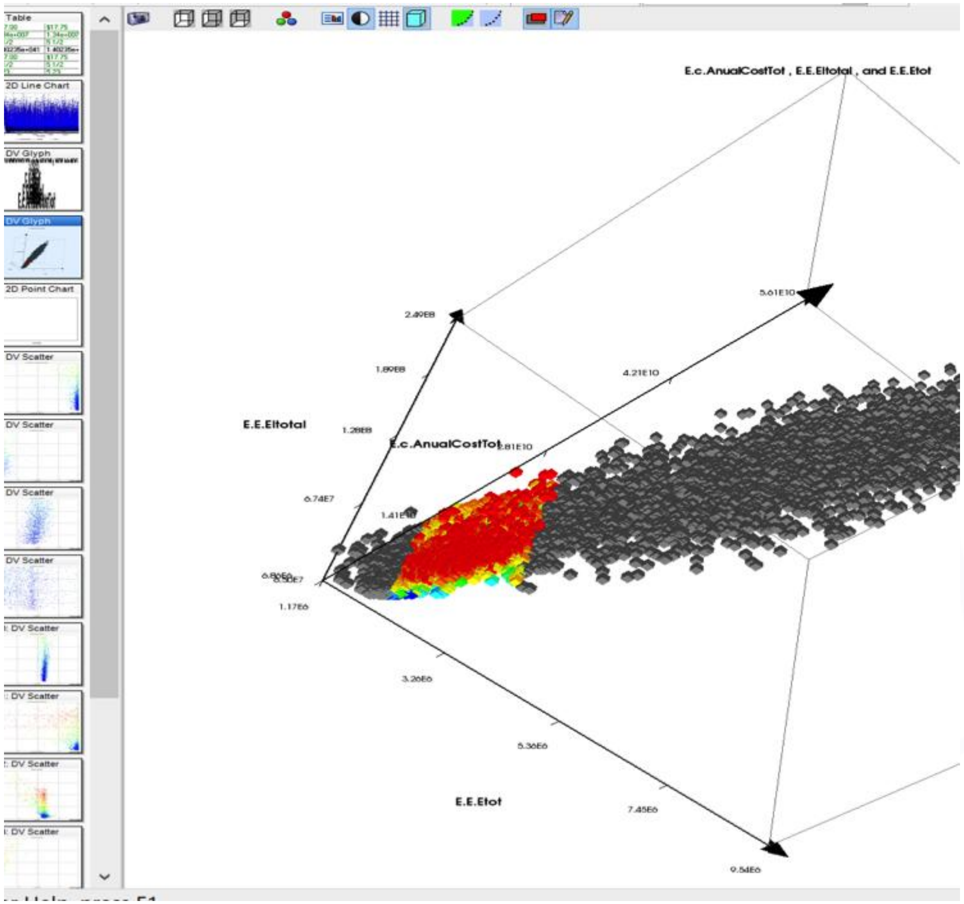
Electrical Power Grid Example (Con't)

- Students built models based on information from utilities and grid operators
- Students then linked interconnect models together to try trading power between interconnects
  - Negotiations between student groups on how much power to trade for how much money, etc.

Biomass		
Total Biomass Production	**211127**	**Mwh/year**
Current Biomass Prodution	16967	Mwh/year
New Biomass Prodution	200000	Mwh/year
Retired Biomass Production	5840	Mwh/year
Wind Turbines		
Total Wind Production	**278335**	**Mwh/year**
Current Wind Prodution	29595	Mwh/year
New Wind Prodution	263200	Mwh/year
Retired Wind Production	14460	Mwh/year
Energy Conserved		
Total Conserved Energy	**951300**	**Mwh/year**
Energy Conserved (industrial)	398700	Mwh/year
Energy Conserved (Residential)	552600	Mwh/year
Energy Bought/Sold		
Total B/S Energy	**13**	**Mwh/Year**
Energy Bought/sold from Quebec	2	Mwh/Year
Energy Bought from Western Interconnection	8	Mwh/Year
Energy Bought from Texas	3	Mwh/Year

Electrical Power Grid Example (Con't)

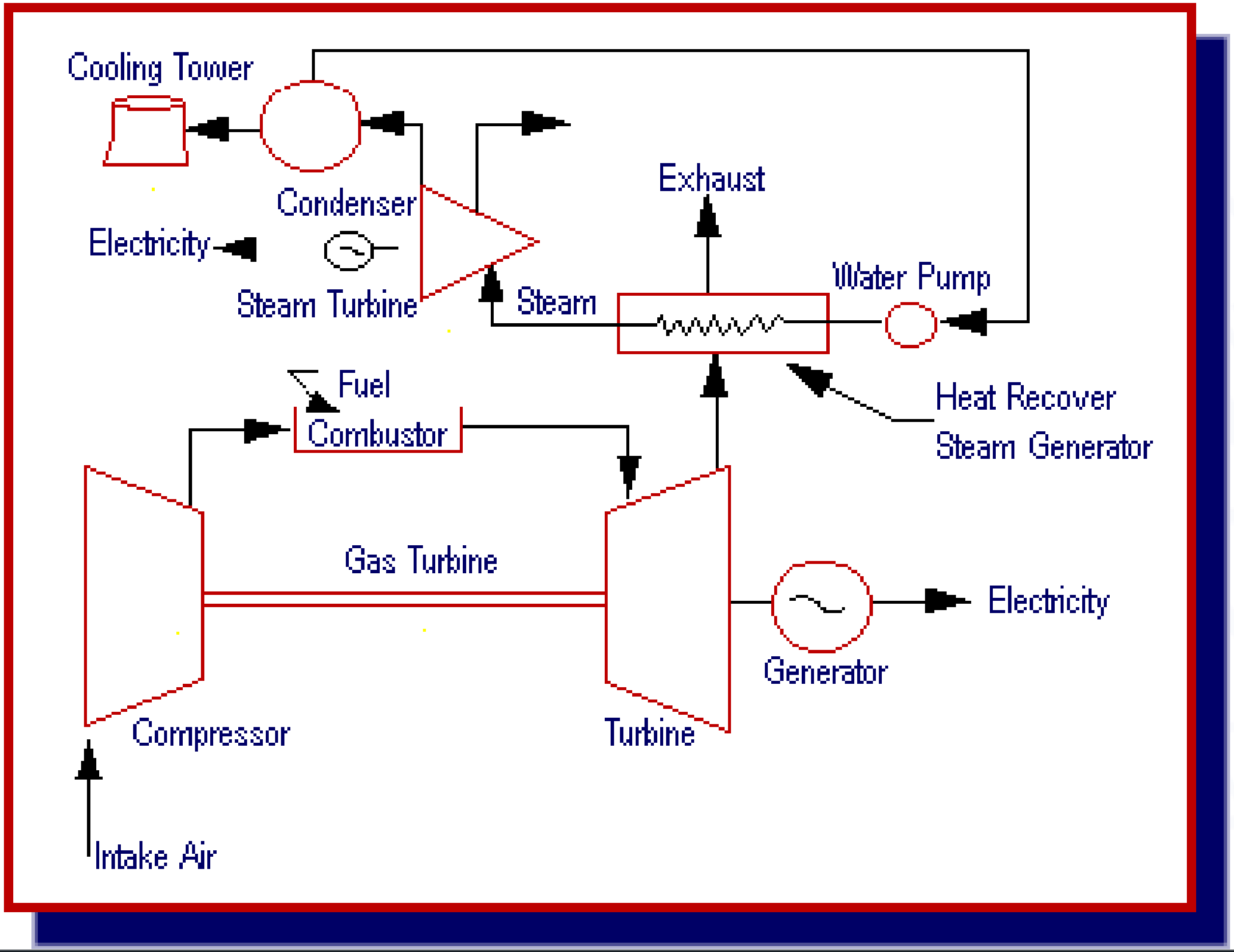
- Trade offs between Energy, Environmental Impact, and Cost



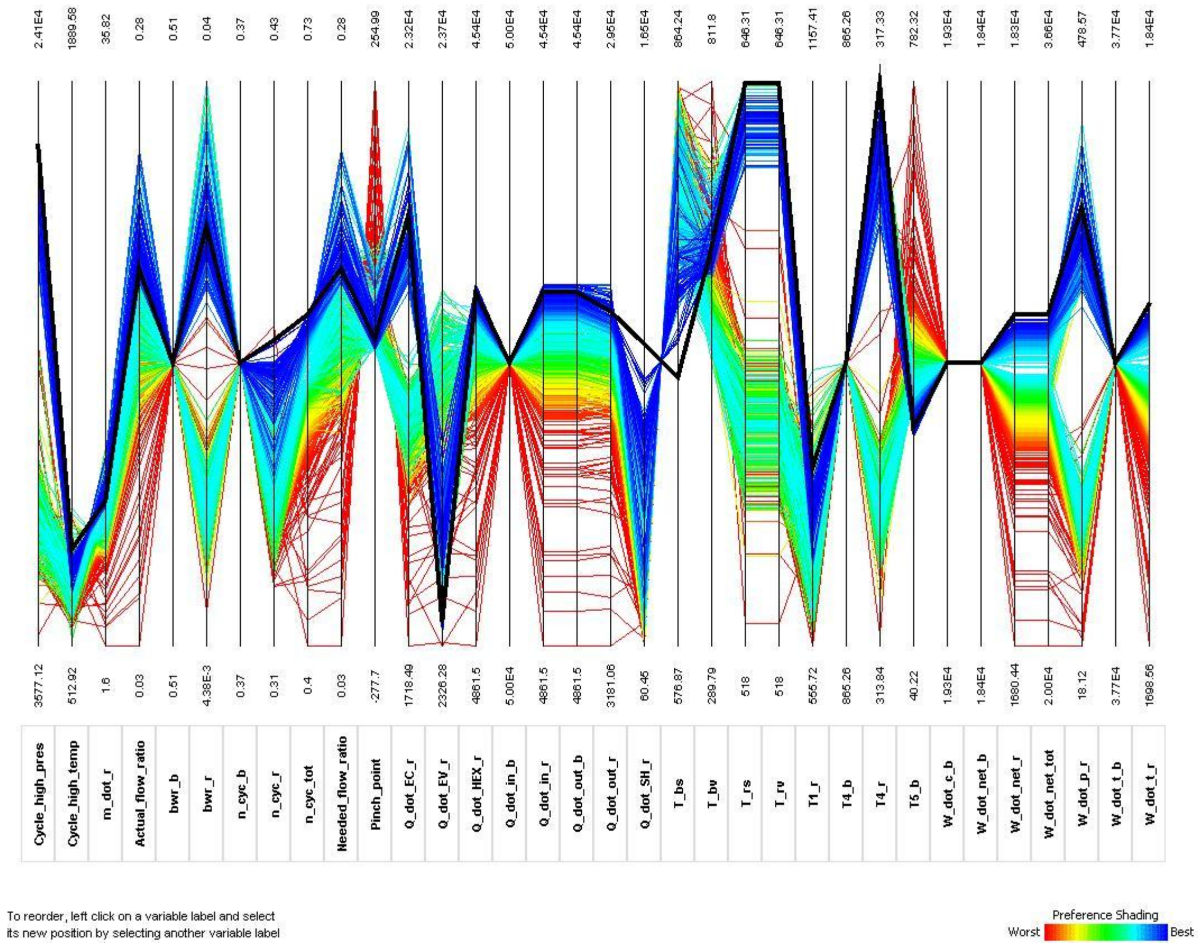
Combined Brayton/Rankine Cycle Analysis

- Students who were introduced to Model Center in the complex systems class quickly began using the software in other classes
- Advanced thermal power systems class project to find optimal design of combined Brayton/Rankine cycle gas co-gen plant
- Students developed model in Engineering Equation Solver
  - Used Model Center to find optimal design through optimization package

Brayton/Rankine (Con't)



Brayton/Rankine (Con't)

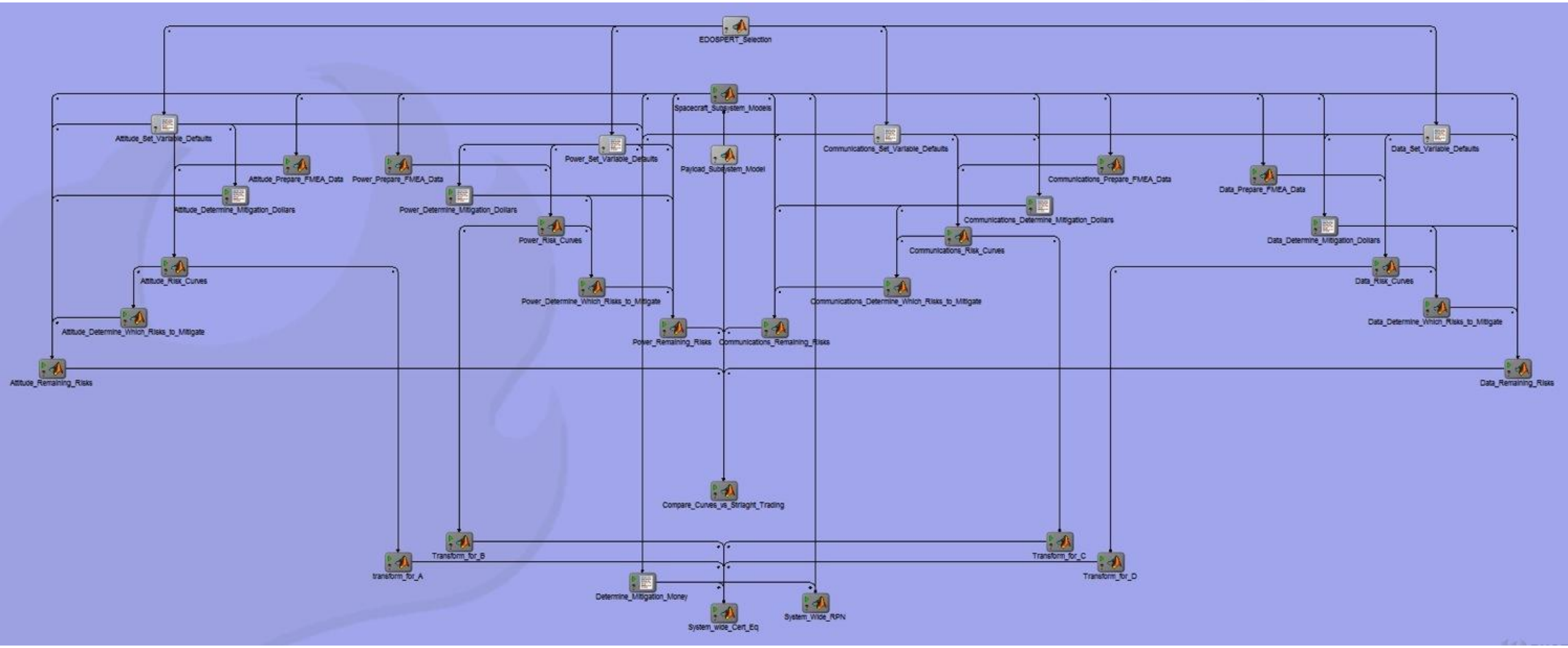


Student Research Using Model Center

- Several students used Model Center as part of their masters and doctoral research after being exposed to the software in class.
  - Trade Study Research
  - Failure Modeling
  - Power Grid Design

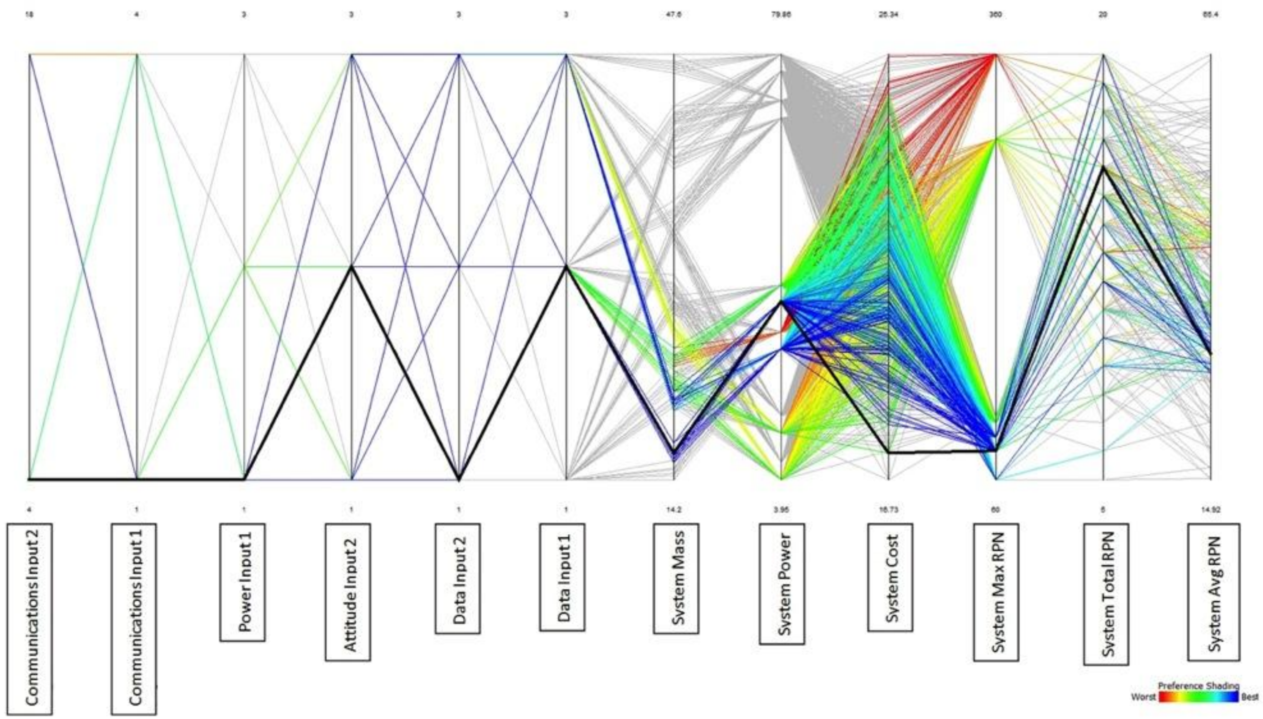
Trade Study Research

- Examined how to trade risk metrics between subsystems in a trade study



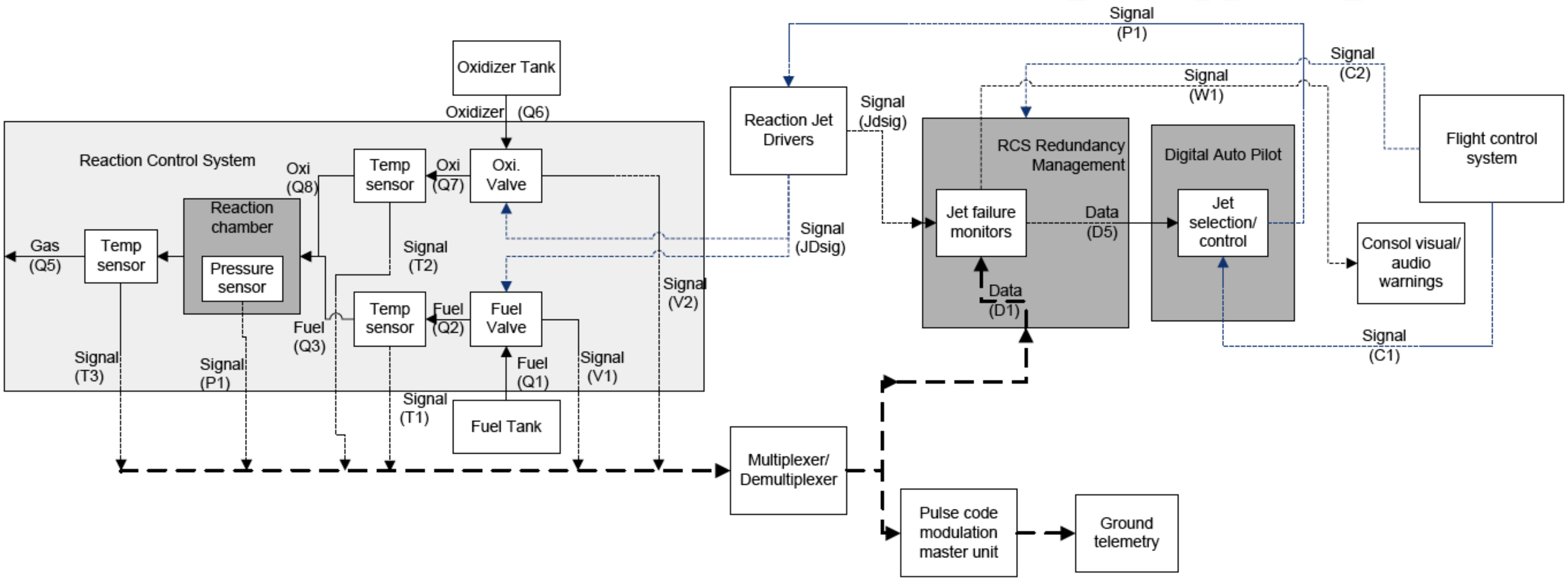
Trade Study Research (Con't)

- Model Center provided a good platform for data collection and visualization of the method



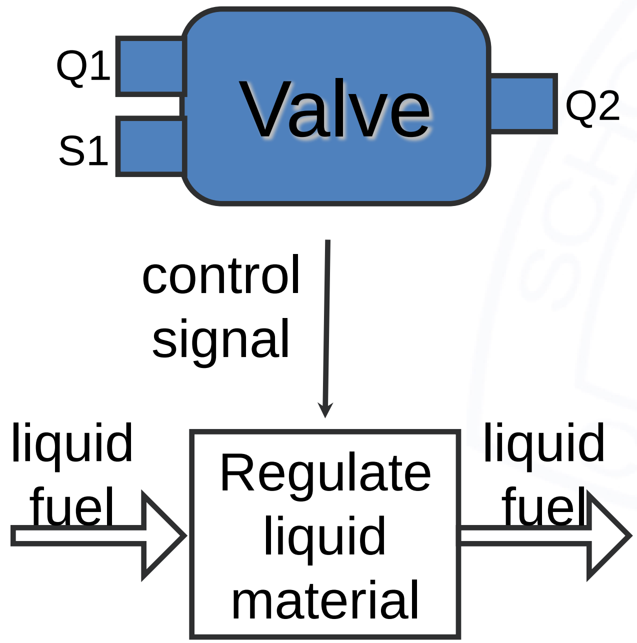
Failure Modeling Research

- Testing of Function Failure Identification and Propagation model using Model Center



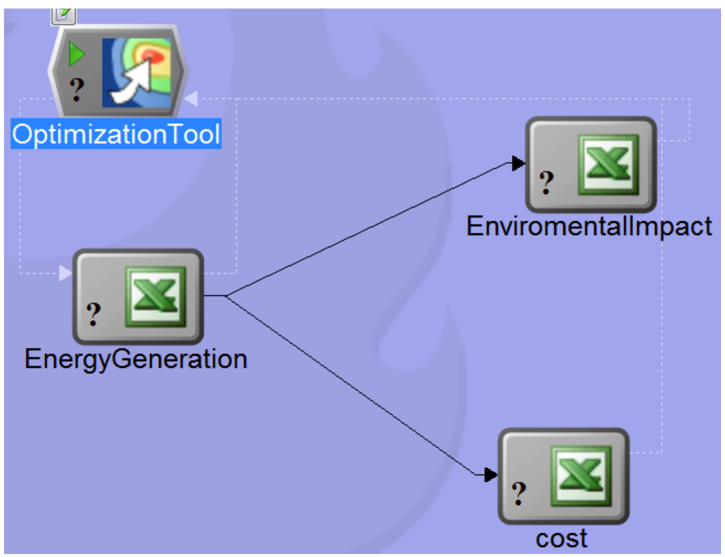
Failure Modeling Research (Con’t)

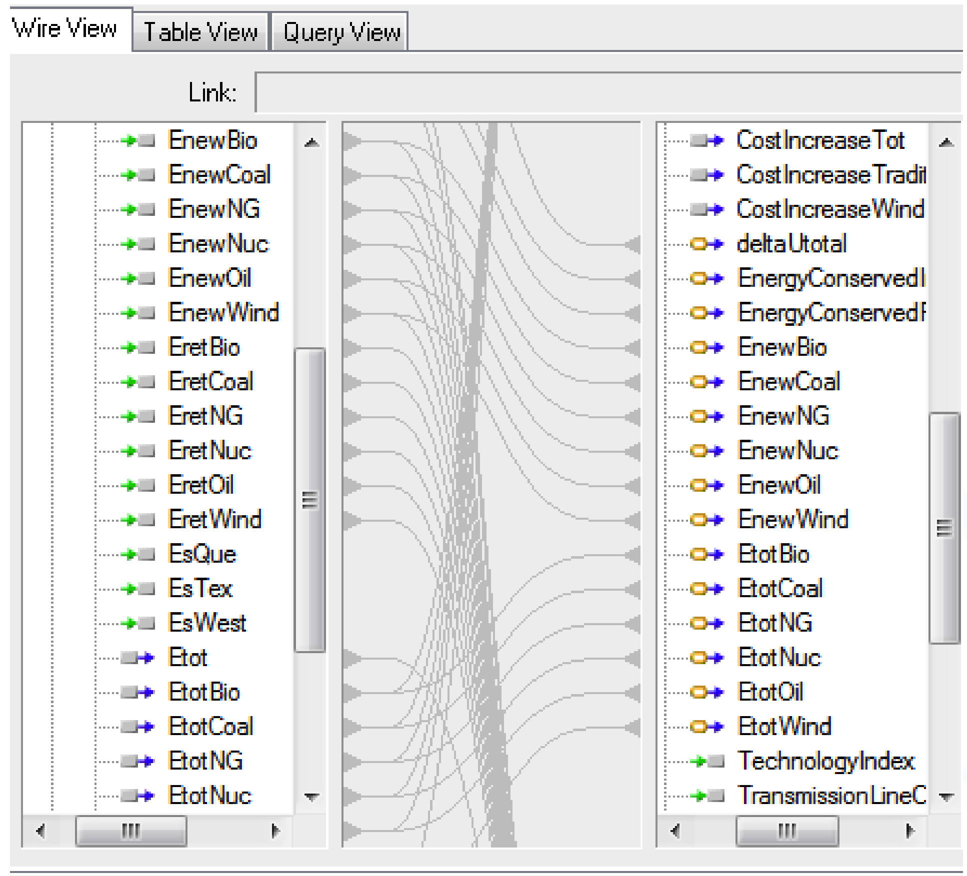
- Code written in MATLAB and trial runs conducted in Model Center to vary input parameters



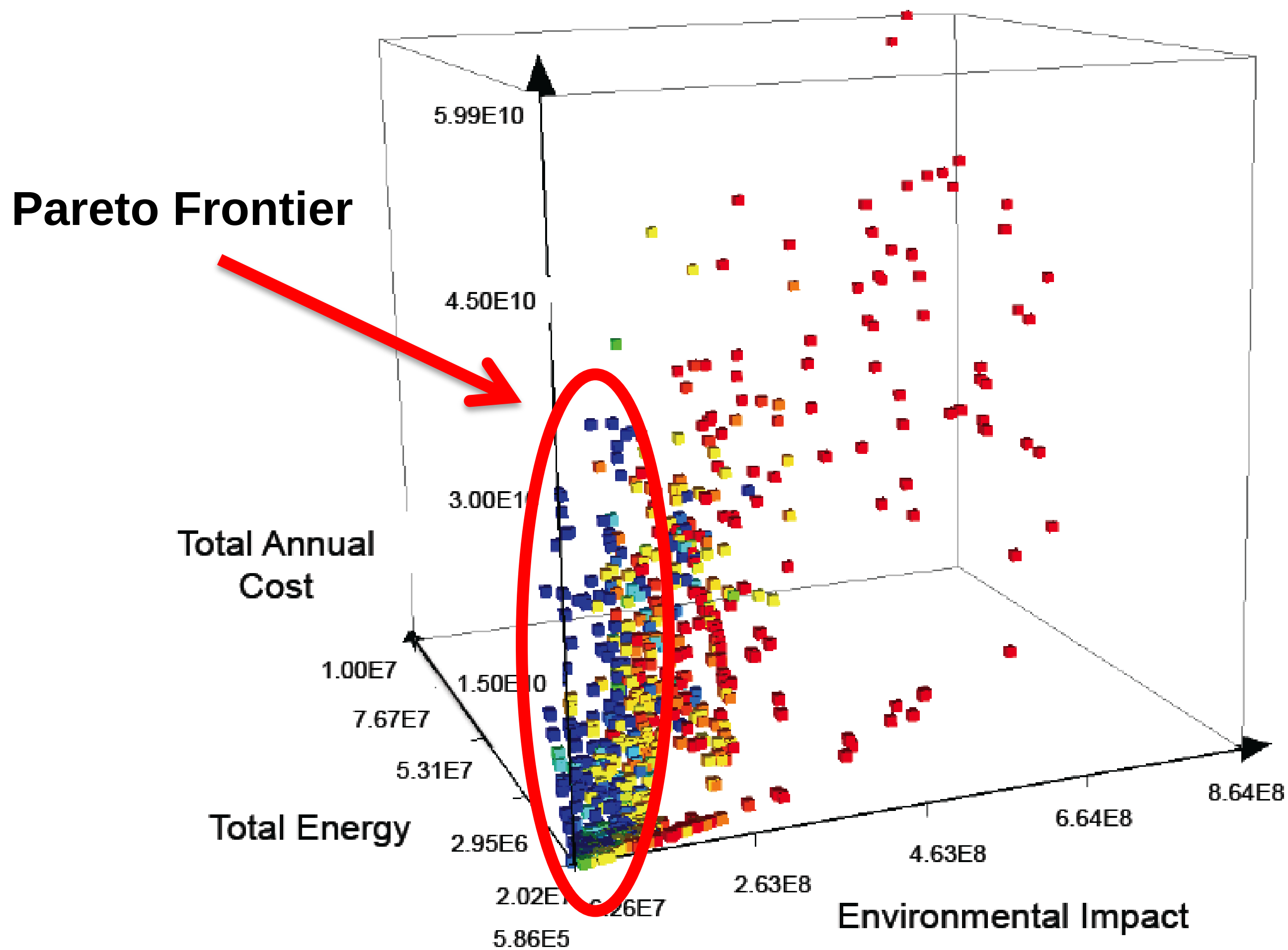

```
if s1 == closed
if Q2== 0
regulate_mat= healthy
else
regulate_mat= lost
elseif s2== open
if Q2==Q1
regulate_mat= healthy
elseif Q2== 0
regulate_mat= lost
else
regulate_mat= degraded
else
regulate_mat= lost
end
```

Power Grid Design Optimization





Power Grid Design Optimization (Con't)



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From Classroom to Research at OSU

- Graduate student research papers
  - D.L. Van Bossuyt, I.Y. Tumer. “Towards Understanding Collaborative Design Center Trade Study Software”, Upgrade and Migration Risks 2010 ASME International Mechanical Engineering Congress and Exposition, IMECE2010
  - D.L. Van Bossuyt, S. Wall, I.Y. Tumer. “Towards Risk as a Tradeable Parameter in Complex System”, Design Trades 2010 ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE2010
  - D.L. Van Bossuyt, C. Hoyle, I.Y. Tumer, R. Malak, T. Doolen, A. Dong. Toward an Early-Phase Conceptual System Design Risk-Informed Decision Making Framework 2012 ASME International Mechanical Engineering Congress and Exposition, IMECE2012
  - D.L. Van Bossuyt, C. Hoyle, I.Y. Tumer, A. Dong, T. Doolen, R. Malak. Toward Considering Risk Attitudes in Engineering Organizations Using Utility Theory 2012 ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE2012
  - D.L. Van Bossuyt, C. Hoyle, I.Y. Tumer, A. Dong. Considering Risk Attitude Using Utility Theory in Risk-Based, Design Arti cial Intelligence for Engineering Design, Analysis, and Manufacturing, Vol. 26, No. 4, pp. 393-406. September 2012.
  - D.L. Van Bossuyt, I.Y. Tumer2, S. Wall. A Case for Trading Risk in Conceptual Design Trade Studies, Research in Engineering Design, (DOI) 10.1007/s00163-012-0142-0. September 2012.
  - **J. R. Piacenza**, I. Y. Tumer, C. Hoyle, and J. Fields, 2012, "Power Grid System Design Optimization Considering Renewable Energy Strategies and Environmental Impact", *International Mechanical Engineering Congress & Exposition*, Houston, Texas.

Complex Engineered Systems Design Lab

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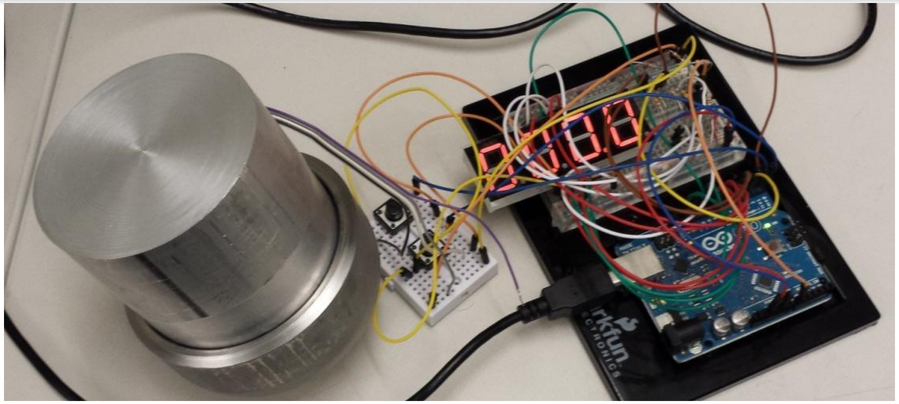
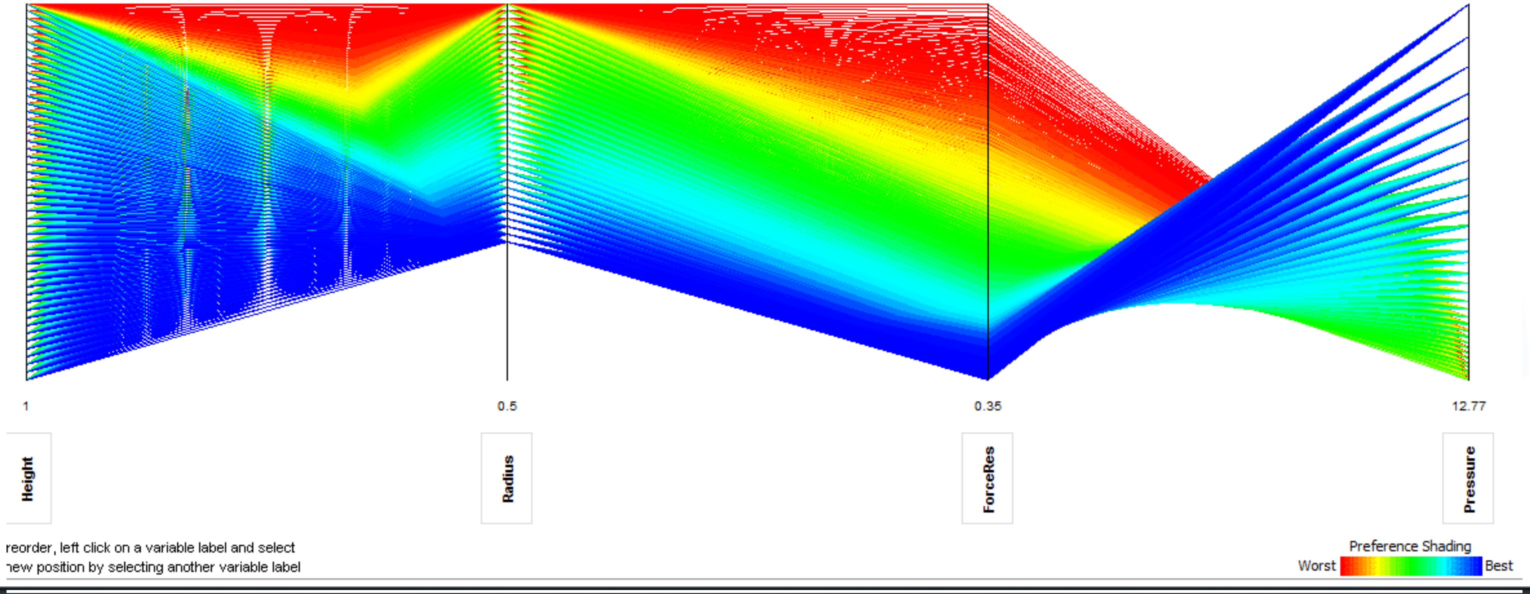
Model Center at Colorado School of Mines

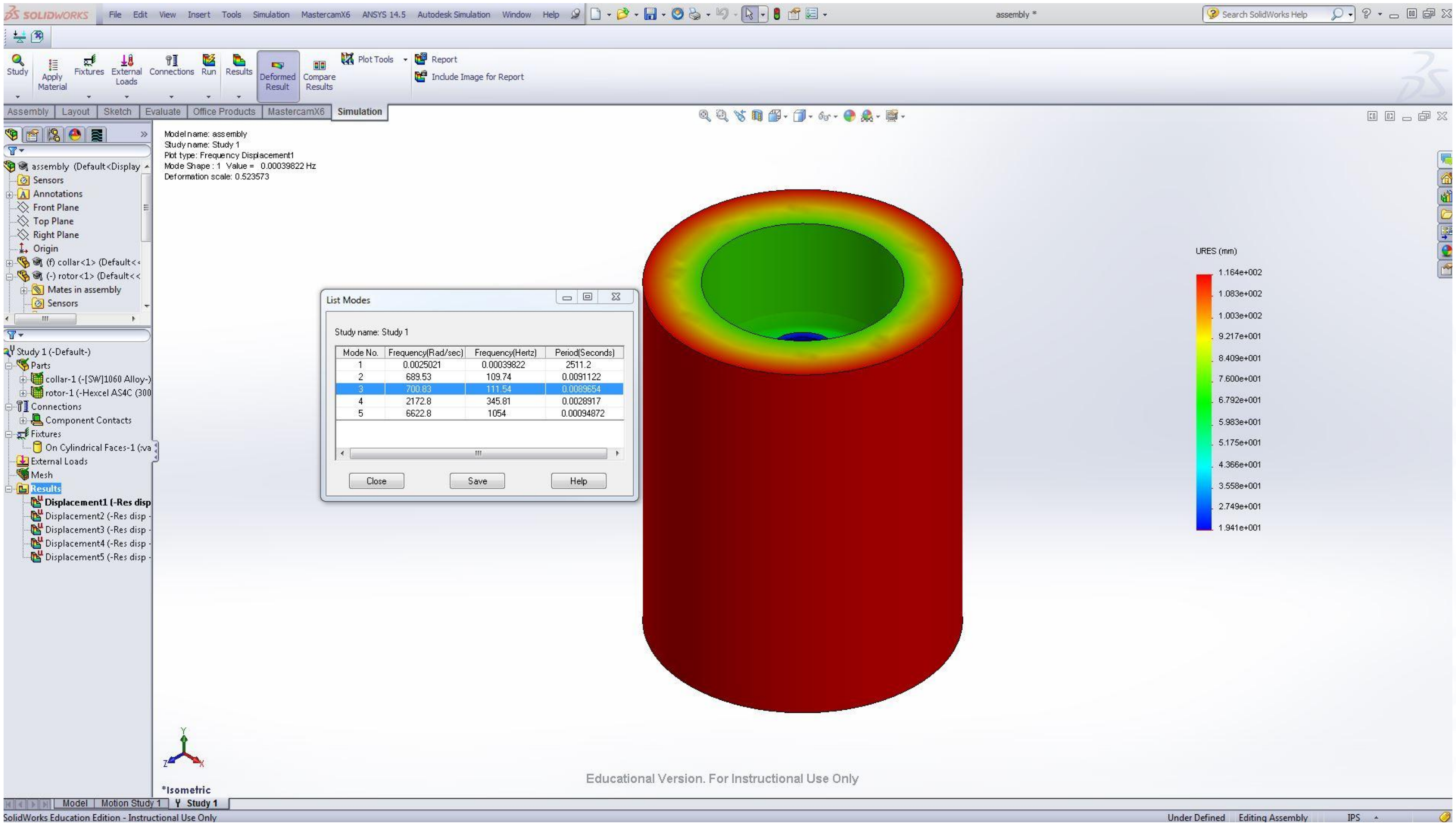
- Graduate class in Advanced Product Design
  - Individual students developed models of household products
- Graduate class in Risk and Reliability Analysis
  - Individual students developed models of complex systems
- Undergraduate class in Machine Design
  - Groups of students developed models of machine design problems to search for optimized solutions

Digital Fluid-Pressure Scale

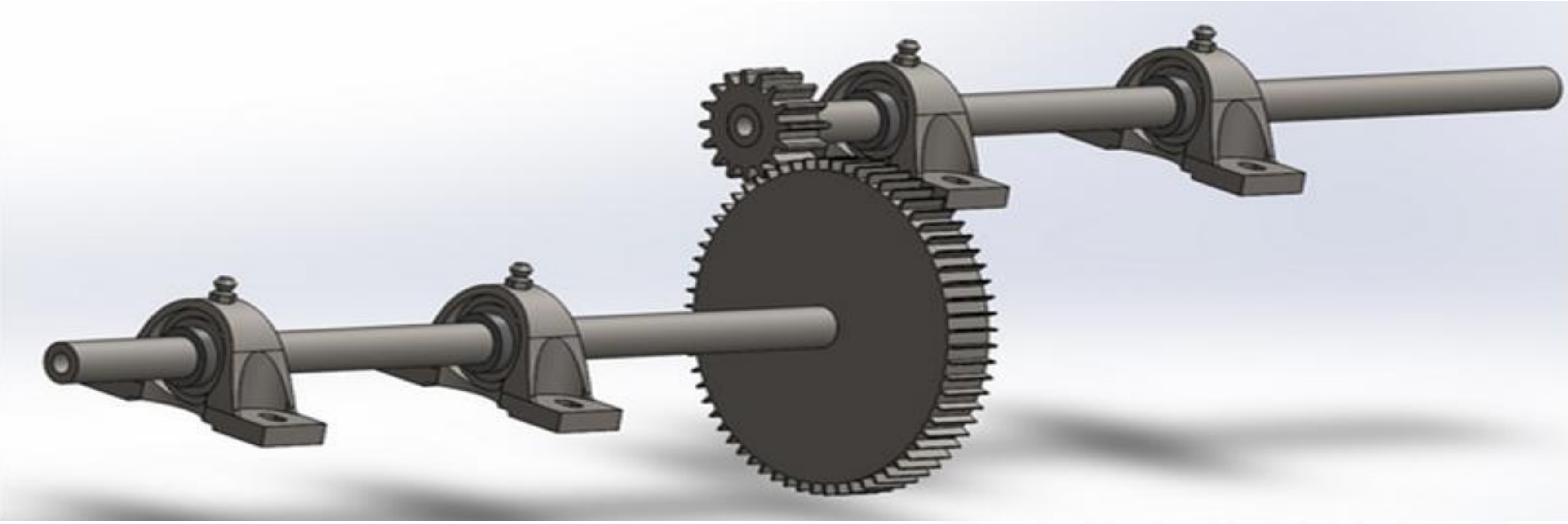




Energy Storage Flywheel for ISS



Wind Turbine Drivetrain



Key Concepts Students Learned Via ModelCenter

- System and subsystem modeling
  - Topic introduced via simple Excel models
    - Some students expanded to MATLAB and Engineering Equation Solver for specific topics
  - Students learned how to apply engineering analysis tools to design problems through modeling of systems
- Design space exploration
  - Used ATSV-derived design space visualization tools to demonstrate to students how multi-dimensional design spaces interact with system models
  - Students better understood that there are families of potential solutions rather than single point solutions

Key Concepts Learned (Con't)

- Trade Studies
  - Showed students how changing parameters in one subsystem impacts other subsystems and final design
- Pareto Optimal solutions
  - Understanding the true meaning of design trade offs
- Concurrent Design
  - Integrating system level constraints into subsystem design
  - Similar to JPL's Team-X group

Lessons Learned

- Important to do live demos in class
  - Build simple system models
  - Use visualization tools to describe design spaces and finding areas to further develop models
- Important to have students use software in class
  - Many students are being introduced to the concept of system modeling for the first time
  - Many students have not encountered situations where there is more than one potential solution to a problem
  - Changing objective weightings in multi-objective optimization is "eye-opening for students"

Lessons Learned (Con't)

- Students working with systems unfamiliar to them struggle more initially but often produce better results
  - Design fixation occurs when a student is too familiar with a system they are implementing in Model Center
    - Ignore potential alternative design solutions and make the results fit pre-conceived notions
  - Students working with an unfamiliar system will have to do more background research to understand the system but will be much more open to alternative system configurations and make full use of Model Center tools

Lessons Learned (Con't)

- Close communications with campus IT support is critical for the success of Model Center in the classroom
  - License servers can unexpectedly crash
  - License file expires periodically and must be renewed
  - Occasional trouble with students using VPN to access license server from home

Best Practices for Implementing Model Center in the Classroom

- Courses with a heavy model-based design component are most appropriate for Model Center
  - Analysis courses can be good places for students to use Model Center once they have already learned the software but are not good places to introduce Model Center
- Class sizes of above 40 become difficult to interact with individual students in a meaningful way when using Model Center

Best Practices (Con't)

- Students need a strong introduction to Model Center through a live demo before attempting to use the software on their own
  - Attempts with using self-study guides were not as successful as live in-class demos
  - Details of how the software works can be lost without a lecturer drawing specific attention to known problem areas

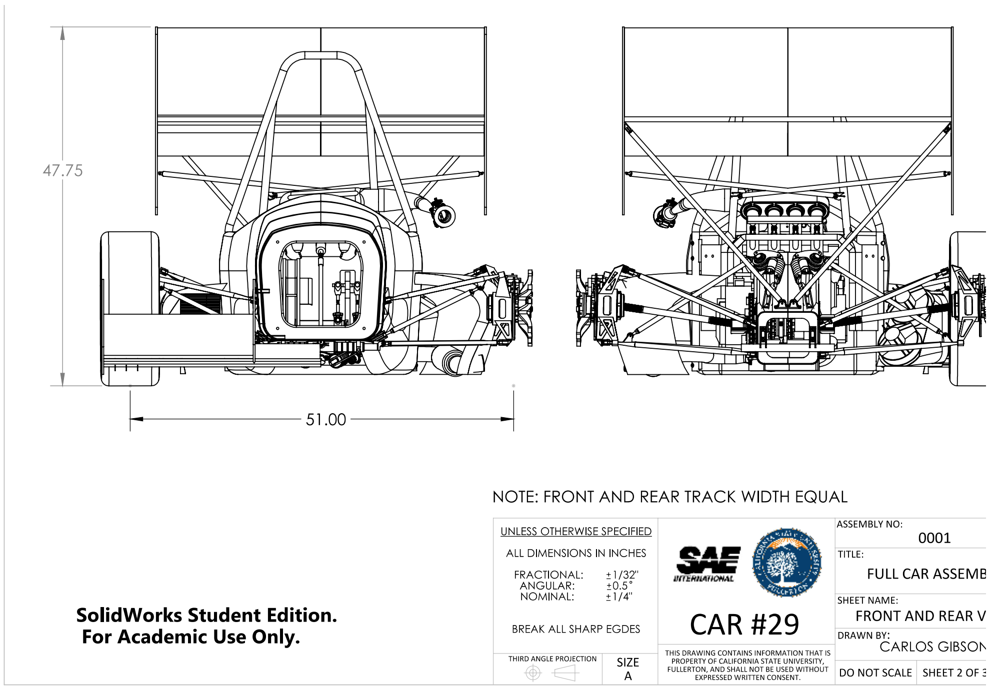
Best Practices (Con't)

- Undergraduates are more successful when provided with a system to model rather than being asked to find a system they want to model
  - In our experience, canned projects using Model Center go more smoothly for undergraduates
  - Many undergraduates seem to have troubles identifying good candidate systems for modeling assignments
  - Less stressful on busy undergraduates to be provided with a system than to ask them to find one on their own

Best Practices (Con't)

- Example files are useful for students to refer to although direct interactions with people who understand software are more beneficial
  - We have found that reference documents are good for referencing but not as beneficial to teach Model Center concepts
  - Having an instructor available and actively working with students helps students to progress with using Model Center much more rapidly and with less frustration

Pending Implementation at CSUF and UoA



- CSUF Teaching Lab

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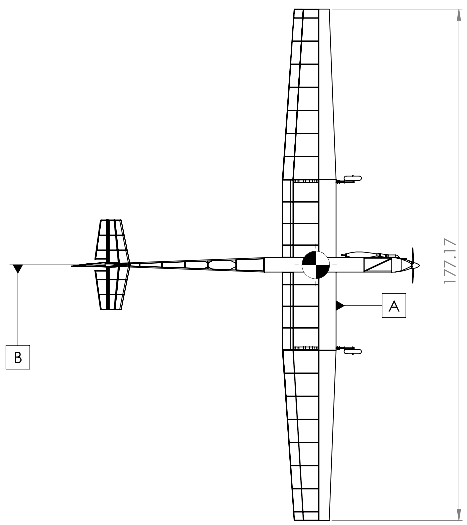
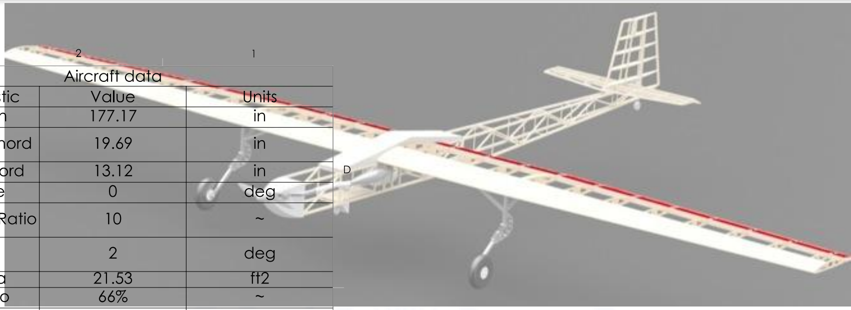
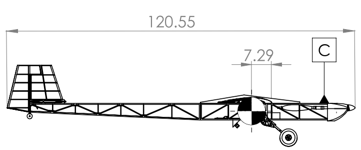
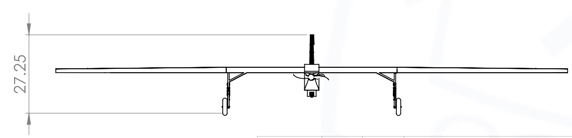
Pending Implementation at CSUF – SAE UAV





Aircraft data		
Characteristic	Value	Units
Wing Span	177.17	in
Wing Root Chord	19.69	in
Wing Tip Chord	13.12	in
Incidence	0	deg
Wing Aspect Ratio	10	~
Washout	2	deg
Wing Area	21.53	ft2
Taper Ratio	66%	~
Wing Airfoil	Naca 63-510 a=0.3 mod	~
Aileron Span	58.96	in
Aileron Area	241.7	in2
Rudder Span	16.15	in
Rudder Area	111.0	in2
Elevator Span	31.1	in
Elevator Area	259.0	in2
Flap Span	27.03	in
Flap Area	291	in2
Propeller	12.25 x 3.75	~
Engine	JF 46 by Jett Engineering	~
Empty Weight	7	lbf





Weight and Balance: referenced from datum A			
Sub-Assembly	Weight(lbf)	Xcg (in)	Moment (in-lbf)
Basic Weight	7.00	-8.84	-61.88
Fuel	0.63	0.30	0.189
Expellable Cargo	3.00	-4.8	-14.4
Static Cargo-Wing	12.5	-4.92	-61.5
Static Cargo-Fuselage	2.5	-28.43	71.08

	NAME	DATE
DRAWN	Nelson Koys	3/9/2015
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

School: California State University Fullerton
TEAM Name: Titan Uav: Advanced Class
SIZE B TEAM NO. 227 REV
SCALE: 1:30 WEIGHT: SHEET 1 OF 1

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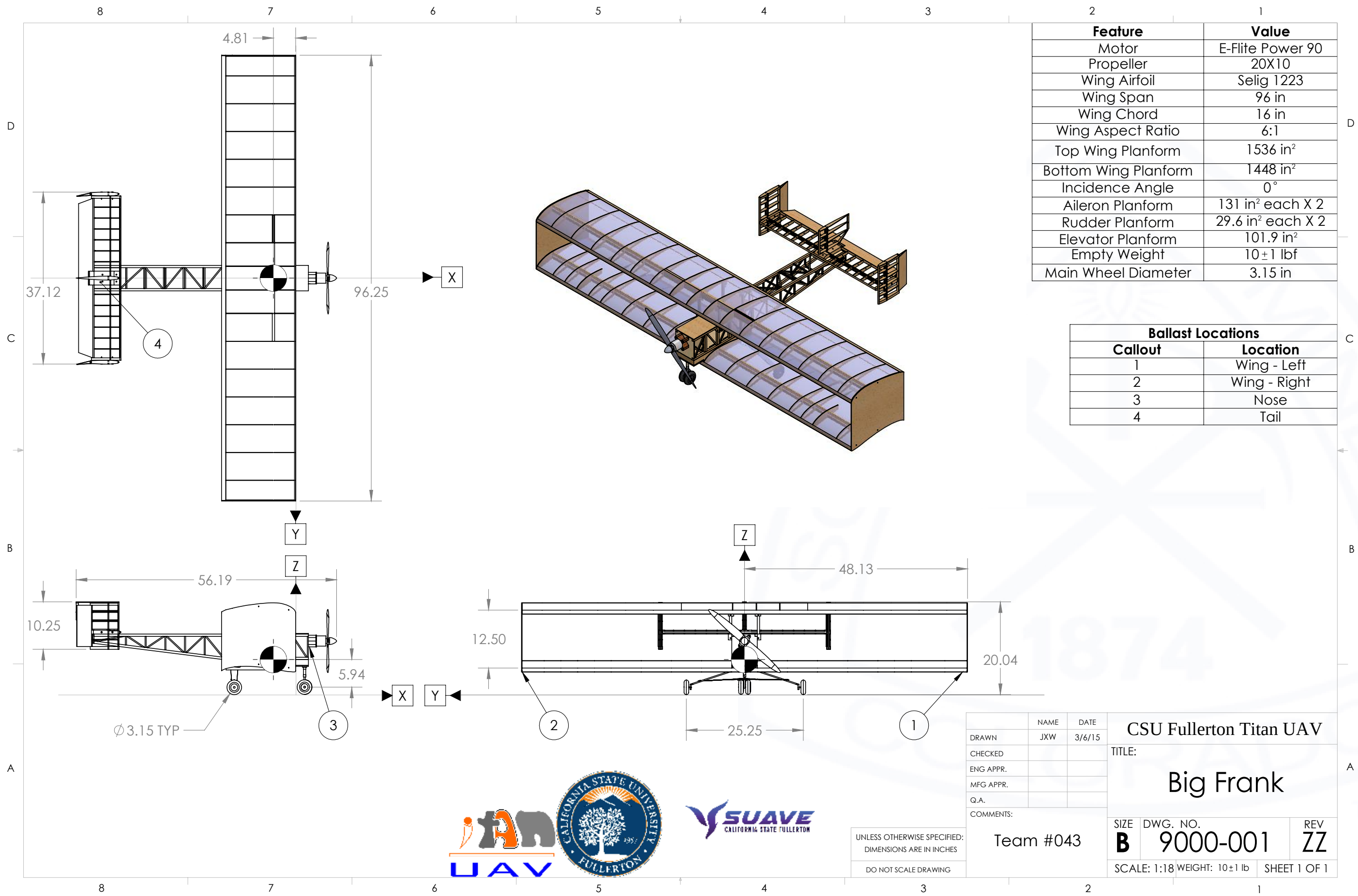

Feature	Value
Motor	E-Flite Power 90
Propeller	20X10
Wing Airfoil	Selig 1223
Wing Span	96 in
Wing Chord	16 in
Wing Aspect Ratio	6:1
Top Wing Planform	1536 in^2
Bottom Wing Planform	1448 in^2
Incidence Angle	0°
Aileron Planform	131 in^2 each X 2
Rudder Planform	29.6 in^2 each X 2
Elevator Planform	101.9 in^2
Empty Weight	10±1 lbf
Main Wheel Diameter	3.15 in

Ballast Locations	
Callout	Location
1	Wing - Left
2	Wing - Right
3	Nose
4	Tail

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Conclusions

- Model Center can be a valuable classroom tool to teach model-based design and systems engineering
- Strong instructor-student interaction and group work help students to learn Model Center core concepts quickly
- Potential for Model Center to be used as a tool throughout engineering curriculum but the Model Center introduction needs to be done in an appropriate course setting

Questions?

- Thank You for Your Time!

- Joseph Piacenza – jpiacenza@fullerton.edu