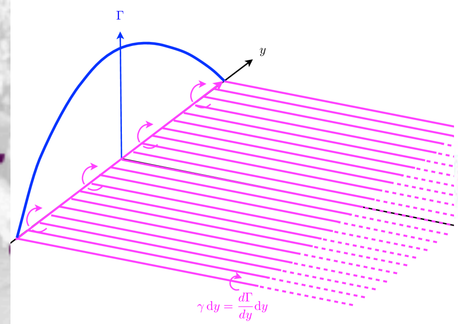

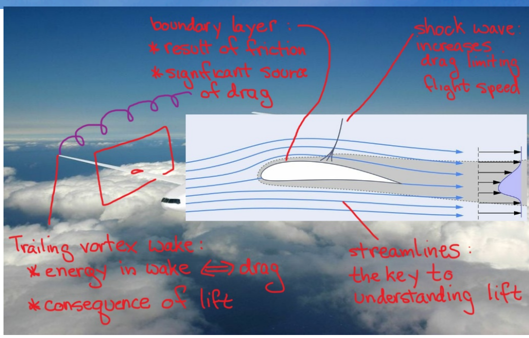

Development of an Outcomes-based edX MOOC using LaTeX

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[1]Professor of Aeronautics & Astronautics
[2]Lord Foundation Post-doctoral Associate

Acknowledgments

- Dr. Alejandra Uranga, co-instructor of 16.101x
- Savithru Jayasinghe, graduate TA of 16.101x
- Undergraduate TAs of 16.101x
- MITx for financial and general support

Outline

- Structure of 16.101x Introduction to Aerodynamics
- Outcomes-based MOOC
- LaTeX-driven edX MOOC development

Relationship to MIT subjects

- Undergraduate aerodynamics on campus taught in:
  - Sophomore core subject Unified Engineering (~12 units)
  - Junior/senior elective subject: 16.100 Aerodynamics (12 units)

- 16.101x:
  - Overlaps with Unified and 16.100
  - But without project-based learning

- Plan to utilize 16.101x material in Unified and 16.100

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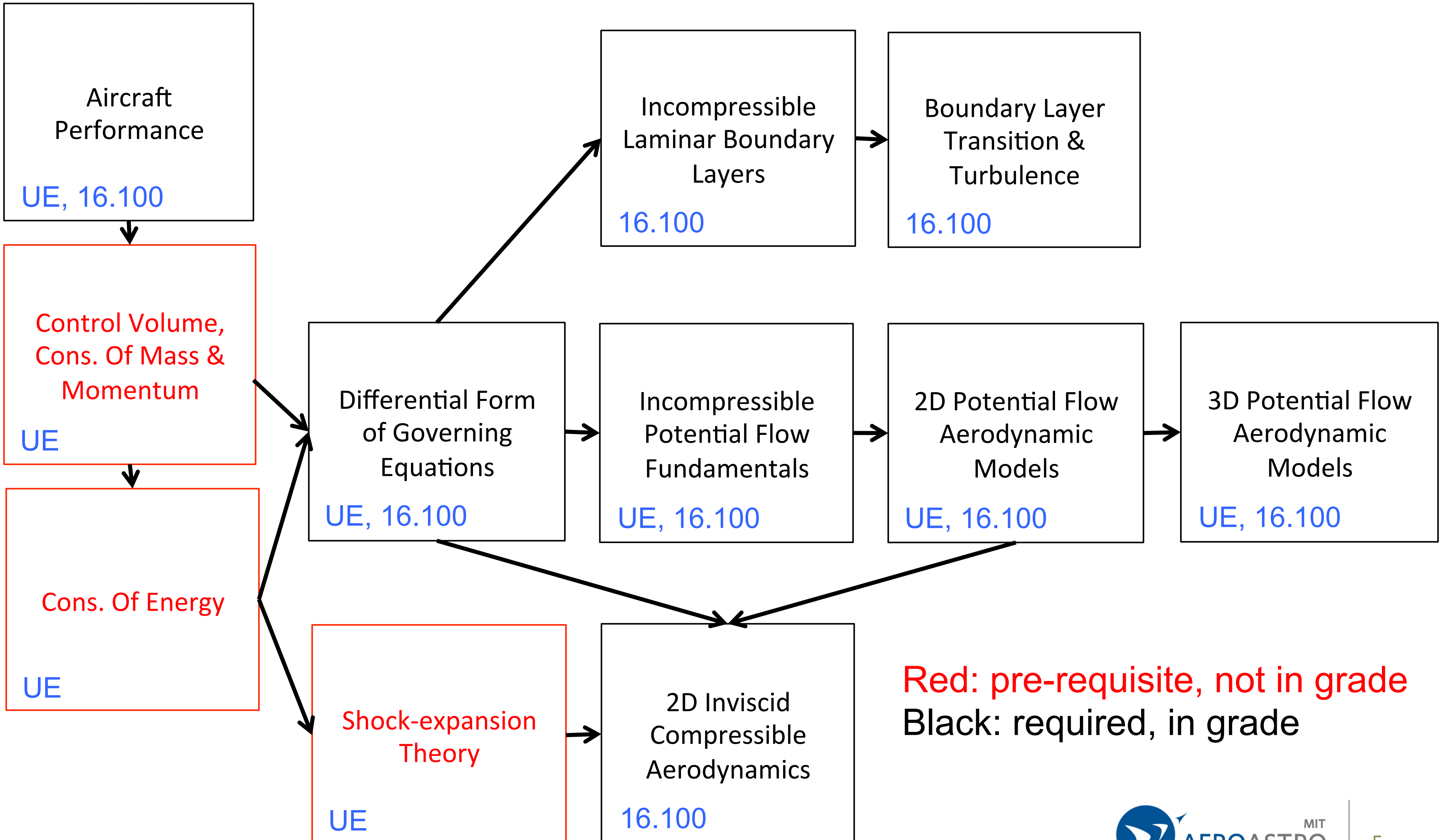
16.101x Modules



Red: pre-requisite, not in grade
Black: required, in grade

Structure of 16.101x Module

- Notes:
  - Embedded questions for checking understanding
  - Solution videos (tablet-based) provided
  - Occasional short (tablet-based) “lecture” videos
- Homework problems:
  - More challenging than embedded questions
  - Solutions videos provided after due date.
- Sample problems:
  - Same level as homework problems
  - Solution videos provided
- Discussion forum

Embedded questions:	5-10
Homework problems:	2-3
Sample problems:	2-3
“Lecture” videos:	2-4
Videos per module:	11-20
Videos in total:	~185

16.101x: Typical module note content

Courseware | Course News | Syllabus | Discussion | FAQ | MO Index | Progress | Instructor | Staff view

RANGE

MO1.8

The range of an aircraft is the distance the aircraft can fly on a specific amount of fuel. In this section, our objectives are to understand how factors such as the weight of the aircraft, the amount of fuel, the drag, and the propulsive efficiency. influence an aircraft's range, and to learn how to estimate the range.

In our estimate, we will not directly consider the fuel used during the take-off and landing portions of a flight. We will only focus on the cruise range. Except for very short flights (an hour or less), most of the fuel is burned during the cruise section of the flight: for a typical commercial airliner in transcontinental flight, the fuel consumed during cruise represents around 90% of the total trip fuel. We will assume that an aircraft in cruise has constant speed (relative to the wind) of V_∞ and is flying level (not gaining altitude). This is commonly refered to as steady, level flight. Placing the freestream along the x-axis, and with gravity acting in the $-z$ direction, the forces acting on the aircraft are as shown in Figure 1.12.

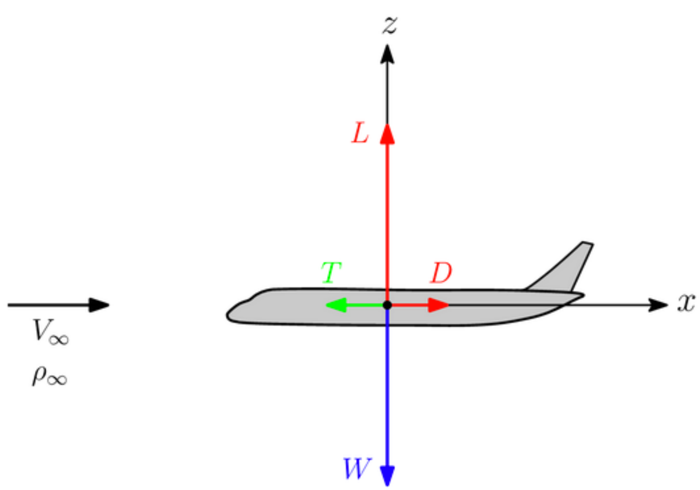


Figure 1.12: An aircraft in steady level flight

Note: This screenshot will be shown in a live demo.

16.101x: Measurable outcome index

MO1.6 (a) Define the Mach number, (b) Define the Reynolds number, and (c) Define the angle of attack.

MO1.7 (a) Explain the concept of dynamic similarity, (b) Explain its importance in wind tunnel and scale-model testing, and (c) Determine conditions under which flows are dynamically similar.

MO1.8 (a) Derive the Breguet range equation, (b) Explain how the aerodynamic, propulsive, and structural performance impact the range of an aircraft using the Breguet range equation, and (c) Apply the Breguet range equation to estimate the range of an aircraft.

Learn

- Range
- Assumptions in Breguet range analysis

Assess

- Range estimate for a large commercial transport
- Sensitivity of payload to efficiency

Note: This screenshot will be shown in a live demo.

CONTROL VOLUME ANALYSIS OF MASS AND MOMENTUM CONSERVATION

MO2.1 Describe a continuum model for a fluid and utilize the Knudsen number to support the use of a continuum model for typical atmospheric vehicles.

MO2.2 Define the density, pressure, and velocity of a flow and utilize a field representation of these (and other) fluid states to describe their variation in space and time. Define the difference between a steady and unsteady flow.

MO2.3 Define pathlines and streamlines and describe their relationship for unsteady and steady flow.

16.101x: Sample embedded question

RANGE ESTIMATE FOR A LARGE COMMERCIAL TRANSPORT (5.0/5.0 points)

MO1.4 MO1.8

Consider a commercial transport aircraft with the following characteristics:

W_{initial}	400,000 kg
W_{fuel}	175,000 kg
η_o	0.32
L/D	17
Q_R	42 MJ/kg
g	9.81 m/sec^2

Note that we have given the weights W_{initial} and W_{fuel} in kilograms, which is actually a unit of mass. This is fairly common usage when giving weights in metric units, that is weights are often given as mass. To find the weight, we need to multiply the given masses by gravity. So, in reality, $W_{\text{initial}} = 3,924,000$ N and $W_{\text{fuel}} = 1,716,750$ N. However, for the Breguet range equation, we only use the ratio of weights which would be the same as the ratio of masses, that is $W_{\text{initial}}/W_{\text{final}} = m_{\text{initial}}/m_{\text{final}}$. But, be extra careful, because if you actually were to calculate the lift, or the lift coefficient, the weight needs to be in units of force (i.e. Newtons in metric)!

Estimate the range (during cruise portion of flight) for this aircraft. Please use kilometers and provide an answer that has three significant digits of precision.

13400 ✔

Note: This screenshot will be shown in a live demo.

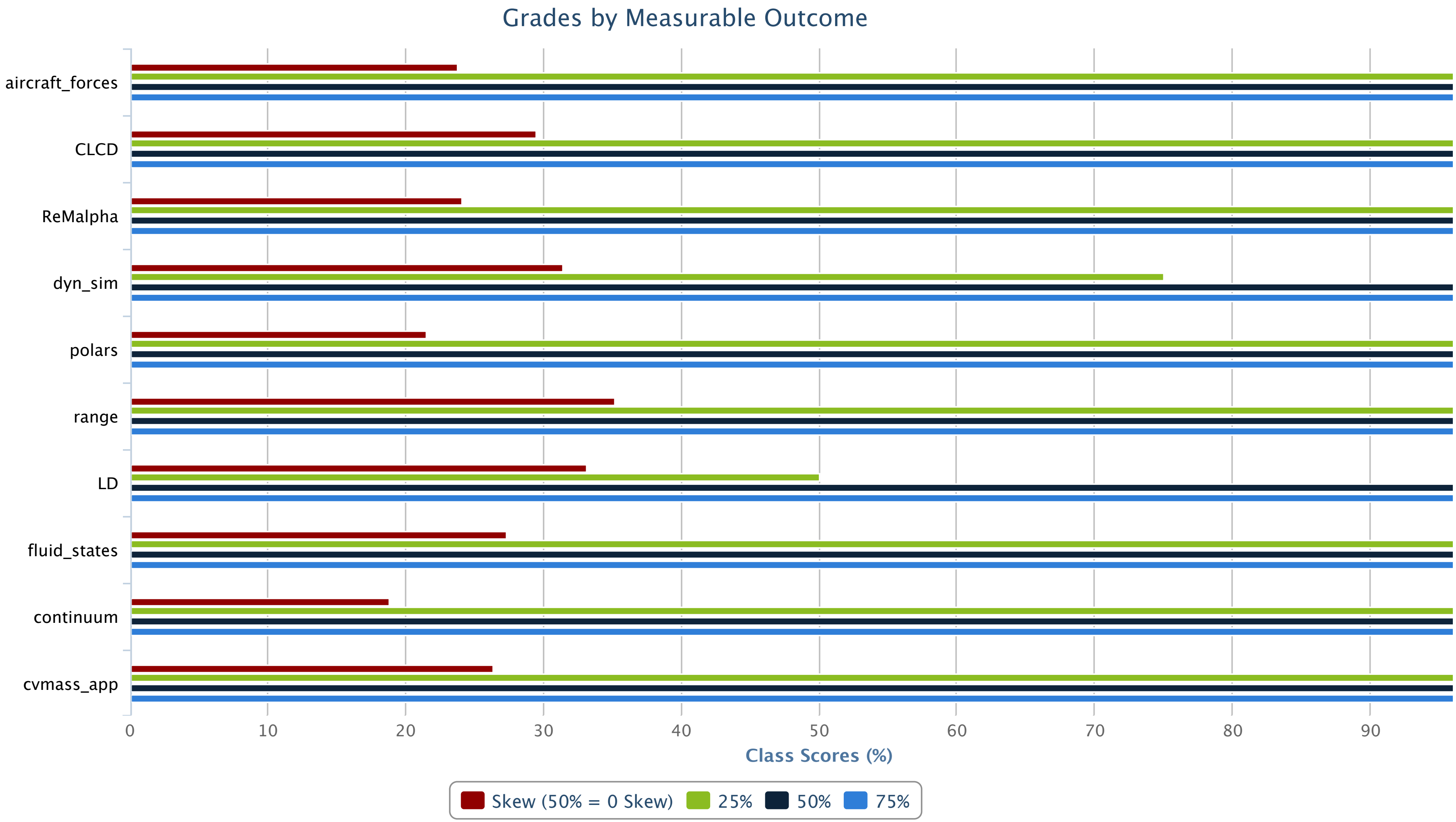
Demo of 16.101x Module Content

- Give a live demo of 16.101x module content
- Show notes, embedded questions, solution videos, "lecture videos", homework problems, …
- Initially do not point out/discuss MOs

Demo of 16.101x M.O.

- Give a live demo of M.O. capability
- Start by showing an Overview section of a module with the M.O. list
- Then show how all content (notes and problems) are labeled by M.O.s (and show hover technique)
- Then click on M.O. to reveal M.O. index

Class performance on all outcomes

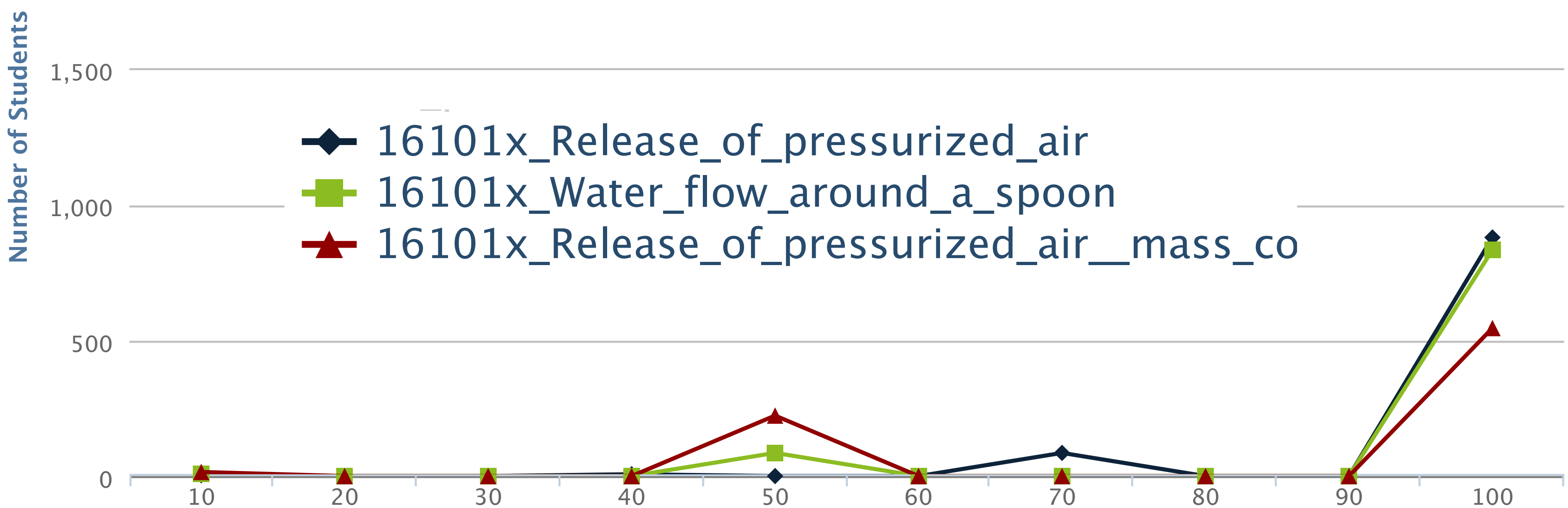


On-going work with OEIT to develop M.O. reporting tool

MIT AEROASTRO

Class performance on a single outcome

MO2.6: Apply the integral form of mass conservation to typical problems in aerospace engineering.



On-going work with OEIT to develop M.O. reporting tool

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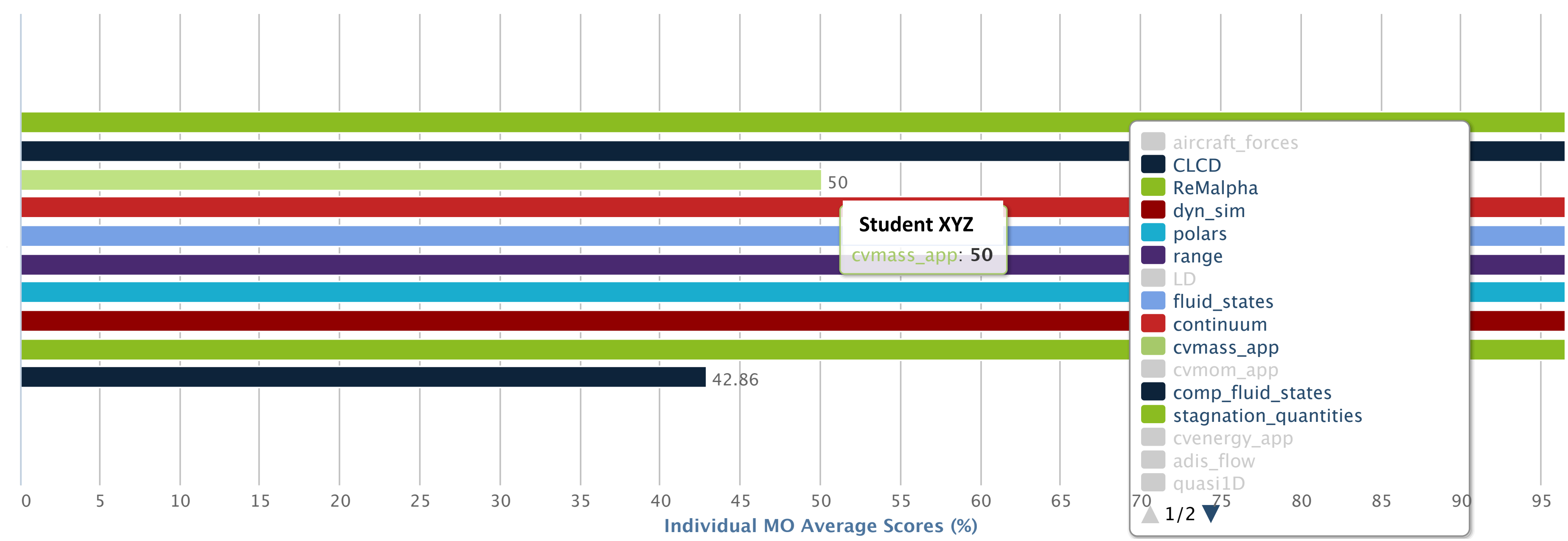
Individual student performance on outcomes



On-going work with OEIT to develop M.O. reporting tool

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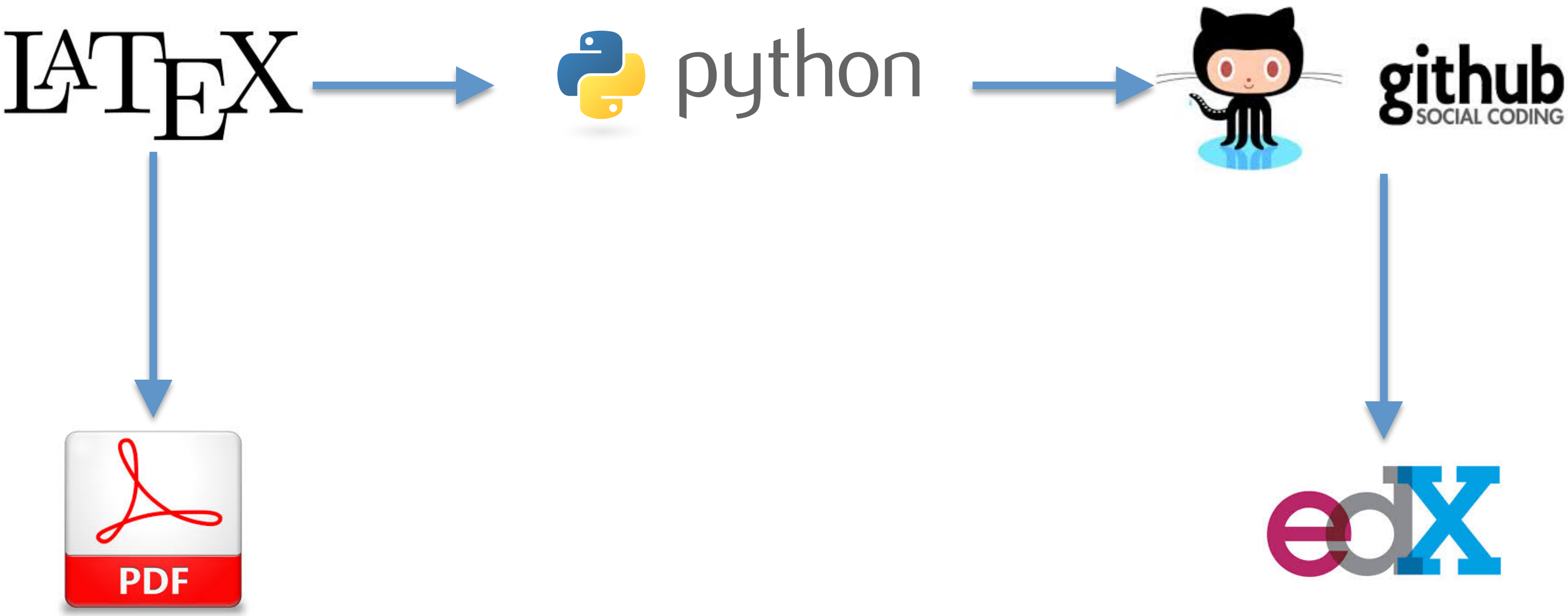
LaTeX-based development process

- LaTeX is a document preparation system and markup language
- Traditionally LaTeX is used in academia for preparing books, journal articles, and lecture notes
- From text source, a PDF is generated according to specified styles
- Some advantages include ease of re-use; section, equation, and figure referencing; hyperlinks; etc.

LaTeX-based development process

- LaTeX2edX is a python-based software utility that produces edXxml from LaTeX source
- Course content is developed in a convenient and well-known form (i.e., LaTeX)
- Content developers are insulated from the complexity/nuance of html/xml in the edX platform
- Easy to re-use content and generate PDFs for offline development and viewing
- Conversion process is automatic permitting generation of MO Index, MO labelling, figure and equation pop-up references

LaTeX-based development process



LaTeX-based development process

Performance.tex

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\item\label{mo:CLCD} (a) Define the lift and drag coefficients,
  (b) Utilize the lift and drag coefficients in the aerodynamic
  analysis of an aircraft, and (c) Employ a parabolic drag model to
  analyze the aerodynamic performance of an aircraft.

\item\label{mo:polars} (a) Explain the relationship between the
  CL-alpha curve and drag polar, and (b) Utilize
  CL-alpha curves and drag polars to analyze the aerodynamic
  performance of an aircraft.

\item\label{mo:ReMalpha} (a) Define the Mach number, (b) Define the
  Reynolds number, and (c) Define the angle of attack.

\item\label{mo:dyn_sim} (a) Explain the concept of dynamic
  similarity, (b) Explain its importance in wind tunnel and
  scale-model testing, and (c) Determine conditions under which
  flows are dynamically similar.
```

```
\item\label{mo:aircraft_forces} (a) Define the gravitational,
  propulsive, and aerodynamic forces that act on an airplane, and
  (b) Relate the motion of an aircraft (i.e. its acceleration) to
  these forces.
```

https://courses.edx.org/courses/MITx/16.101x/2013_SOND/courseware/Aircraft_Performance/Overview2/

- Overview of 16101x
- Office Hour Videos
- Aircraft Performance
  - **Overview** due Oct 03, 2013 at 21:00 UTC
  - **Forces on an Aircraft** Aircraft Performance Embedded Questions Sequence 1 due Oct 03, 2013 at 21:00 UTC
  - **Non-dimensional Parameters and Dynamic Similarity** Aircraft Performance Embedded
  - 21:00 UTC
- Control Volume Analysis of Mass and Momentum Conservation

1.1.1 MEASURABLE OUTCOMES

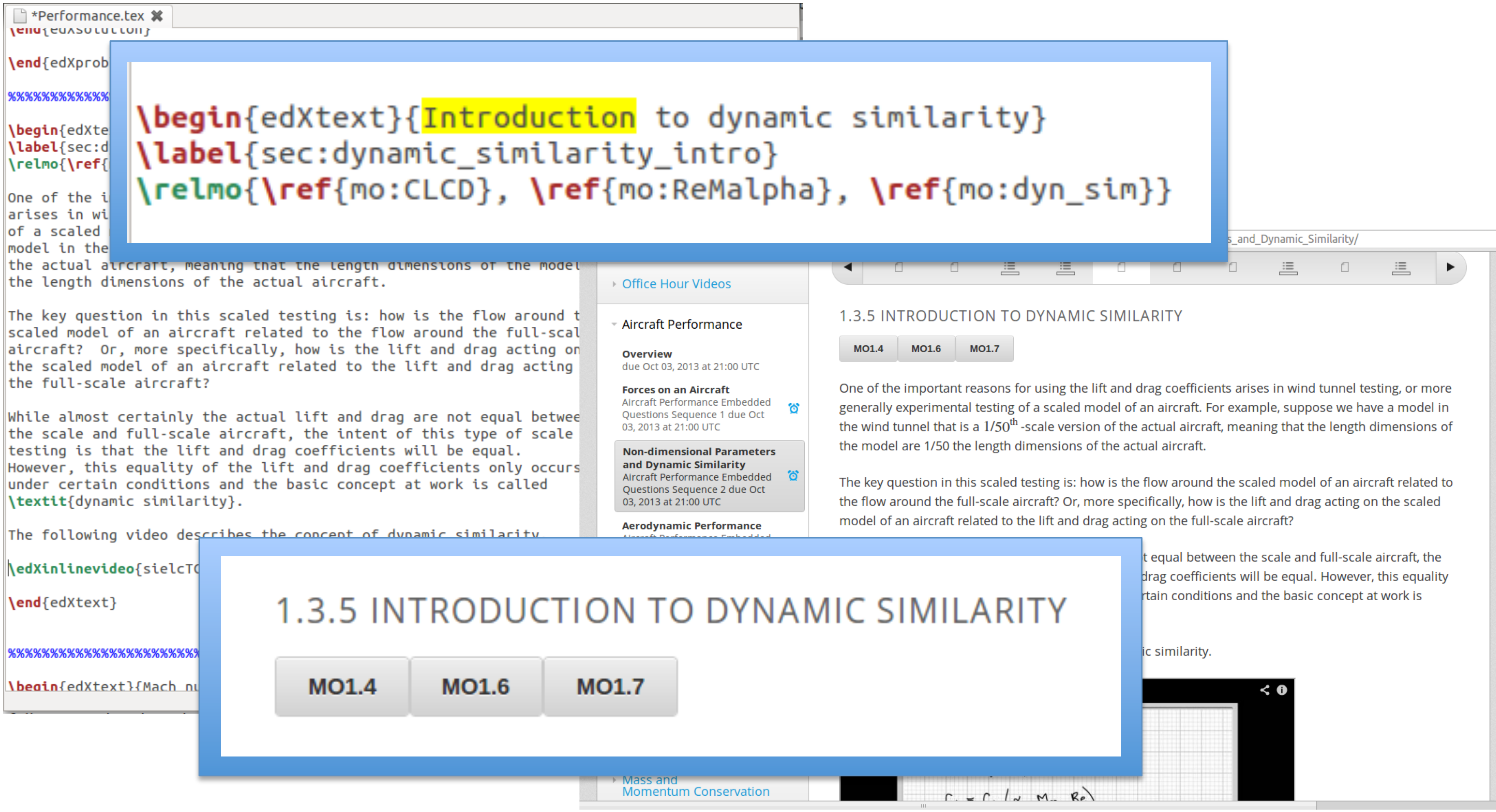
The objectives of this module are to introduce key ideas in the aerodynamic analysis of an aircraft and to demonstrate how aerodynamics impacts the overall performance of an aircraft. For aircraft performance, our focus will be on estimating the range of an aircraft in cruise. The focus on cruise range is motivated by the fact the fuel consumption for the flight of transport aircraft is dominated by cruise, with take-off and landing playing a generally smaller role.

Specifically, students successfully completing this module will be able to:

- MO1.1: (a) Define the gravitational, propulsive, and aerodynamic forces that act on an airplane, and (b) Relate the motion of an aircraft (i.e. its acceleration) to these forces.

- MO1.5: (a) Explain the relationship between the CL-alpha curve and drag polar, and (b) Utilize CL-alpha curves and drag polars to analyze the aerodynamic performance of an aircraft.
- MO1.6: (a) Define the Mach number, (b) Define the Reynolds number, and (c) Define the angle of attack.

LaTeX-based development process



Future Plans

- Utilize 16.101x resources for on-campus subjects
- Improve edX support of outcome-based MOOCs
- Encourage LaTeX-driven development of edX classes