INTRODUCTION

This research report details the investigation of the current learning outcomes and topics being emphasized in introductory aerospace engineering courses. This research was performed as a means of informing **Task 1.1 Survey of Learning Objectives**, as well as informing the production of questions to be asked in a focus group of aerospace engineering faculty concerning their ideas of best practices and outcomes in introductory aerospace engineering courses.

To determine the most common and relevant learning objectives and topics in introductory aerospace engineering courses, I completed three tasks.

- Determine the frequency and use of Bloom's taxonomy within introductory aerospace engineering course syllabi through conceptual content analysis.
- Determine the skills emphasized most frequently in learning outcomes from introductory aerospace engineering course syllabi.
- Determine the most common topics covered in introductory aerospace engineering courses.

I found that the most common tier of Bloom's language used in the syllabi was from tier 1, with words like understand, describe, and learn making up 32% of the most frequent Bloom's words. The most common skill emphasized in aero course syllabi was understanding aero principles, with 46% of words and phrases coded mapped to this skill.

The exemplary learning outcomes were identified as the following, with their school and national rank (CollegeFactual) provided:

Georgia Tech (#7)

- Generating an engineering model and translating it into a mathematical equation
- Applying an engineering model to describe or predict an aspect of atmospheric flight
- Conceive, Design, Build, Test, Evaluate, and Analyze (CDBTEA) an Aerospace Device. Document results.

Purdue University (#18)

- Give oral presentations and write technical reports required of design engineers.
- Understand and implement the design process for aerospace systems

UC San Diego (#40)

- To introduce the student to the field of aeronautical and astronautical engineering including vehicle types and definitions, historical perspective, overview of modern

design and analysis practices, and review of current aerospace related research and development.
- To introduce the student to the various disciplines that make the aerospace engineering degree unique, including aerodynamics, propulsion, stability, structures, and materials, and associate engineering analysis.

University at Buffalo (#45)

- Make professional decisions considering ethics and factors such as societal, environmental, and economic, in addition to technical aspects.
- Understand at an introductory level the physical mechanisms underlying the standard atmosphere, aerodynamics, aircraft performance, stability and control, and space flight.

The following list of topics covered in introductory aerospace engineering courses was compiled based on two criteria. The list contains the 5 most common sets of topics covered, as well as some of the more unique topics covered in the courses investigated. The criteria are as follows:

1. Contains most frequently used phrases/words. Amount of references noted.
2. Contains unique aspects not seen in the majority of other topic sets. School is noted on these.

- Performance: The Design Mission. Range. Endurance. Climb. Descent. Lift. Takeoff. Landing. (13 References)

- Propulsion: Producing Thrust. Types of engines. Propulsion Design Considerations. (10 References)

- Aerodynamics: One-dimensional Flow. Two-dimensional Flow. Viscosity and Drag. Airfoils. Finite Wing. Wings and High-Lift Systems. Drag Prediction. (10 References).

- Aircraft Stability: Center of Gravity. Static Longitudinal Stability. Other Measures of Stability. Static Lateral Stability. Design Considerations. (7 Reference)

- Spacecraft: Elements of space mission design. Launch requirements and rocket performance. Introduction to astrodynamics. Overview of spacecraft subsystems. Introduction to spacecraft systems engineering. (7 References)

- Structures: Structural Design Process. Design Criteria. Structural Design Layout. Aircraft Structure Types. Materials. (5 Reference)

- Rockets and Spacecraft: Rocket Trajectories. The Rocket Equation. Staging. Geocentric Orbits. Heliocentric Orbits. Orbital Parameters and Maneuvers. Spacecraft/Rocket Sizing. (5 reference)

- Formation of engineering models without assuming calculus beyond simple integration / derivation. Examples include wind triangles (vector addition), force-body diagrams to identify required forces of flight and/or accelerations during flight, basic orbital mechanics (1 Reference, Georgia Tech).

- Tackling large, open-ended problems with no one correct answer, mentored to examine how to break down problems. (1 Reference, Georgia Tech)

RESEARCH METHODS

Task 1: Determine the frequency and use of Bloom's taxonomy within introductory aerospace engineering course syllabi.

To fulfill this task, I first performed an NVivo word frequency query across 18 course syllabi. I then tallied how many of these words matched those in the tiers of Bloom's taxonomy. Bloom's Taxonomy is a framework for categorizing educational goals. It consists of six major categories. These six categories, as well as their associated language are best illustrated in Appendix A. This figure is from a secondary source from Campus Labs used specifically for writing learning outcomes. Using these words as indication of educational goals set by instructors, I compared the 150 most frequent words across all syllabi (Appendix B), with Bloom's language to determine what tier of language is most commonly used in aero course syllabi. In the context of the words used in the learning outcomes, only four of the six tiers were found to be relevant.

Task 2: Determine the skills emphasized most frequently in learning outcomes from introductory aerospace engineering course syllabi.

To determine the skills being emphasized in the learning outcomes, I first created a document containing the learning outcomes of every course syllabi which had them. I performed qualitative analysis by coding the learning outcomes using NVivo software. A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data… Qualitative coding allows you to interpret, organize, and structure your observations and interpretations into meaningful theories (Saldana, 2013). I coded every learning outcome for every school, assigning each learning outcome to a skill. I assigned the specific words used in the learning outcomes, to the skill most relevant to the outcome both in the context of aerospace engineering, and in Bloom's taxonomy. I created a map for each node (skill) containing what words and phrases were classified into each skill (Appendix C). After three rounds of coding, I was able to classify each learning outcome into one of six nodes/skills.

Task 3: Determine the most common topics covered in introductory aerospace engineering courses.

To determine the most common topics covered in introductory aerospace engineering courses, I created a document which contained all of the topics covered in the syllabi. I then used NVivo to perform a word frequency query to help determine what words/topics are most present in the topic lists. If a word did not directly represent a topic, I compiled words and topics together based on their relation to aerospace disciplines. For example, takeoff, thrust, and lift are often taught together, so I grouped them in the same topic. I then noted how many schools contained these topics based on the amount of times the word or words were referenced.

RESULTS

Task 1: Determine the frequency and use of Bloom's taxonomy within introductory aerospace engineering course syllabi.

After tallying the percentages of words used in relation to Bloom's taxonomy, I obtained the following results:

- 32.2% of the 150 most frequent words used in the syllabi were related to the Understand tier of Bloom's taxonomy.
- 31.6% of the 150 most frequent words used in the syllabi were related to the Create tier.

School	*Understand (% of Doc)*	*Apply (% of Doc)*	*Analyze (% of Doc)*	*Create (% of Doc)*	*Totals*
UWestMichigan	0.2	0.86	0.4	0.26	**1.72**
USC	1.52	0.38	0.38	1.14	**3.42**
U Maryland	4.56	1.14	0.57	1.7	**7.97**
U Florida	0.2	0.89	0.28	0	**1.37**
UC San Diego	1.96	1.12	2.51	3.06	**8.65**
UC Boulder	0.27	0	0.27	0.7	**1.24**
U Buffalo	1.75	0.5	1	0.5	**3.75**
U Cincinnati	1.77	2.08	0.64	1.45	**5.94**
Wichita State	0	0	0.48	0.55	**1.03**
VirginiaTech	1.85	2.96	0	0	**4.81**
Cal Polytech	0.83	0	0	2.5	**3.33**
Alabama Huntsville	3.24	0.81	0.36	1.8	**6.21**
Stanford	0.73	0.36	1.45	0.73	**3.27**
San Jose State	1	0.43	0.29	1.72	**3.44**
Purdue	2.24	3.37	1.92	3.86	**11.39**
Notre Dame	1.17	0	0.39	0	**1.56**
MIT	0.88	2.11	1.23	4.91	**9.13**
GeorgiaTech	4.34	1.86	0.93	3.1	**10.23**
Total	**1.5839**	**1.0483**	**0.7278**	**1.5544**	**4.9144**

Figure 1. Word frequency percentage of Bloom's Language in Course Syllabi

Task 2: Determine the skills emphasized most frequently in learning outcomes from introductory aerospace engineering course syllabi.

Using the skill map I created, I was able to classify each syllabi's learning outcomes as emphasizing one of six skills. Four of these skills were the original Bloom's taxonomy tiers, and the other two were decided based on the most common phrasing and skills mentioned in the learning outcomes.

My principle findings were:

- 46.3% of learning outcomes coded promote student understanding of aerospace engineering topics.
- 20.7% of learning outcomes coded promote student application of aerospace engineering formulas, concepts, and calculations to various scenarios.
- 10.9% of learning outcomes coded promote development of professional competency.
- There is no correlation between rank and skills emphasized, and the only two schools to promote all six skills were Purdue University, and Georgia Institute of Technology.

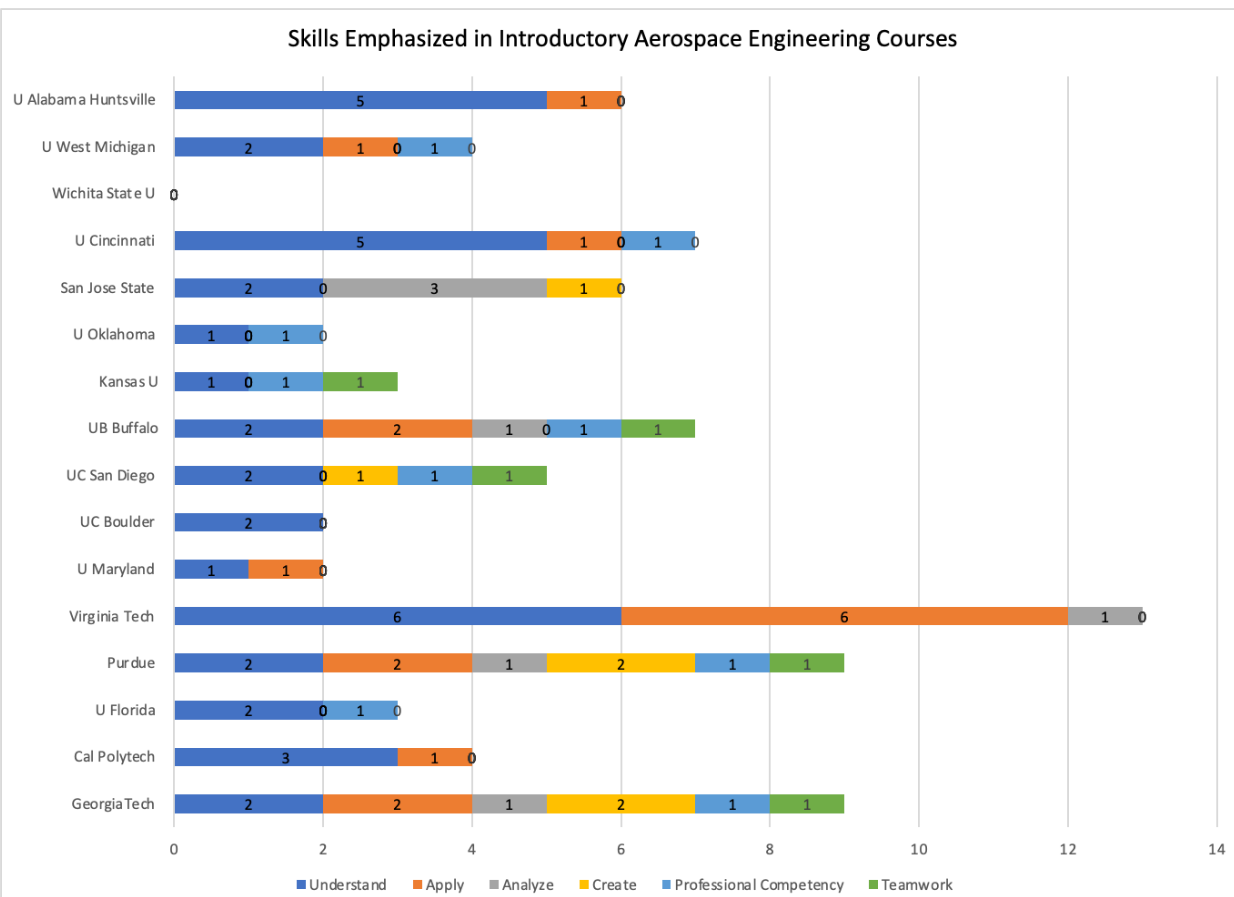

Figure 2. Skills most Emphasized in Course Syllabi Learning Outcomes

Task 3: Determine the most common topics covered in introductory aerospace engineering courses.

After an analysis of the word frequency query, I was able to determine the most common topics covered in the syllabi. The most common topics covered were drag, flight, stability, design, and performance.

Figure 3. Word Cloud of Topics Covered in Introductory Aerospace Engineering Courses

CONCLUSIONS

After the completion of both qualitative and quantitative analysis across various course syllabi, I identified specific learning outcomes as the most relevant, and was able to create a list of relevant topics. These were decided considering the skills they promote, and the language they use. They are accompanied by their respective school and aerospace program rank.

Georgia Tech (#7)

- Generating an engineering model and translating it into a mathematical equation
- Applying an engineering model to describe or predict an aspect of atmospheric flight
- Conceive, Design, Build, Test, Evaluate, and Analyze (CDBTEA) an Aerospace Device. Document results.

Purdue University (#18)

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UC San Diego (#40)

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- To introduce the student to the various disciplines that make the aerospace engineering degree unique, including aerodynamics, propulsion, stability, structures, and materials, and associate engineering analysis.

University at Buffalo (#45)

- Make professional decisions considering ethics and factors such as societal, environmental, and economic, in addition to technical aspects.
- Understand at an introductory level the physical mechanisms underlying the standard atmosphere, aerodynamics, aircraft performance, stability and control, and space flight

This list of topics was created by grouping together common topics, related topics, and by manipulating pre-written topic statements that were frequent among the syllabi. The list was compiled based on two criteria:

1. Contains most frequently used phrases/words. Amount of references noted.
2. Contains unique aspects not seen in the majority of other topic sets. School is noted on these.

- Performance: The Design Mission. Range. Endurance. Climb. Descent. Lift. Takeoff. Landing. (13 References)

- Propulsion: Producing Thrust. Types of engines. Propulsion Design Considerations. (10 References)

- Aerodynamics: One-dimensional Flow. Two-dimensional Flow. Viscosity and Drag. Airfoils. Finite Wing. Wings and High-Lift Systems. Drag Prediction. (10 References).

- Aircraft Stability: Center of Gravity. Static Longitudinal Stability. Other Measures of Stability. Static Lateral Stability. Design Considerations. (7 Reference)

- Spacecraft: Elements of space mission design. Launch requirements and rocket performance. Introduction to astrodynamics. Overview of spacecraft subsystems. Introduction to spacecraft systems engineering. (7 References)

- Structures: Structural Design Process. Design Criteria. Structural Design Layout. Aircraft Structure Types. Materials. (5 Reference)

- Rockets and Spacecraft: Rocket Trajectories. The Rocket Equation. Staging. Geocentric Orbits. Heliocentric Orbits. Orbital Parameters and Maneuvers. Spacecraft/Rocket Sizing. (5 reference)

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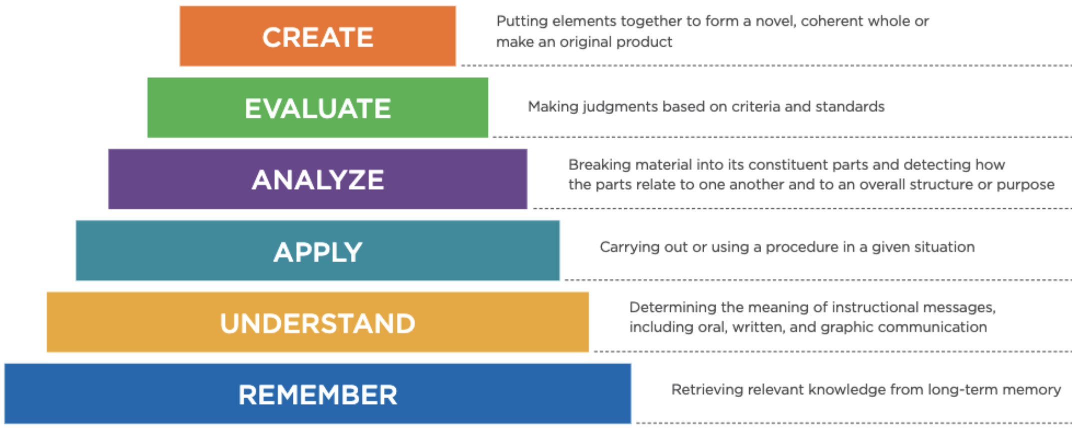
APPENDIX A. Bloom's Language

Bloom's Taxonomy: Cognitive Domain

The cognitive domain of Bloom's Taxonomy of Educational Objectives offers a framework for classifying learning outcomes. The framework is hierarchical in nature, beginning with a foundational layer (*Remember*) and accelerating in a stepwise manner (from *Understand* to *Apply* to *Analyze* to *Evaluate* and on to *Create*). Select from this word bank when writing your learning outcome statements.



Adapted from A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (Anderson, L.W. (Ed.), et al., 2001)

REMEMBER	UNDERSTAND	APPLY	ANALYZE	EVALUATE	CREATE
Cite	Articulate	Compute	Calculate	Argue	Act
Define	Ask	Construct	Categorize	Assess	Arrange
Find	Characterize	Demonstrate	Compare	Check	Assemble
Identify	Clarify	Employ	Contrast	Convince	Build
Indicate	Classify	Exercise	Correlate	Critique	Compose
Label	Describe	Illustrate	Deconstruct	Debate	Construct
List	Discuss	Make	Detect	Decide	Create
Locate	Elaborate	Model	Diagram	Defend	Design
Match	Estimate	Operate	Differentiate	Determine	Develop
Memorize	Explain	Perform	Distinguish	Judge	Formulate
Name	Infer	Plot	Examine	Justify	Generate
Outline	Interpret	Practice	Experiment	Measure	Improve
Quote	Paraphrase	Present	Graph	Predict	Invent
Recall	Recognize	Produce	Integrate	Prioritize	Modify
Recite	Report	Provide	Order	Rank	Plan
Recognize	Restate	Show	Organize	Rate	Prepare
Repeat	Summarize	Sketch	Select	Recommend	Revise
Reproduce	Translate	Solve	Sequence	Reflect	Synthesize
State	Visualize	Use	Solve	Relate	Write

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APPENDIX B. Word Frequency Results

Word	Length	Count	Weighted Percentage	Similar Words
aerospace	9	25	2.85%	aerospace
engineers	9	23	2.62%	engineer, engineering, engineers, engines
basic	5	22	2.51%	basic, basics
design	6	21	2.39%	design, designed, designs
aircraft	8	19	2.17%	aircraft, aircrafts
performance	11	18	2.05%	perform, performance
understand	10	16	1.82%	understand, understanding
students	8	15	1.71%	student, students
vehicle	7	15	1.71%	vehicle, vehicles
flight	6	14	1.60%	flight
aerodynamics	12	13	1.48%	aerodynamic, aerodynamics
course	6	12	1.37%	course, courses

including	9	12	1.37%	include, includes, including
stability	9	12	1.37%	stability
orbits	6	10	1.14%	orbit, orbital, orbits
propulsion	10	10	1.14%	propulsion, propulsive
analysis	8	9	1.03%	analysis
apply	5	8	0.91%	apply, applying
atmosphere	10	8	0.91%	atmosphere, atmospheric
control	7	8	0.91%	control
systems	7	8	0.91%	system, systems
use	3	8	0.91%	use, using
airplane	8	7	0.80%	airplane, airplanes
concepts	8	7	0.80%	concept, concepts
level	5	7	0.80%	level
spacecraft	10	7	0.80%	spacecraft
ethics	6	6	0.68%	ethical, ethics
introduce	9	6	0.68%	introduce, introduces, introducing


Learning Outcome Language
Teamwork
Team skill s
Part of a team
culture of teamwork
work in teams
Professional Competency
Professional skills
Credible information
Gaps in knowledge
Oral presentations
ethical , ethics
industry
societal , environmental, economic aspects
realistic economic constraints
professional career
Apply
Generate
Apply
Use
How to...
Implement
Analyze:
Analyze
Develop
Calculate
"Evaluate and compare in context"
Understand
Exposure
understand
basic
acquire
explain
describe
fundamental
demonstrate basic knowledge
introduce
review
principles
expose the student to...
Create
Conceive
Design
Implement design process
miro

Word	Length	Count	Weighted Percentage
drag	4	21	1.78%
flight	6	21	1.78%
design	6	20	1.69%
stability	9	19	1.61%
aircraft	8	18	1.53%
define	6	15	1.27%
performance	11	15	1.27%
lift	4	14	1.19%
orbits	6	13	1.10%
propulsion	10	13	1.10%
flow	4	11	0.93%
wings	5	11	0.93%
orbital	7	11	0.93%
spacecraft	10	11	0.93%
space	5	10	0.85%
control	7	10	0.85%
basic	5	9	0.76%
thrust	6	9	0.76%
airplane	8	9	0.76%
aerodynamics	12	9	0.76%
airfoils	8	8	0.68%
aerospace	9	8	0.68%
power	5	7	0.59%
orbit	5	7	0.59%
static	6	7	0.59%
rocket	6	7	0.59%
materials	9	7	0.59%
engineering	11	7	0.59%
aerodynamic	11	7	0.59%
wing	4	6	0.51%

high	4	6	0.51%
range	5	6	0.51%
climb	5	6	0.51%
history	7	6	0.51%
explain	7	6	0.51%
elements	8	6	0.51%
maneuvers	9	6	0.51%
endurance	9	6	0.51%
structures	10	6	0.51%
atmosphere	10	6	0.51%
body	4	5	0.42%
types	5	5	0.42%
intro	5	5	0.42%
matlab	6	5	0.42%
forces	6	5	0.42%
systems	7	5	0.42%
landing	7	5	0.42%
engines	7	5	0.42%
airfoil	7	5	0.42%
required	8	5	0.42%
pressure	8	5	0.42%
equation	8	5	0.42%
viscosity	9	5	0.42%
calculate	9	5	0.42%
speed	5	4	0.34%
level	5	4	0.34%
weight	6	4	0.34%
stress	6	4	0.34%
review	6	4	0.34%
motion	6	4	0.34%
section	7	4	0.34%