**Flight Lab outline**

Generally I’ve taken bits and pieces, probably from across projects, to present one cohesive story. In terms of what exactly they’re testing, can we say that they’re working on sending signals *to* the LAMs and locating the drone by triangulation? And then we’ll leave off as the next step will be sending those signals *from* the ground back to the drone so it knows where it is?

* Previous stages of the project tested and validated that it is possible to send the signals from the drone to the LAMS then to the folks on the ground and locate it via the LAMS’ triangulation. The work we are trying to do now is send that information from the ground back to the plane. However, as you point out below we haven’t done any flight testing related to the current phase of the project, so if you want to focus on that first stage for the flight testing/troubleshooting in this book, that could work.

**2-3 intro to Hannah and Flight Lab**

Professor Lum welcomes Hannah to the lab. Establishes she is a pilot and excited to learn from this new perspective. She has come to the right place—this is a great hands-on way to get involved in the technology of the future. Classroom setting, perhaps they look out the window at a flight test in action.

* sidebar: the real Hannah with a photo and background on being a pilot and coming to the lab. Introduces the lab by name.
* sidebar: what’s a drone (unmanned) and how they’re useful (3 Ds)

**4-5 establishing problem/explaining the solution in progress**

It’s not really clear how this particular team came to work on TRAPIS, so perhaps Professor Lum assigns Hannah to a team, in the process explaining what the team is already working on. Thus he gives a brief explanation of how GPS is used, why losing that signal is a problem, and that the team is working on a way to use ground signals to make up for a loss of GPS. Perhaps other (generic?) students can offer parts of the explanation so there’s variety.

* sidebar/diagram to provide explanatory info on GPS, transponders, and LAMs

**6-7 building a model: software**

Shows the software team at work. Intro text identifies what this team does generally. Frames show students discussing coding to send the signal from the drone to the ground antenna (focusing on triangulation), perhaps with code and/or a diagram on a computer screen and/or whiteboard. Page 7 shows them bench testing it by walking around with a transponder and the dot for the transponder correctly moving around on a computer screen map. Text will suggest how important it is to work as a team, and that everyone brings diverse skills.

**8-9 building a model: hardware**

Similar to previous spread but highlights the work of the hardware team. Shows them modifying the body of the drone. Examples are adding the flight controller, GPS receiver, or radios. Not sure I understand where exactly these would be placed. Do they also need to modify the wings etc. to make sure it’s still aerodynamic with the new parts? Page 9 gives an example of bench testing. Need a specific, easily visible example here: perhaps a part of the drone, such as just wings or just the motor for a purpose related to sending signals? Something related to the body rather than circuits will be easier to show/explain.

\*\*\*\*Which team would Hannah be on, at least in theory? What of the above would she be doing?

* Most of the hardware goes inside the vehicle, as shown in the photos. The GPS receiver and radio antennas are mounted on the outside. These parts are small enough that it doesn’t significantly affect the aerodynamics. For almost all of our projects we take off the shelf airframes and integrate off the shelf electronics.
* On the hardware side, most of the work has been going into constructing new aircraft to carry the payload, so bench testing could include testing the motor: spinning it up to verify that it is functioning on the newly built plane (see motor testing photo). Could also include testing the servos to verify they deflect in the proper direction. The servos are what cause the ailerons, elevator etc to deflect to steer the plane while it is in the air. This is a process we go through every time we put together a new aircraft (this isn’t really innovative research, but is required to fly a new aircraft).
  + We are also 3D printing the case (small box about 5 inches long) to house the payload itself, which has required printing and reprinting a number of iterations (~5 so far) to get everything to fit nicely inside of it, and to get the box to fit within the plane. 3D printing could be interesting for the younger audience since it is becoming more and more common in a variety of applications.

**10-11 field test**

Finally, the two teams come together for a real test. Some things go right, some things go wrong. Professor Lum assures the teams that learning from failure is critical to making improvements and moving forward—this is exactly why we do flight tests.

Someone releases the drone by hand? Is someone working a remote control?

What are they testing here? If no real tests have been conducted, can we use a previous test? Can we say it’s whether or not the triangulation works? Or use something that was really only a bench test but put it in this scenario?

And then for whatever is being tested, what didn’t work? Ideally something visual.

Does Hannah have any specific role in the test?

* As shown in the photos, the vehicles are hand launched (thrown into the air kind of like one would throw a paper airplane, just on a larger scale).
* Hannah’s role in flight tests is to coordinate the overall test, to make sure everyone else has a role and to keep the operation moving forward. During the actual flights, she is usually the one using the remote control to pilot the vehicle for all stages of the flight that aren’t autonomous. This typically includes takeoff, landing and during emergencies. Hannah is one of the few FAA certified Part 107 pilots in the lab, which allows her to pilot the vehicle. Part 107 certification allows someone to fly drones commercially or for research.
* During a previous stage of this project a couple of years ago, the lab actually did verify that the triangulation works with our vehicle (Hannah wasn’t directly involved in this phase). Our students were able to fly our UAS in the vicinity of the LAMS system and could track it on a computer on the ground without getting that info from the GPS. There were a number of flight tests leading up to this final demonstration.

**12 learning from the flight test, trying again**

The team discovers some minor software bugs in sending and receiving signals. The software team now knows exactly what they need to go back into the code to fix—shows them huddled around back at the computer. They try and bench test again. The hardware team works on fixing the proximity of the transponder to the antenna by putting the shielding in to keep the electronics working and the signals clear. They also bench test. Will probably need some assistance with visuals here, in terms of what’s located where and what shielding would look like.

* The shielding consisted of simply lining all of the wires and the interior of the payload box with aluminum foil. The antenna position is shown in the photos. It should be oriented vertically on the tail. The transponder/payload are located inside the main body of the aircraft.

**14-15 success**

Finally the team is ready to head out for another flight test with all their fixes in place. The signals work! And/or what would success look like? Without GPS, the drone is completely located and tracked the whole time it flies?

Page 15 features a diagram of the drone with all its parts and what they do, perhaps referring back to what was fixed from the previous test or what each team contributed. It would be great if Hannah can provide a diagram with parts labeled—just the basics.

* Without the use of GPS, being able to track (see the plane moving around accurately on a computer map) the plane the entire time is definitely a success. This was successfully demonstrated in September 2016.

**16 contributing to the big, real-world picture**

Every successful flight test is important, but there are many steps to completing the whole solution. Now that the triangulation works by sending signals to the ground, the team’s next step will be to send those signals to the plane so that its autopilot system can use them to keep flying properly. Hannah and the team know that more flight tests and more failures are to come, but that they will help them get to the end goal—helping drones and even real commercial planes fly when they lose a GPS signal. Transition to potential real-world applications.