Human Practices:

Applications of Drones

An Investigation of the Scientific and Humanitarian uses for a Biological Unmanned Aerial Vehicle

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S-B-S
iGEM

2014

USES OF A BIOLOGICAL UAV

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The 2014 Stanford–Brown–Spelman International Genetically Engineered Machines (iGEM) team is working on a series of interrelated projects towards the construction of a biological unmanned aerial vehicle (UAV). In order to compete with existing drones, our model will be modular, biodegradable, and waterproof and will employ biosensors in tandem with traditional electronics. Thus, our model will not only be able to complete missions which may be dangerous for humans but will also integrate safely into the environment after its flight.

The purpose of constructing a biological drone is to make a plane that is cheap, durable, and ecologically unobtrusive. This drone should not only be easily producible but should also be non-toxic to local flora and fauna or the environment where it lands; to this end, we will engineer any cellular components of the UAV to be “amberless”, which prevents horizontal gene transfer between our modified organisms and microorganisms in the environment, as this is a constant concern with synthetic biology.

Still, the use of UAVs in the environment carries a stigma due to the prevalence of their use in the military. For this reason, our team has elected to interview leading scientists and engineers from diverse fields, so that we can begin to build a more complete picture of how UAVs are used across disciplines and of how their use benefits scientific and humanitarian causes.

Yours in Science, Engineering, & Design,
The 2014 Standord-Brown-Spelman iGEM Team

Naval Air Station, Moffett Field, Mountain View, CA 94035

PROJECT ABSTRACT

Towards a Biological UAV

We are currently working on a series of projects towards the construction of a fully biological unmanned aerial vehicle (UAV) for use in scientific and humanitarian missions. The prospect of a biologically-produced UAV presents numerous advantages over the current manufacturing paradigm.

First, a foundational architecture built by cells allows for construction or repair in locations where it would be difficult to bring traditional tools of production.

Second, a major limitation of current research with UAVs is the size and high power consumption of analytical instruments, which require bulky electrical components and large fuselages to support their weight. By moving these functions into cells with biosensing capabilities - for example, a series of cells engineered to report GFP, green fluorescent protein, when conditions exceed a certain threshold concentration of a compound of interest, enabling their detection post-flight - these problems of scale can be avoided.

To this end, we are working to engineer cells to synthesize cellulose acetate as a novel bioplastic, characterize biological methods of waterproofing the material, and program this material's systemic biodegradation. In addition, we aim to use an “amberless” system to prevent horizontal gene transfer from live cells on the material to microorganisms in the flight environment.

Visit our wiki, 2014.igem.org/Team:StanfordBrownSpelman, for more information on our projects.

INTERVIEWS WITH FIELD EXPERTS

SUBJECT

Dr. Lynn Rothschild

Dr. Lynn Rothschild is an evolutionary biologist from NASA Ames. She has worked at Ames since she was a post-doctoral fellow with the National Research Council in 1987. She has recently started pioneering the research related to biological UAVs and serves as an advisor to the Stanford-Brown-Spelman iGEM team.

Q: For how long have you been working with UAVs?
A: Even though I have been here a very long time, I only started getting interested in UAVs about six months to a year ago. For various reasons, I think UAVs are useful for the science that we conduct at Ames, and I think we can contribute to their building.

Q: Could you elaborate on the reasons UAVs are important in your career?
A: My primary interest has been in looking for life elsewhere in the universe. One of the things UAVs could be particularly good for is surveying the surface of a planet. Now on the Earth, it seems that every square inch has been covered by Google Maps. But that isn't true for Mars, or Titan, or Europa. When you land on another planetary body with a mothership, it might be very cool to be able to release UAVs at the surface and find out about interesting areas. I am also, of course, interested in planet Earth, given it is my home. I have been interested in the use of UAVs remotely in Earth Science. For example, to monitor coral reefs. I am mainly interested in ground-based research, and I can get much more detail about where I am looking by doing ground-base experiments. But once you get in the air, you can cover much more area.

Q: How are UAVs connected to synthetic biology?
A: Well, in the past, UAVs have not been connected to synthetic biology at all. But I am in the Earth Science group at NASA Ames, and periodically

UAVs get lost- for example, on coral reefs or in other sensitive habitats. As I started to hear about this, I thought, "Well, wouldn't it be useful if the UAV was biodegradable, so if it crashed somewhere that was sensitive, it wouldn't matter if it dissolved. Synthetic biology can do that. In addition, these UAVs could be lighter and certainly a lot cheaper to make. You can make many more and not harm the environment, so that's why I got interested in combining the two.

Q: Do you think a biosynthetic UAV would be as efficient as it's more conventional counterpart?
A: I think that synthetic biology UAVs could be equally efficient. Where my dream is to make a UAV where every single part of it could be replaced with something you could make biologically, that may not be completely practical. For example, you might want to have a camera on a UAV, and it might be really difficult to have an organism perform the same function or produce images that are worth anything. So, realistically, this is going to be much more of a hybrid vehicle. But much of the body of the vehicle could certainly be made biologically. There are many biosensors, there are many bits and pieces that we could do. That's one of the many things that my lab, particularly the Stanford-Brown-Spelman iGEM team is exploring this summer.

Q: What is the biggest drawback to using a biosynthetic UAV?
A: I think the biggest drawback is having it crash. There's a big difference between having a living organism on there, and just products an organism made. For example, our team is thinking about using microbial cellulose. Cellulose itself is in wood, most of cotton, and all around nature. Once the cells make it, it really doesn't matter whether it came from a cotton plant, a tree, or the microbes in the lab. I'm not concerned about that. However, if you having living organisms acting as biosensors and then the plane crashes, there certainly could be problems as this plane interacts with the environment. Hopefully people could think of this in advance, and design such that this never became a problem. For example, on crashing, the cells might die. Or the cells could be attenuated. There are all sorts of other processes to keep them from contaminating the environment. But that, to me, is the largest concern with a biological UAV- having living things on the UAV.

SUBJECT

Vince Ambrosia

Vince Ambrosia is a NASA Earth Scientist who is also affiliated with the California State University Monterey Bay. He has been with NASA since 1980 and has been involved with remote sensing of ecosystem processes. More recently, he has been involved with natural disaster systems and improving understanding of them.

Q: How do you use UAVs in your work?
A: We have done, in particular with wildfire analysis or disaster analysis is look at both small UAVs and large UAVs for tactical versus strategic observation of natural disasters to help those on the ground make more informed decisions about how to mitigate that wildfire event or how to respond to that wildfire event. So in essence, it is taking sensory data and massaging it such that we can make real time decisions about where that fire is and where it is going. We also use UAVs for natural resource inventories in areas that are hard to get to or difficult to get to. You can think about this in the 3-D model, or Dull Dark and Dangerous missions, where a UAV is really important to be put to use most effective. For example, you would want to employ a UAV in an urban area that has just has a toxic plume blowing through it, and you don't want to but anybody at risk. So you fly a UAV to collect all the data you need to start informing decision on how to deal with the disaster.

Q: So, what are some of the limitations you have seen in the conventional UAVs you have worked with?
A: There aren't many limitations of UAVs themselves, but more so limitations based on regulations of operations of the crafts. What we really want to see, though, is improved miniaturization of the sensory technology on UAVs so that they can be used more ubiquitously. So taking a small UAV, for example a hand-launched UAV or one that only

needs a very small take-off area, and flying it around for 15 to 20 minutes to observe the features you want to observe. Those features exist, but the really important sensor technology that gets that data that you as a scientist want? That sensor technology doesn't exist in small enough packaging to be used on a small UAS.

Q: So is that somewhere that synthetic biology can be important?
A: Absolutely, given that microorganisms can act as sensor technology.

Q: What is your opinion of synthetic biology at large?
A: I think that synthetic biology is the next wave of innovation in the science of creating things. It could prove particularly useful in UAVs such that you could have a small UAS with great sensor technology, flown in conditions harmful to humans, and ultimately have it land and be completely biodegradable and not impact the earth system at all. A perfect situation for that technology is a Fukishima-like meltdown, and you want to be able to measure radiation output. But, you don't want to subject anyone to the radiation poisoning necessary to get the UAV out of that system. If you could have a UAV collect that information, and then biodegrade or destroy itself naturally, it might be a great application for UAVs and you still get your measurement capability!

Q: Do you think biosynthetic UAVs will be as efficient?
A: It's hard to say. I could see roles where synbio UAVs could be more useful, and easier to create, and thus cheaper. If you could have a disposable platform, it could be tremendous cost savings. In that sense, they could even be more efficient.

Q: As I'm sure you are aware, there is a huge stigma surrounding the use of UAVs, much like the stigma surrounding synthetic biology. What can we do, as a community of scientists, to counteract that stigma?
A: Right now, we see a lot of concern around the use of UAVs in civilian society. I think a lot of that worry comes from the fact that people only see UAVs in the context of their military usage and think that all UAVs are used for spying or for launching missiles. They are concerned about the integration of UAVs into the daily regimen of normal society. We, as a scientific community, need to be more transparent about the really beneficial scientific use of UAVs- for example, mitigating natural disasters. They really need to know about how UAVs can be used to societal benefit. The same can be said of synthetic biology.

Q: When do you think UAVs will become a part of our everday lives?
A: Really the only thing stopping the domestic use of UAVs is public perception and the law. I think if we try to flush out this concept of spy-planes, rules and regulations could be loosened, and UAVs could be everywhere in about 5 years.

SUBJECT

Randy Berthold

Randy Berthold is a NASA Earth Scientist who specializes in the use of UAVs for data collection about ecological systems. Mr. Berthold began working with UAVs in the 1980s. In his career, he has worked with all kinds of UAVs, including hand-launched, small UASs to large vehicles that have a 100 foot wingspan.

Q: What is the most significant advantages of the UAVs you have worked with?
A: Different categories of UAVs have different strengths and weaknesses. With the small ones, we find their ability for easy deployment, shipping, operation, and maintenance very advantageous, and we try to use those whenever we can. In terms of using other UAVs, we decide which craft to use based on things like duration of the mission and how heavy the payload it is. The larger aircrafts obviously give us more resources in the sense that the fly longer and carry more.

Q: What are some situations where the use of UAVs are ideal?
A: We use UAVs quite a bit when sound is a factor- meaning you want to take observations while make as little noise as possible. It turns out that electric UAVs that are small, are ideal for sound-sensitive missions, like watching wildlife. Other than that, UAVs are really useful when we are working with a harsh environments, for example icy places, or situations with large updrafts, like fires, or even places where there are particles in the air that make it dangerous for humans to physically be there.

Q: How do you feel about synthetic biology at large?
A: Well, my opinion is still evolving. It is a new field of research, and it seems to have some immense potential to it. I think it's full application has yet to be truly discovered. From what I have heard so far, though, it's

capabilities are well suited to advanced UAS development.

Q: What are the advantages of using synthetic biology in concert with UAVs?
A: The first that comes to mind is the environmental aspect of it. We fly in some very very sensitive environmental zones. If an aircraft was to be inadvertently lost or a component of some sort, the concept of biodegradability of an instrument is a very strong feature.

Q: We have realized recently that a pretty big issue with small UAVs is upmass.
A: Right, one of the limitations of certain types of UAV research is the mass and volume of the technology we would have to take. For example, mass spectrometers and particle counters are ridiculously large and hard to get into the air and consume a lot of power.

Q: What sort of things are you normally trying to sense?
A: If we're mapping a volcano, we are concerned with emissions- SO_2, CO_2, and even water vapor distribution. If we are looking at a plume, we are concerned with particle distribution. We also are interested in identifying some species we see while employing these vehicles.

Q: What if synthetic biology could fix those upmass issues by replacing a mass spectrometer with a cell that was capable of sensing all the things you just mentioned?
A: Well, that changes everything.

Q: How else do you think synthetic biology can help with making UAVs better?
A: Well, being able to duplicate UAVs easily and with little expense could be enormously useful. It would be amazing to carry a small UAS with me to the Amazon, or to a volcanic site. It would be even more amazing to just make one on site.

Q: How do we counteract the stigma surrounding UAVs?
A: Well, to be honest, I think a lot of people have legitimate concerns. Safety is, of course, first and foremost. If we could come up with a very high level of confidence and a safety record for an aircraft, it would make use in the national airspace much more feasible and accepted. Communities are concerned about command and control, and I think scientists and engineers can work hand in hand to make the crafts safer and thus more appeasing to the public eye.

SUBJECT

Matt Fladeland

Matt Fladeland is a NASA Ames scientist whose job it is to manage the airborne science activities done to support NASA's satellite missions such as characterizing space-borne instruments and understanding Earth system processes.

Q: When did you first start using UAVs in your career?
A: When I came to Ames in 2002, I started working for a group that develops instruments for UAVs. The first project I was involved with was the Western States Fire Mission, where we used NASA's predator UAV to image forest fires and produce real time data products that could be used to battle wildfires. I am more recently working with UAVs and volcano plume measurements.

Q: What were some of the limitations of the many UAVs you have worked with?
A: Most of the limitations are not with the UAVs aren't the technologies themselves, but the policies and procedures that go with safe access to the airspace. That is being worked on by the FAA right now. We know all about the limitations of the crafts, and we modify them to meet our needs.

Q: What is your opinion of synthetic biology?
A: I think it is an interesting new area of science that will likely benefit us in many ways. I think it is critical to NASA's mission objectives to develop new materials and tools to further our exploration.

Q: How do you feel about the idea of somebody making a UAV using synthetic biology?
A: There are likely places for that- in some places we fly UAVs and consider them to be expendable. They are very dangerous, and there is no other way to get the data, and it's likely that the craft will not come back,

but you still get your scientific measurements. Nobody likes to litter, so it would be nice if those UAVs would break down. The concern would be that we need to characterize, to a high fidelity, the strength and durability of the materials. A concern would be about the degraded capability of the materials to contribute to structural integrity.

Q: How the the scientific community counteract the stigma that surrounds UAVs?
A: One thing that we have been trying to do through our research is that there are plenty of beneficial things that UAVs do for society. You know, much like the work we do with processes that come together to create climate, and how that is changing. There are certain variables that you can only get with UASs. It's opening up a vantage point for us that ultimately helps us understand how our planet works. There are many civilian technologies for UAVs, and the more we get the word out, the more we can assuage their fears. But there will always be people who are irrationally afraid of new technology, and that's just how it is.

Q: How do you think that the conventional means of production of UASs and UAVs compares to the biosynthetic one?
A: I can certainly imagine there being advantages to the biosynthetic UAVs. Some may be producing them faster, or making them moldable, and cheaper.

Q: What do you think about the risks involved with using synthetic biology to make UAVs?
A: Again, I think it would just be about people's perception out of ignorance that it would be something dangerous. When we fly a mission, there are large discussions about what material we use to build. The public doesn't care about plastic versus metal or biomaterial. So it really just is a comprehension thing.

SUBJECT

Jim Head

Dr. James Head is a planetary scientist from Brown University. He specialized in geology in his education, and began studying lunar geology as well as exploring other planets when the Apollo program began.

Q: How are UAVs useful in your career?
A: Of course, we would all like to go to these planets ourselves, but unfortunately only a few people go, and I was lucky to be associated with those programs and work with the astronauts who went to the moon. But, we use remote sensing data. We explore every possible way we can to get data remotely. I spent a lot of time in Antarctica studying volcanoes and things like that. So, I have always been interested in things where we can gather additional information and optimize our return by going to a variety of different places, by trying several approaches to remote sensing. My interest in UAVs obviously stems from that. They are a platform that is incredibly cheap, in a lot of ways, and very versatile- it can do tons of different things with sensing and so on. As a geologist, it gives you eyes in places you couldn't otherwise go. So, UAVs have been a very strong interest to me for my own fieldwork and research on other planets.

Q: If you were to improve current UAV models to help with your remote sensing technology, what would you add or remove from current models?
A: One of the key things about UAVs is scientific capability- so the more you can carry on a UAV, the more you can understand. Instruments weigh pounds or kilos, so you need to be able to make some choices. The more you can miniaturize the instruments, the more you can manage to carry on a UAV, the better off you are. And the more instantaneous kind of analyses you can do- if you can devise remote sensing technologies that allow you to, on-the-spot, detect certain kinds of minerals by sorting through massive amounts of spectra through good on-board processing, that would be pretty awesome.

Q: You just mentioned that you would love to have miniaturized remote sensing technologies on a UAV. How do you feel about using biology, or cells, for that purpose?
A: Well, I think using biology is a really critically important thing to do. There are a lot of capabilities here- not only their detection or their modification, but also trying to develop ways in which you could take things to other planetary bodies without a mass deficit. One of the big problems with planetary science is the payload of vehicles, or the upmass as it is called. You really want to minimize that but optimize the science, so if there's anything you can that builds these capabilities when you get there, that's just great. Synthetic biology and anything you can do in that arena- that's just gold.

Q: What do you think are some of the benefits and dangers associated with using synthetic biology on UAVs?
A: I think obviously synthetic biology has both benefits and dangers. The thing that is most important to me is that it represents an unbelievable capability to take advantage of nature, as we know it today to benefit humans. Like anything that has to do with technology, or biology, [...]

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