On Advancing Learning
In An Upper-level Engineering Course

Narayanan Komerath
Professor
Daniel Guggenheim School of Aerospace Engineering
Georgia Institute of Technology

"Don't send us CFD experts, or EFD experts,
we have no shortage of those.

*Please do send us UFDs - who **understand** fluid dynamics!"*

- Top level aerospace engineer on the challenge in knowledge transfer, circa 2004.
- Requirement for graduates with the depth to enable knowledge transfer, and to develop the next generation of innovations.

Acknowledgments

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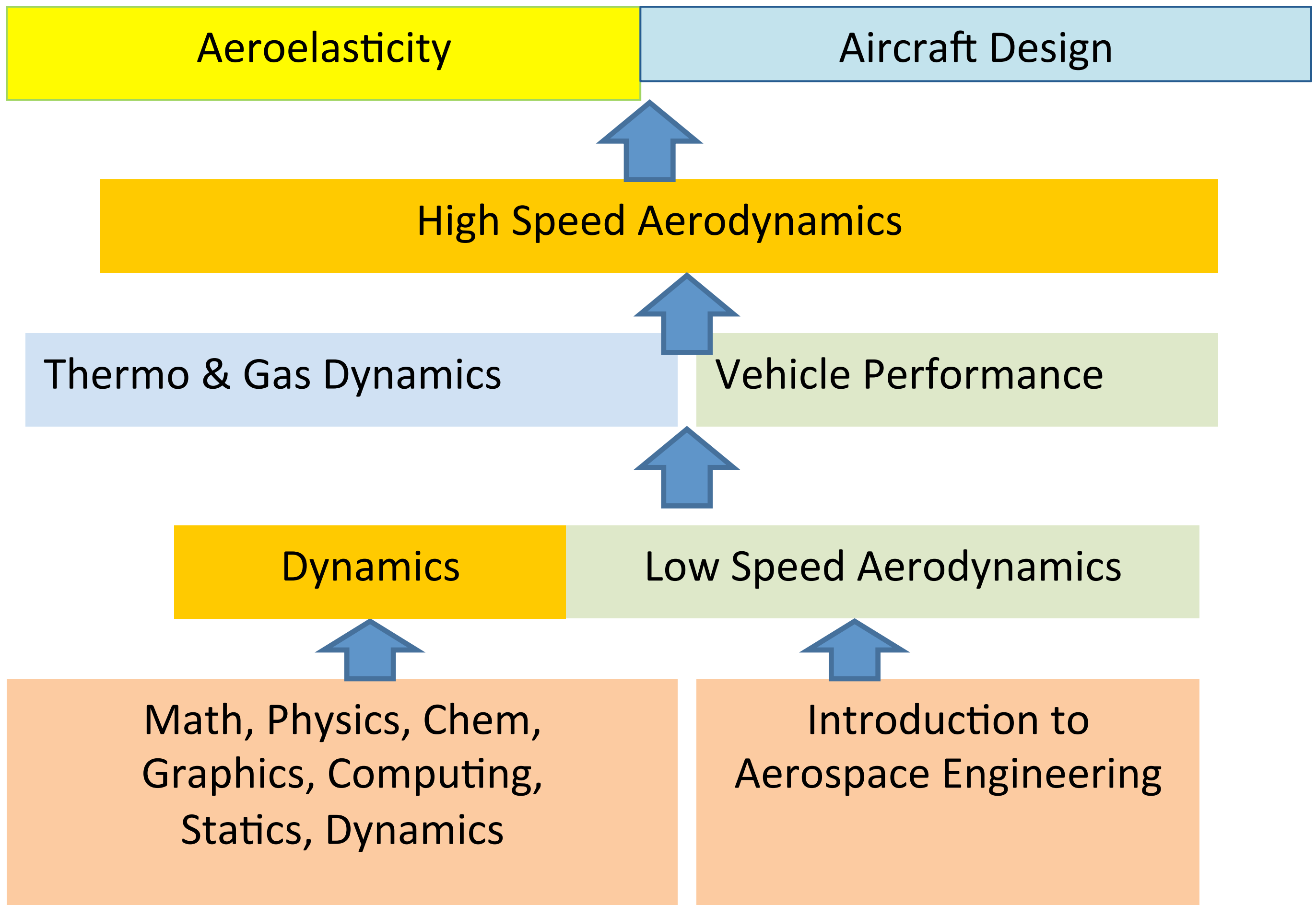
Summary Of Conclusions

- Curricular compression has cut the time available to convey depth in engineering.
- Student capabilities and motivation show a very large spread.
- Resistance to analytical skills poses a competitive threat.
- Deterrence to blind formula substitutions is needed, and can be achieved.
- An iterative learning solution succeeds, within the constraints of a core course.
- Proper opportunity to do integrative projects implies early completion of material.
- Rewards for excellence include bonus points and exemption from the final exam.
- End-of-semester student course evaluations appear to be dominated by those who have not attended class, read the syllabus nor paid attention to the Honor Code, yet this is the prime metric for teaching used by university administrators.
- Comments from the top students show strong concerns regarding the above – and success in encouraging depth of understanding.

AE Curricular Structure



•***Curricular compression has cut the time available to convey depth in engineering subjects***

Compression of the Engineering Core

AE3000 (3.3)

AE3001 (3.3)

AE3002 (3.3)

AE 4000 (4)

13.9 equivalent semester hours

AE2020 (3)

AE3004 (3)

AE3021(3)

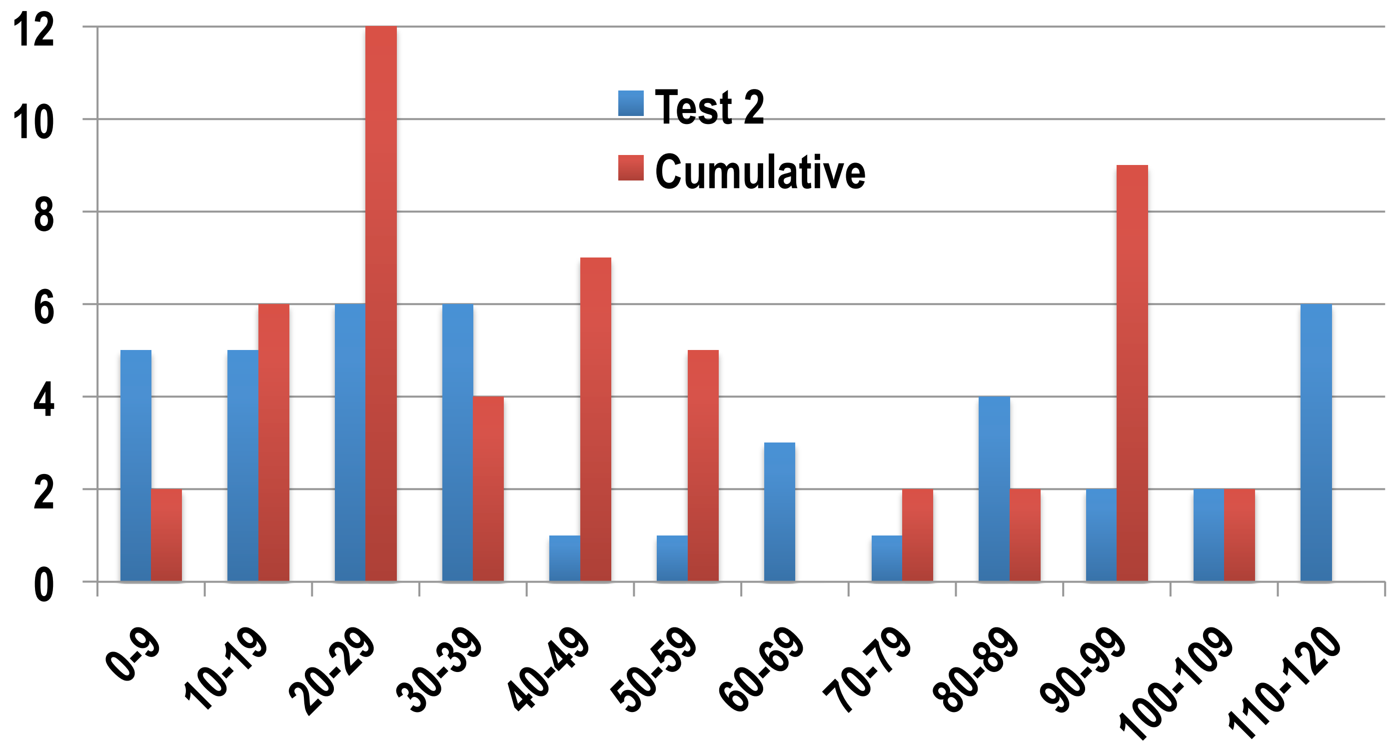
AE 3051(2)

11 semester hours

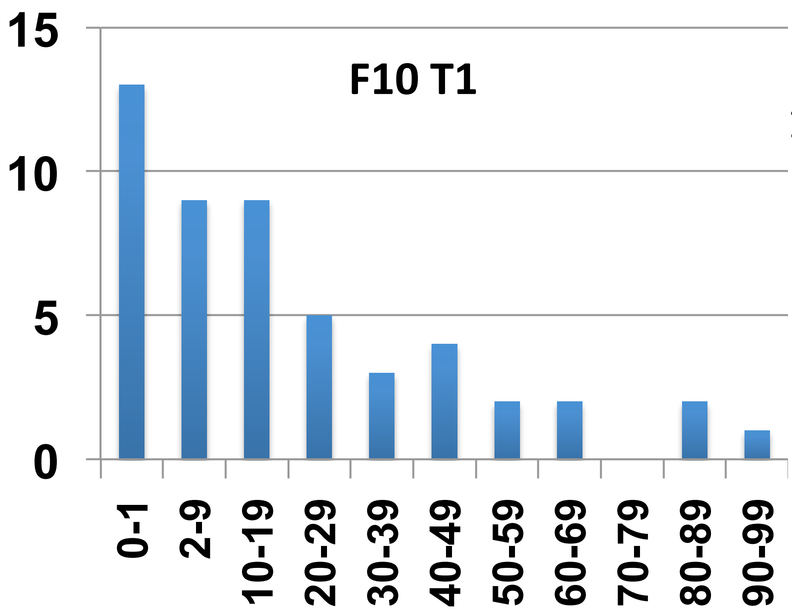
Added material

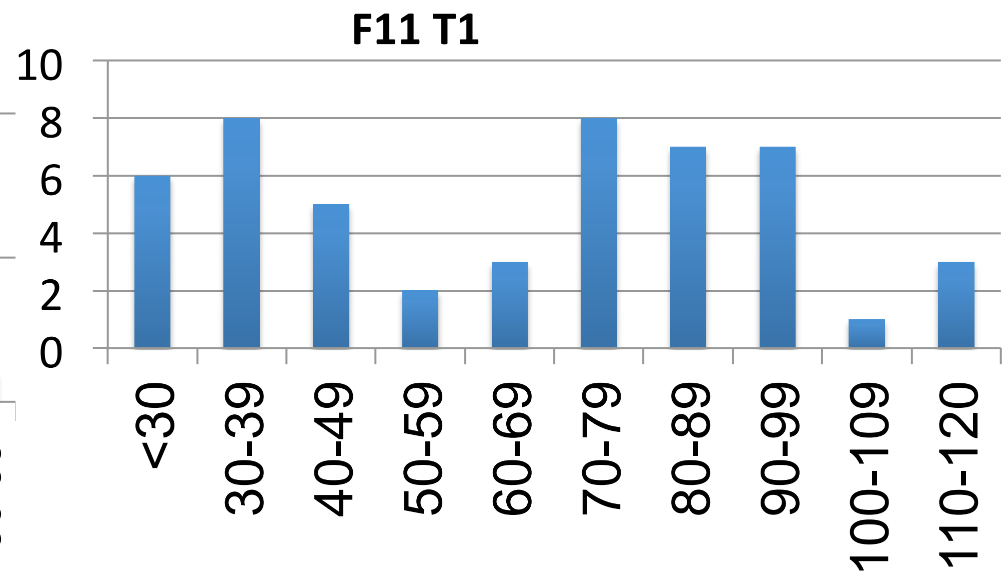
- Design content
- Compr b' ndry layers
- Slender wings & bodies
- Minimum drag analysis
- Integrative material
- Vehicle perf. review
- Numerical methods
- MatLab
- Web-based programs
- Presentations
- Lab Report-writing

- *Student capabilities and motivation show very large spread*



•*Resistance to analytical questions poses competitive threat*





Assessment Bases

1st half of semester: several homework assignments.
Tests mostly on theory, sense of numbers.

2nd half: large open-ended assignment to integrate theory and prepare the students to do aerodynamic design.
Done in teams of two,

a) Early 2000s – 2009: select two high-speed airplanes, and use aerodynamic analysis to determine their lift to drag ratio at a subsonic cruise condition and a supersonic dash (or cruise if possible) condition.
b) 2010: Liquid hydrogen SST based on demographics, carbon market/ fuel price issues and low-Mach parameter space.
c) 2011: Aerodynamics-based Missile Defense System for the CONUS
d) 2013: Aerodynamics of Large-Scale Runway-Based Space Launch for SSP

Tests on advanced methods and work on assignment.

Sp 2013: Choice given on large assignment vs. weekly problem sets. Few chose problem sets. Many more should have. ☹

Iterative Approach: Quit Lecturing Early, Let the Students Think. Reward those who do!

Aerospace Digital Library/
EXTROVERT Resources

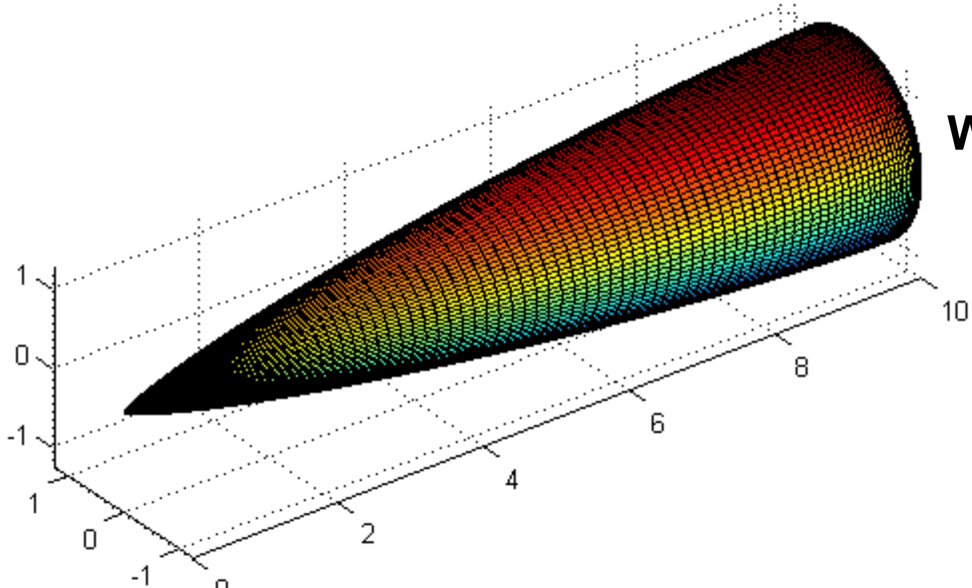
- Notes
- Examples
- eBooks
- Concept Essays
- Advanced concept projects
- Results from student work

Classes
Homework
Tests

More in-depth learning
"On-the-job experience"
Innovation confidence

Large Integrative Assignments

What the students have been doing



Wave drag minimization

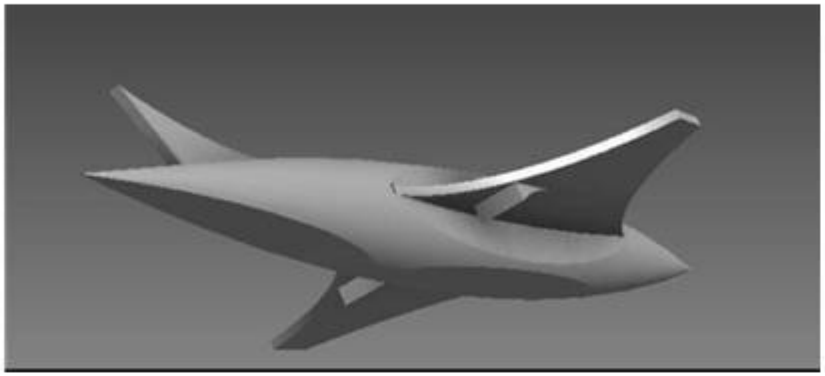
Sonicruiser, courtesy Boeing Co.

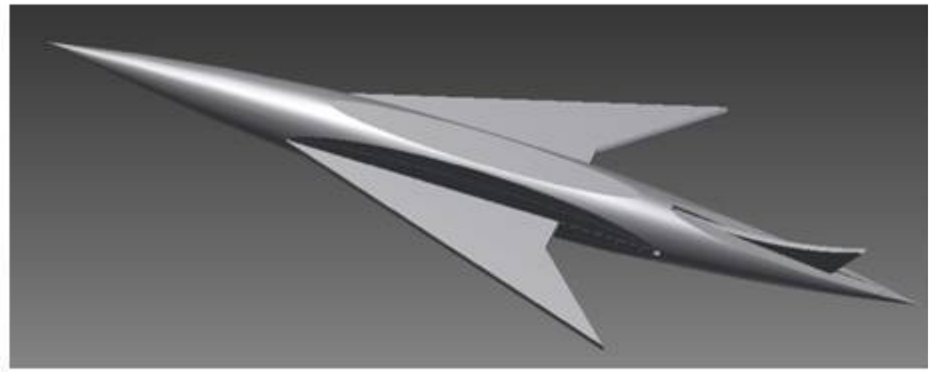
Aerodynamics of Missile Defense System

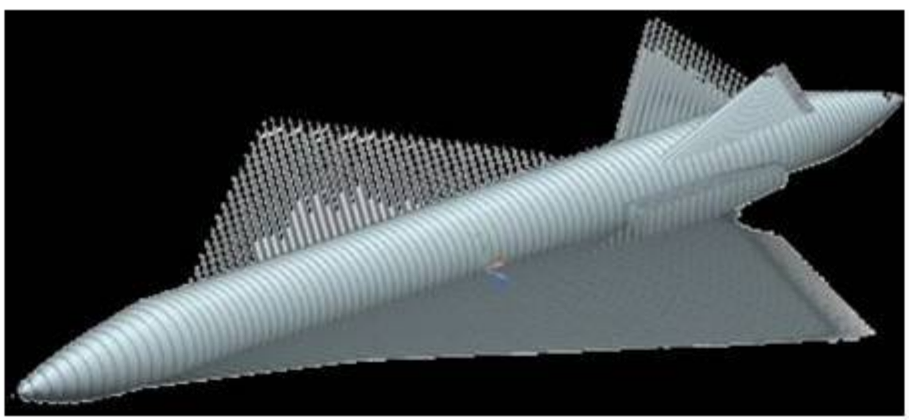
SST exploration

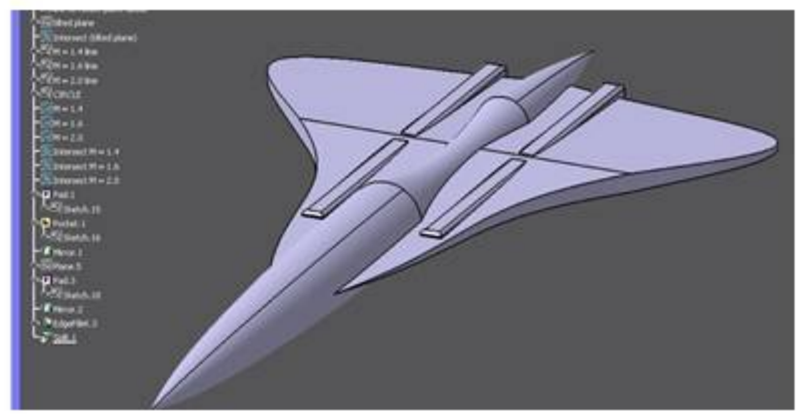
Configuration before and after supersonic area ruling.

EXTROVERT: Learning To Innovate Across Disciplines







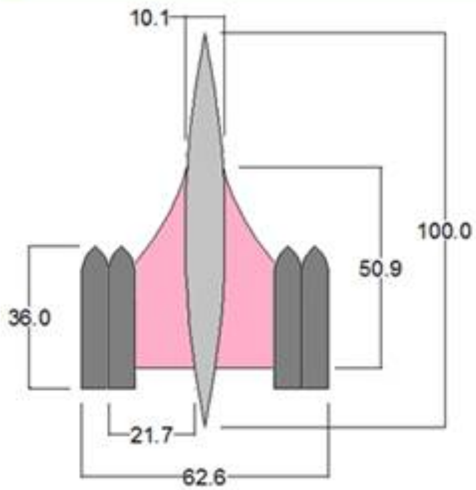


Dr. Narayanan Komerath

Cielo

Horizontal Takeoff and Landing Space Access Vehicle

Jennifer Bayard
Traci Thomason



Aircraft Stage

2 Turbojet Engines

Subsonic
- Thin Airfoil Theory
- Slender Wing Theory

Supersonic
- Shock-Expansion Theory
- Skin Friction Drag
- Wave Drag

Hypersonic Stage

4 Liquid Air Cycle Engines

Airbreathing

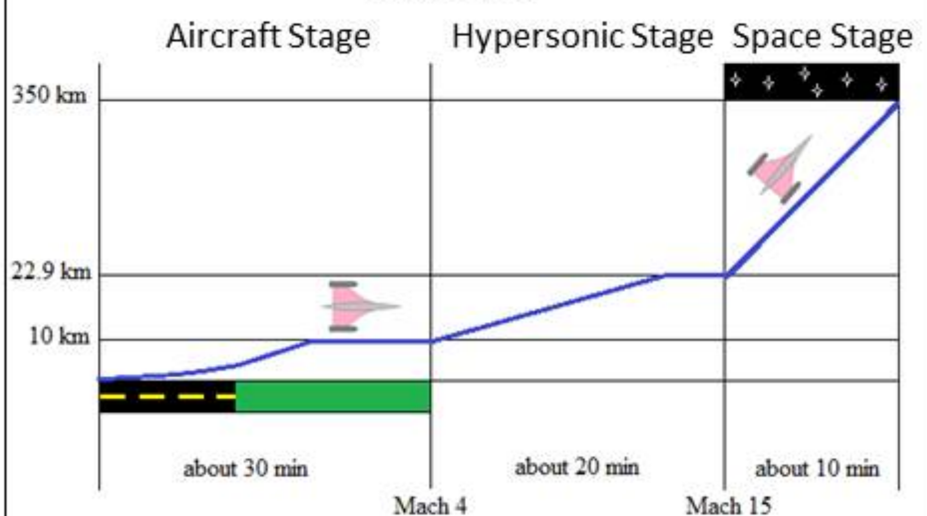
Hypersonic
- Modified Newtonian Theory
- Skin Friction Drag

Space Stage

4 Liquid Air Cycle Engines

Use onboard Oxygen

Trajectory

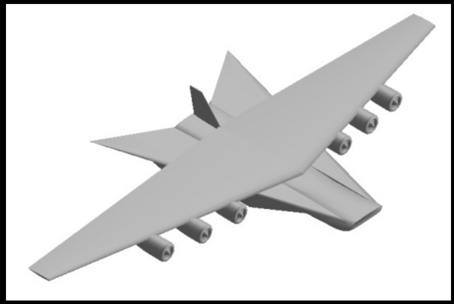


	Mass (kg)	Density (kg/m³)	Volume (m³)
Liquid Hydrogen	61238	70.85	864
Liquid Oxygen	233318	1140	205
Total Volume			1069
Sears Haack Body Volume			4626
Excess Volume			3557

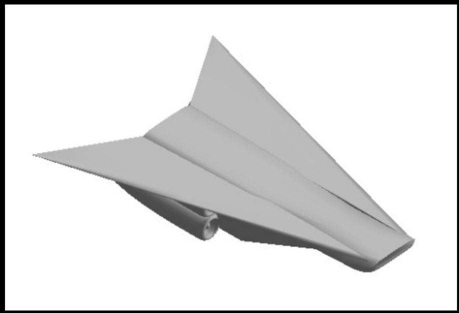
Stage	Total Drag Coeff	Total Lift Coeff	Thrust Available (N)	**Excess Thrust (N)**
Final Space	0.00333	0.02711	11760000	2940000
Initial Space	0.00358	0.02711	11760000	7542730
Final Hypersonic	0.00358	0.02711	11760000	7542730
Initial Hypersonic	0.00363	0.02711	7840000	6221444
Final Aircraft	0.15829	0.02711	75971371	5436894

X-57 Condor Launch System

Courtesy Sean Chait & Brett Kubica, AE3021, Sp. 2013

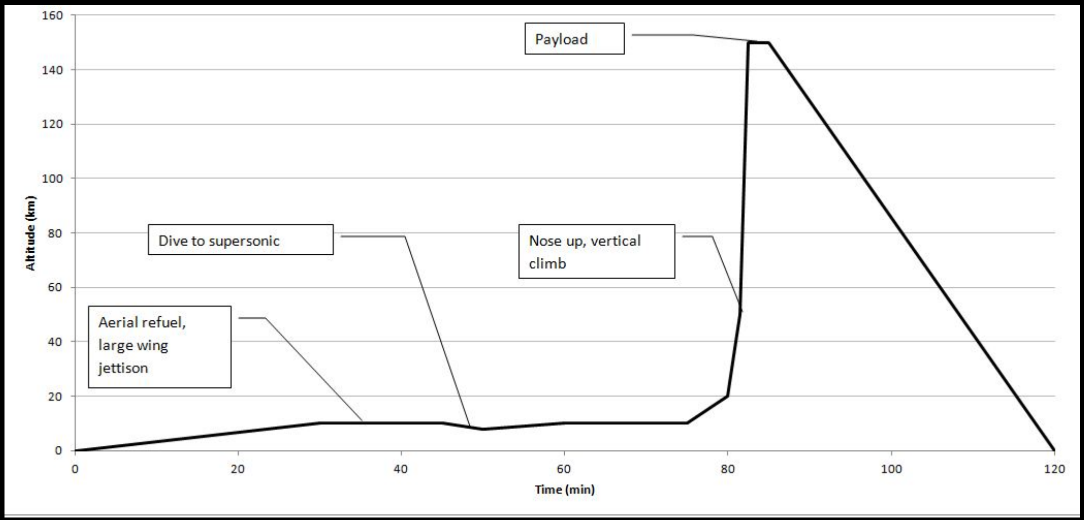


Condor Subsonic Configuration

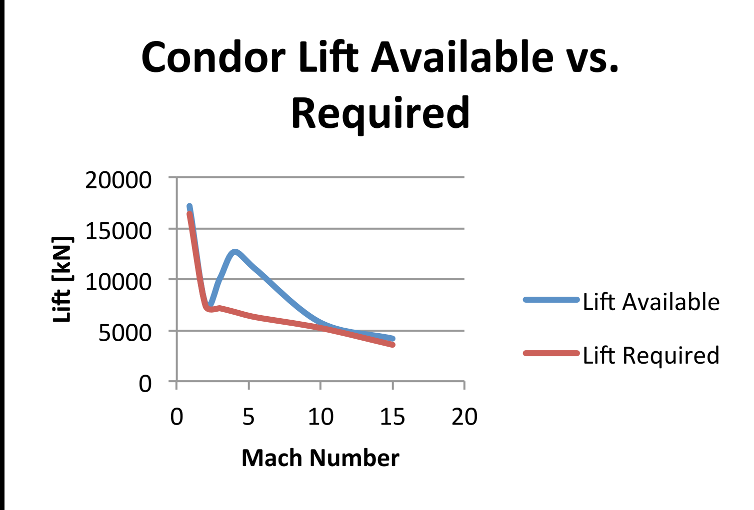


Condor Supersonic/ Hypersonic Configuration

Mission Flight Profile



The X-57 Condor Launch System is the next generation in Low Earth Orbit access vehicles. The system is capable of delivering a 100,000kg payload into orbit, return safely to Earth, refuel, and be capable of repeating the mission in the same day! Although significant technological advancement is necessary for the system to come to fruition, its concept sets a basis for a potentially high value launch system.



Discussion Points

1. Resistance to "derivations"; tendency to depend on memorized formulae
2. Difficulty with order of magnitude estimation ("sense of the numbers")
3. Resistance to going outside minimal syllabus.
4. Thought survey questions on tests
5. No place to hide.
6. Resource glut? Providing access to prior materials brings resentment!

On the other hand:

The top half of the class performs far beyond what their predecessors could do. Amazement at how much they learned.

The top 30% "get" what we are trying to do for them

– the core of the future aerospace industry.

New Realities

Core knowledge content is distilled into vertical streams in specific disciplines from freshman to doctorate levels. Low and high speed steady aerodynamics, flow diagnostics and control techniques, unsteady aerodynamics, jet propulsion, rocket and space propulsion, and composite materials, dynamics, vehicle performance, flight mechanics and controls, high temperature gas dynamics, and aeroelasticity.

24/7 – 365 access from anywhere. Includes

- Worked examples on-line.

- Module-based assessment through thought surveys.

- Concept Development assignments in courses and research projects.

- Case Studies from history and current projects

- Skills Library

- Realistic, large, open-ended assignments in classes, well beyond single course.

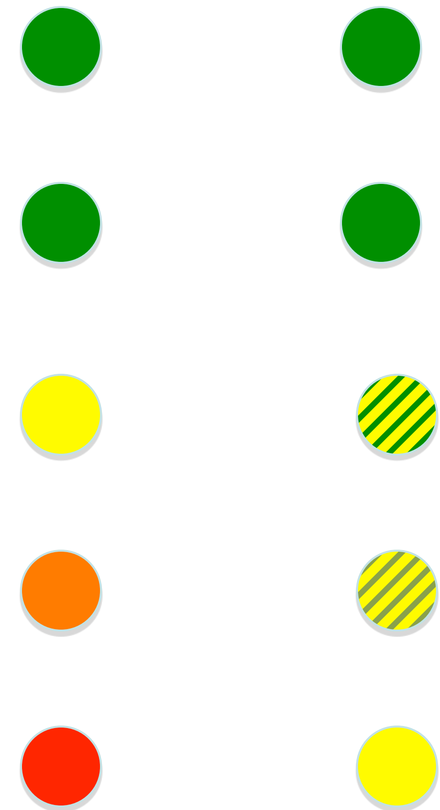
- Intense undergrad participation in research; peer-reviewed publication.

Benefits and risks associated with trying to advance learning.

Please read the paper. ☺

SUMMARY OF OBSERVATIONS

	ASEE'11	ASEE'13
Use of "skill" tools		
Intrinsic ability (when pushed)		
Applying "theory" learned in classes		
Capturing essence of logic methods		
Using analysis to develop bounds		



RESULTS

Table 2: Relation of Student Educational Outcomes to ABET

Outcome	Mode of Address
A. Fundamentals: Ability to apply knowledge of mathematics, science, and engineering.	Vertical streams of rigorous content in technical disciplines, with problem-solving.
C. Design: an ability to design a system, component, or process to meet desired needs.	Design-centered introduction, case studies and concept development exercises
E. Problem-solving: an ability to identify, formulate, and solve engineering problems.	Module-based surveys, solutions library, enabling deeper problem sets and tests.
H. Broad education to understand the impact of engineering solutions in societal context.	Advanced concept development exercises.
I. Life-long learning: a recognition of the need for, and an ability to engage in life-long learning.	Experience of having to solve problems in areas outside formal lectures. College instructors help learn these techniques.

Products Portfolio

- Conceptual design experience
- MatLab problem formulation & solution
- Complete reports for assignments
- Supersonic aircraft analysis
- Experience with wave drag minimization
- High-Reynolds No. compressible friction drag
- Experience with panel/boundary layer codes
- Experience with advanced concepts estimation
- Advanced concept analysis team report