

PROFESSOR 1: About yourselves, so raise your hand, I guess, if you're from Wellesley. Nobody at Wellesley wants to fly. OK. Harvard? OK. Everybody else can boo. Who has no MIT affiliation? All right. Awesome. Well, welcome. Raise your hand if you've never been in a light aircraft, if you have no experience in a little airplane. OK.

PROFESSOR 2: That's good. That's a good number. For the MIT folks, how many of you are undergrads? OK. That's a good number. How many of you are graduate students? It's an even larger number, and how many of you are neither? You're just like an MIT alumni or staff. Just a few, OK, great. Well, welcome, all of you.

PROFESSOR 1: And let's just go through the goals. Let's see who's in the room. Who wants to eventually fly an airplane? Whoa. How about a helicopter? Good. I'm happy to see that. What about drones?

PROFESSOR 2: All right. That's a larger number than last year. That's great.

PROFESSOR 1: All right. So your course objectives are to get ready for your official FAA Knowledge Test. This is sometimes called the written test as opposed to the practical test or the check ride that you do at the end of your flight training. It's available in a bunch of different versions, including for airplanes and helicopters. We're going to concentrate in this class on airplane, partly because of the show of hands.

You will also be prepared though for the FAA's remote pilot test, if you decide to go direct entry into the world of commercial drones. We hope that this is also going to help you. Any kind of thorough study usually helps you make more efficient use of your in-aircraft time. And cause we have Tina here, with her PhD in aero-astro, you're going to learn something about the engineering as well.

So what is great about aviation? People were dreaming about flying a long time ago going back to the ancient Greeks. Only recently, we've been able to do it which is a good thing.

One thing I like about it is to look at the geology and the organization of human settlement on the planet. It's a lot of interesting structural patterns that one can see from above. Flying, a lot of the greatest engineering achievements of the last 100 years or so are embodied in the aircraft that you can personally go down to the local airport, rent, and fly.

Also, everybody at MIT is pretty good at doing stuff at a desk and thinking about hard

problems when sitting at a desk, but there's no emotions to manage other than depression. So flying combines everything. You might be a little bit afraid. It's not natural to be up in the air.

So you're working all of your human capacities at one time. You're managing your fear, you're working your brain to think about what's coming next, and you're also working your muscles. Finally, you can get to the beach quickly, but as I note here, most places, unfortunately little airplanes when you factor in the weather and all the training that you have to do, a lot of times, you could've gotten door-to-door faster.

PROFESSOR 2: I might also just ask a couple of you guys, pretty much everyone raised their hand about wanting to fly, so maybe we can just hear from a couple of you why do you want to fly? What's your interest in taking the course? Yes.

AUDIENCE: I'm also a PhD student in aero-astro, so like you learn all the theory for now, like, 5 years already, and I think it's a normal step to like want to do it yourself.

PROFESSOR 2: That's great so just for the folks that couldn't hear-- and what's your name? Lawrence. Lawrence was saying, he's a PhD student in aerospace engineering and has learned all the theory, and so it's a natural step to want to go and do it yourself. That's great.

PROFESSOR 1: All right. Can you do it? Yes, as in fact appears on the slide here, there are a whole bunch of little airports near us, and we'll show them on a subsequent slide. They all have flight schools, and you can rent either airplanes or helicopters or both, as well as find an instructor to teach you. You can actually learn to fly in about 10 hours.

To me, it's a little bit unfortunate that so much emphasis is placed on getting a pilot's certificate, because it is an independent achievement to actually be able to take off, cruise around, and land without the instructor having to touch anything. So that achievement, unfortunately, isn't recognized with a little certificate, but that's actually learning to fly. The rest of the training, which takes three times as long as actually learning to fly, is directed at flying a broken aircraft or a lost aircraft, all this stuff that prepares you to be the only pilot in the aircraft, which may not even be a goal. For passengers, they would rather have two pilots in the front not just one pilot, but there's a bizarre focus on training one person to do everything, which we'll get into a little bit more.

OK. So here's our local area, and watch this fancy device here. Whoa. So we're somewhere between Logan Airport on the bottom right and Hanscom Field which is surrounded by dashed

blue line, telling you it's a towered airport. So those are the two closest airports, I think. Norwood is just about as close. I'll show that right here on the lower left of the figure.

These airports that are in a magenta color, those don't have control towers. Over here is Beverly, and here's Lawrence. I think we've covered the airports that MIT folks most normally fly out of, but there's also Nashua not too far away. So you're surrounded by airports, even if Logan is the one that you're most familiar with.

Hanscom Field is the most substantial of the airports. This is only about a third of the ramp space and hangars and structures built up around Hanscom. That's a picture that I took from a Robinson R44 helicopter, which you guys could be flying in next week. And Tina's going to tell you what she likes to do on a typical trip.

PROFESSOR 2: So we heard from a couple of you that are observers or participants in the MIT flying club. Did anyone participate in the fly-out a couple of years ago to Maine, to Bar Harbor? All right. So this is a picture from that flight to Bar Harbor. Just grab the clicker for me. Thanks.

So if you were to drive, we took off just, as Phillip was describing, one of the nearby airports is at Hanscom. So we took off from Hanscom. If you were to drive, it would be a 4 1/2 hour drive to get there and back. So it wouldn't really be something that you could easily do as a day trip, but since we were flying, it was a great day trip.

So we flew up along the coast all the way to Bar Harbor, and what was really great about that is that we could go hiking. So all these folks flew in little airplanes from the Boston area through the MIT flying club, and we all flew up to the Bar Harbor, Maine. And then we went hiking in the Acadia woods and forests, and it was really beautiful, wonderful day, and then we flew back and landed just after sunset back here. So it was a really beautiful experience and a lot of fun to fly along the coastline. So I highly recommend it. If you're looking for a longer trip.

PROFESSOR 1: So I designed this. You can check it out on my web blog. It is a trip in a little Cirrus that'll take you to all 48 states in just 18 days and only about 50 hours of flight time, and that's a pretty standard little airplane. But more importantly, so people who-- I just came back from Bentonville, Arkansas, and there's a guy there who's the grandson of Sam Walton, the founder of Walmart.

So he can pretty much do anything he wants, and what does he like to do? He has a couple P51 Mustangs. He was flying alongside this little game Verde aerobatic plane that we were

testing out. He's got a super Corsair. There were only 10 built. He started as a little flight school at the local airport. He flies his little Phemon 300 business jet all over the world.

So I think that's a proof that flying is fun, because people who could do anything that they want to do also fly. You're going to meet people from all around the world of all different ages. It's a very diverse group, especially if you like older guys, [LAUGHTER] which I do.

Is it safe? OK. So we're going to show you how to make it safe. It's not safe statistically, compared to JetBlue, but that's not because little airplanes are feeble. As you'll see in this class, I think it's because of the way that people have been flying them.

So we're going to show you how, if you train like the airlines and fly like the airlines, you can get much closer to airline level of safety in little airplanes, as long as you're a little bit conservative with the weather. And if all else fails, if you're flying a modern design airplane, reach up and pull the parachute. And the whole airplane will float down, and you'll get out into a swamp. All right. I'm taking mine back. I thought that she was on air, but she's not.

OK. So this is me. I was class of 82 at MIT. It was much more challenging then than it is for you guys. That's because the Wisconsin ice sheet was covering the campus to a depth of about 100 feet. So we had to tunnel our way from East Campus into the main buildings.

I've been flying since 2002. I'm an instructor at East Coast Aero Club at Hanscom Field. I was also a regional jet pilot. I decided to learn to fly jets, and there's no better way to do that than at the airlines.

So I flew a 50-seat regional jet called the CRJ, Canadair Regional Jet, for Delta. I have type ratings, which we'll get into later. You need specific licensing for each turbo jet powered aircraft that you fly.

So I've got two of those. One of them is for the smallest Cessna business jet. I usually fly though, these days, a four-seat Cirrus, a Robinson R44, a four-seat helicopter, and a Pilatus PC-12 which holds either 11 people total or 60 sea turtles, which we'll get into a little bit later.

PROFESSOR 2: So this is a little bit about me. In the top left corner, you'll see me. I'm actually sitting in a Cessna 172, here at Hanscom, and I'm doing my engine run-up. And what do you see out the window? Does anyone recognize it?

AUDIENCE: An F-18.

PROFESSOR 2: An F-18, so what's really cool is that this airport that I fly out of, Hanscom, is also a military Air Force Base. Which is really exciting, because upon occasion, you'll actually see military jets come out. And they, of course, did not wait for me, even though I was first in line. They nicely cut in front.

They called themselves jet 1 and jet 2, and they went out. And it really looked like they didn't take any space at all, any of the runway length to take off. It really looked, from where I was sitting, right next to it, like they just turned like a rocket ship and took off, and it was really amazing.

PROFESSOR 1: Sorry, Tina.

PROFESSOR 2: No problem. So this is just a picture of me just going on a flight with some other MIT folks in the area, and then, of course, if all else fails, you can just jump out.

So a little bit of background. So I'm also aero-astro, just like you, Lawrence, and so I studied Course 16 here. I did my undergrad in 2009, and I was really passionate about it and continued on. And I did the MIT System Design and Management Program for my master's degree and then continued on in an interdepartmental PhD across Aero-Astro Engineering Systems and Sloan. It was a really great experience.

One of the things that got me really excited about it is that, when I was an undergrad in the Course 16 department, we were developing a satellite, and we needed to test that satellite. So we actually got to go on a zero gravity flight. So I don't know, has anyone heard of a zero gravity flight or the Vomit Comet?

All right. So a couple of folks didn't raise their hands. So the idea is that the plane flies in a parabolic trajectory. And much like a roller coaster, when you're at the top of the parabola, or the top of the roller coaster, you know how your stomach feels like it's lifting? All right, we're getting some head nods. The rest of you guys really need to go on a roller coaster.

So when you get that, you can actually, when an airplane flies like that, you can have everyone inside the airplane float up and have that sensation of zero gravity, or microgravity. It lasts about 30 seconds, and that's also how they filmed certain movies, like *Apollo 13*, to show the astronauts in weightlessness. So we use that to test our satellite. So it was a really great experience. It got me really excited about things, and then I felt very similar to you, that I wanted to see the theory in action, and so I became a pilot.

In terms of my professional career, I developed electronic warfare systems. I went on to Raytheon. I was the chief engineer of a \$40 million advanced radar and electronic warfare system. Now, I'm into entrepreneurship and have my own company in the security space. And I've been a pilot since 2012, and I love flying with the MIT Flying Club.

And I'm currently working on my IFR. Who knows what an IFR stands for? Shout it out.

[INTERPOSING VOICES]

PROFESSOR 2: Good job. Instrument flight ratings. If you don't know, that's fine. We're going to cover that. So we'll explain it all, but right now, I fly a, pretty much usually, the training aircraft, the Cessna 172. It's a very, very safe and stable aircraft. So we'll talk about a bunch of different aircraft.

PROFESSOR 1: All right. So let's hope that you've done the pre-reading. If you hadn't, I know everybody here in this room, at least the MIT and Harvard folks, are good at the book stuff. So please do hit the books.

Some of the thornier and less interesting topics we're going to rely on you to read through the book. So don't worry if you get everything in the class. We're giving you the highlights that are in the books, and passing is 70 on the test.

All right. Optional supplies, just for your reference, if you study a typical flight student, a lot of them will have a non-FAA textbook. It's not necessary, but some people like the different perspective. There's a free online one that we reference later that is written by a PhD physicist which is kind of interesting.

A lot of people have in hard copy a big, thick book called FAR/AIM with the regulations and the FAA's overall guidance on how to use airports and electronic navigation. There are test preparation books that you can get and electronic versions of this that just give you sample tests. You're going to use one of the websites from the King Schools. It's a popular vendor for those.

And then before your check ride, you'll be reading the Airman Certification Standards. FAA still use this sexist language. There's airman and airmen for all pilots, and this tells you what you need to demonstrate when you're getting your final check.

Most people will also buy their own personal headset. The noise-canceling ones make life a lot

better. Lightspeed is probably a little more rugged than Bose. Bose is more comfortable on the ears. The front desk of a typical flight school will have all of this stuff for sale.

The process, a lot of people wonder, well, how do I get my private pilot's license. You need the flight training. You apply for student pilot certificate on an FAA website. I don't know if that's still running completely. I just renewed the registration for an aircraft, so that part of the FAA is running. I don't know if they're sending out Student Pilot Certificates during the shutdown or not.

You have to do one medical exam in your life at least with an aviation doctor who's been blessed by the FAA, and you get your third class medical. After, eventually, you'll be able just to go to your regular doctor, if you want. Then, you take this knowledge test, and that's what you're being prepped for in this class.

And finally, you'll do your practical exam with an FAA-designated examiner, one of whom should actually be here tomorrow. So you can ask him how he tortures people on the check ride. Actually, I had to take one-- you have to do a lot of these steps over again, when you do a type rating for a new aircraft.

So when I worked at the airline, the oral, there is a guy who is famously harsh. And he would keep people who were trying to fly the Canadair Regional Jet in knots for hours and have them sweating during the oral exam. And the first question he asked me, the airplane has these hydraulic pumps. They're AC motors, and it has the engines generating the AC power. But a lot of stuff runs on DC, and I'd really wondered about the electrical systems of the airplane.

So I called up a friend of mine. It's a physics professor at UC Berkeley, and we had a one-hour discussion about when it made sense to generate AC and pipe that around the airplane and high voltage versus low voltage and DC. And so I hung up and said goodbye to my friend, Joel.

And then a few weeks later, there was the oral exam, and the first question the guy asked me was-- and I'd put on my resume that I just had a bachelor's degree. I didn't list any of my other degrees. I have a PhD in AAS, it happens.

So this guy who is the bane of all the pilots at this Delta subsidiary, he said, Philip, why does the airplane have both an AC and a DC system? So I gave him a little five minute spiel based on my conversation with my physics professor friend. He said, OK the oral is over. It's time to

go into the simulator. Didn't ask me a single other question.

All right. So let's do the part that we should have done earlier. Now, at least, I know how to put on the mic. So it's conventional in religious settings to bring in a reformed sinner, and that's what we have here, somebody who's found faith and is now living with faith.

GUEST SPEAKER: Thank you so much, Phillip and Tina, for having me here. I'm Minakshe. I'm a fourth year PhD student at Harvard. I do neuroscience, and when I'm not trying to understand how the brain works, I like to do most things adventurous. And I had really awesome friends who introduced me to the MIT Flying Club, so that was my first general aviation experience.

I was a passenger on a fly-out to the Republic Airport. It's in Long Island. It's really nice, because most of the times, if we get cleared, you get to fly over the Hudson, and you get this really nice view of the New York skyline.

So the other photo is actually Phillip and his sitter. So we're super lucky to be on another fly-out out as a passenger, and I got to fly in his Cirrus. So this is to Chatham, another really beautiful airport in the Cape Cod.

So all of that inspired me to become a pilot, but what really enabled me was precisely this course. So I am doing my PhD in neuroscience. My aviation knowledge was literally like [INAUDIBLE] it was like, OK, there are all these little buttons and dials, probably just have to check all those things and just like magic the planes are flying. So this course was what really laid the foundation for the aviation experience in the rest of my life.

And Tina was one of our instructors, when I took the course. It was a slightly different format. It was over the entire semester, once a week, but I really enjoyed it. So at the end of it, I felt really ready to take the practical flying lesson. So I was a student pilot at East Coast Aero Club, Bedford.

So my two years of grad school stipend that I saved was like put to really good use and the picture on the left is my first solo. So that's me doing the traffic pattern at Bedford. So I didn't have any like fancy electronic flight back then. It was just all paper maps. So that was just the GPS on my phone tracking me doing the traffic pattern Bedford, and like you can see how happy I was with all my solos, the smileys on my logbook.

So then, think end of September, got my private pilot's license. So I flew the Warrior, so yeah. So that's me right after passing the check ride in the Warrior. So after PPL, I wanted to take

spin training and did a little bit of aerobatics in the decathlon at East Coast.

So decathlon is a tail-wheel aerobatic aircraft, and when you do your PPL, they're always going to tell you like you will do stalls, and they're always going to tell you like OK, and we don't want to spin. I was like, OK, I want it feel heart is going. Yeah?

PROFESSOR 2: Maybe share what PPL stands for.

GUEST SPEAKER: Oh, sorry. Yeah. PPL is Private Pilot's License which is what all of us are here for. So yeah, so after a little bit of aerobatics and spin training, so my recent flying experience is being a lot with the MIT flying club now as a pilot.

So I did the same-- the first time I was ever on the light aircraft was this fly-out with the MIT Flying Club to Republic Airport. And very recently, I did that as a pilot, getting passengers with the Flying Club. So that felt really nice. So you can see, like I'm over the Hudson, 2,000 feet southbound, towards the Republic, and you get this really awesome view of the New York skyline, and yeah. It's really beautiful.

You get to talk to like Laganardia, New York, and I spoke to Kennedy tower. That was like literally a dream come true for me. So I would relive this moment like any number of times. I'm 500 feet above the ground level, and like you can see, the tiny shadow of my aircraft and like talking to JFK. And in 500 feet, because there are all these commercial jets descending to land at JFK, so it's a totally beautiful feeling.

So I've also been flying with my friends, and like this is the Winnepesaukee lake near Laconia, New Hampshire, and yeah, for the Harvard folks-- I think it's just one person-- you can probably recognize like Sanders Theatre. So this is a city tour. So you get cleared into the Boston class Broadway airspace. Yeah.

This is one of my friends who took a photo of like the Harvard campus. You can see Sanders Theatre at Memorial Church and just the fog setting in. So my mom visited me from India. I took her flying. So that was a very beautiful feeling like to show her what this means to me. Although, she was totally terrified the whole time.

Yeah. So I guess, obviously, I love it. It's really fun the beautiful view is experience and like the super adrenaline excitement every time I have the plane. And it is challenging, and it's really something like new rewarding to learn from every single experience, every single flight and, of

course, the people. So yeah. Thank you, and just sharing my experience from like having no aero-astro background to being here, I hope it inspires some of you. Thanks.

[APPLAUSE]

PROFESSOR 2: Thank you so much, Minakshe, for coming back and sharing your experience. So that could be you guys next year. So a little bit about the FAA written exam. So as we said, sometimes it's called the written.

That is the knowledge-based exam. So that is what, ideally, you'll be prepared to pass with flying colors. So it's a computer-based multiple choice exam. They usually give you about 2 1/2 hours, and you don't necessarily need the whole time. There are 60 questions, and they basically shuffle those questions.

So we're going to be teaching content somewhat that goes beyond this exam, because this is an MIT course. So we're actually in teach a little bit more about the aerodynamics and how really planes fly and go a little bit beyond just the course, but we will cover all of this material. And then, so as Phillip already said, to pass you need as a 70, but we believe that you can score higher than that. So we really encourage you to take this exam right after the course.

Phillip can actually endorse your log book, or you can actually print out a log book and endorse you to take that written exam. So just following the course, the final exam of this course, will be a practice a exam, and so you can take that. You can actually take it as many times as you want in order to pass, but hopefully, you don't have to take it too many times. And after that, we'll endorse you so that you can actually go take the actual FAA written exam and get that out of the way. So you can be on your way to becoming a pilot.

PROFESSOR 1: OK. So most East Coast Aero Club-- I'm an instructor there-- most of the people that I've seen will skim through at least the FAA books about three times before they take the test. They will use a test prep book, and they end up getting a 98 or 100 on the exam. So they do a little bit-- they go a little bit overboard if the goal is just to pass.

Again, if you have the physics question, a physics-type question, we do recommend this free online textbook from this physics PhD. These presentations, of course, are all available from the course homepage. You can download them and follow all the links.

As Tina mentioned, I can endorse you. Any aero-astro majors who complain that it's too hard,

remember that everything that you're reading from the FAA is designed for somebody who's still in high school. Tina.

PROFESSOR 2: So this is just a sample question. They give you a flavor. Obviously, we haven't touched the material yet, but why don't we just take a minute to read this, and then see if you guys can have a good guesstimate as to the answer? So I thought this would be appropriate, given the weather conditions. You guys had to trudge through a lot of snow and slush to get here today.

So here's a question about frost. Why is frost considered hazardous to flight? OK. Who thinks it's A? Who thinks it's B? All right. Who thinks it's C.

All right, good job, guys. Just generally, icing, bad for a plane. So anything that's really increasing lift or increasing control effectiveness, that's not what you're getting when you have frost. It's a bad thing. So we'll discuss this in more detail.

PROFESSOR 1: All right. Here's the schedule for the next couple days. We'll just talk about the parts that are fun. This afternoon, we're going to be visited by an F-22 pilot. That's a little better than a Cessna, Piper, or Cirrus in terms of performance, if not in terms of cost-effectiveness. Lunchtime, there's going to be pizza and a slideshow about Oshkosh, the big aviation gathering that happens in Wisconsin every year.

Tomorrow, you're going to hear from a designated pilot examiner, Marc Nathanson, who's also an acrobatics instructor and a US Air Force F4 fighter pilot veteran. Day three, Michael Holdsworth who's going to come in. He's a local drone pilot for Hollywood. So he'll tell you about using the commercial drone license to do something interesting.

At lunch on day three, on Thursday, you're going to hear from a veteran. Actually, no, he's an active duty officer in the Brazilian Air Force who's here at MIT, and he's going to tell you about being a test pilot. And then at the end of the class, we've tacked on the founder of ForeFlight which is one of the most successful aviation app companies. They're in a lot of airline cockpits now as a replacement for paper, and they do a lot of flight planning.

And so he's going to bring himself to talk about any questions you might have about starting a company and being successful in business and also one of his engineering folks, I think, to talk about the engineering behind the app. That's going to be a little bit more informal. It's optional, but we think it'll be interesting.

OK. So welcome again, and now you're part of the community of aviators, at least as soon as

you go on your first MIT Flying Club fly-out. It is better to be on the ground wishing you were in the air than vice versa, but people have been wishing to be in the air for tens of thousands of years. And we think that-- well, we feel lucky to be some of the few who are able to control our own destiny through the air. So now, it's time for questions. While you're formulating your brilliant questions, enjoy these photos which I snapped at the Reno air races, where the Blue Angels obviously already visited.

AUDIENCE: What's the [INAUDIBLE] on the airplane?

[LAUGHTER]

PROFESSOR 1: So what why do you have both AC power and DC power on a big jet? Big jets, the flight controls are too heavy to be operated by a human, so you need hydraulic power. Basically, there may still be steel cables going out to the flight controls, but they're just modulating hydraulic pressure. How do you generate hydraulic pressure?

There's a big motor to pump the hydraulics, and it's easier to run a big motor with AC power compared to DC power, and the engines are also spinning. So if you just think about Maxwell's equations, it's simpler to run AC for that, and also, of course, you can have higher voltage and transform it down. And then for the electronics, DC power is what they want. So that's why the DC's in there, to run radios and so forth.