> **"Open science is a collaborative culture enabled by technology that empowers the open sharing of data, information, and knowledge within the scientific community and the wider public to accelerate scientific research and understanding. (Ramachandran et al., 2021)"**

-Ramachandran et al., 2021

This definition was derived after reviewing numerous open science definitions from agencies, institutions, and organizations around the world. Many of the existing definitions had changed over time as the collective understanding of open science matured and became more nuanced. Let's break down the definition a bit more:

- Research products and processes should be available to all, not just a small subset of experts, particularly if funded with public funds.
- Collaboration is the heart of open science. Researchers with different areas of expertise and backgrounds can bring new perspectives and strategies to the project.
- Advancing technology has changed the way we share results. These advances can be harnessed to enable greater collaboration, increase distribution and exposure for the research products, and accelerate the pace of new discoveries.
- While open science is our aim, security and privacy remain important concerns. Therefore, select sensitive information should be protected.

The goal of NASA's Open Science 101 is to push the community as a whole towards open science as an ethical responsibility to share knowledge.

Questions:

- What does the act of open science look like? Does a researcher use or create something specific that would characterize their research as open? What comes to your mind?

  Open science looks like a group or individual committed to documenting their process of knowledge assertion or creation in such a way that compels others to review their work and learn from it. I imagine the practice to be a day to day commitment, where you produce results in high enough quality to be interpretable by highly interdisciplinary teams

- Describe how you currently share your materials (data, code, results).

  I share my work mostly by posting it online. My website hosts a lot of what I do, and my documentation of my projects is made in such a way that It is highly reproducible by others at my skill level or higher in STEM. My hope is to find more ways of publishing work I do in order to better get it out to the public, responsibly. Keeping all that I do under a domain I own still does not compel open practices as much as I feel could help the scientific community.

- How might you share materials in the future more openly?

  I hope in the future to find an organization, student journal or other such group that would be willing to publish my work and documentation for others to use, and find through their services.

- What stands in the way?

  I am not exactly sure where to put the work or research I do. I kind of imagine that my discoveries or learning experiences may not be useful, since I haven't seen stuff at an undergrad level published frequently. With this benign said - I think in the future, to best support open science, the process of publishing should be more easily extended to students in the form of university journals or "starting" journals. It will help students like myself get into the habit of producing open research so that they feel compelled to when their work reaches higher levels of academia.

Goals of open science include the following:

- Facilitating collective benefit.
- Expediting development and innovation.
- Realizing unbiased outcomes.
- Ensuring appropriate control over the data you use, make, or share throughout your research process, and comply with policy, regulatory, and legal guidance on release.
- Nurturing respectful relationships with the external communities who might provide or interact with your data, code, and results.
- Actively engaging with interested scientific and public communities to increase collaboration and consultation throughout your research efforts. Members of communities that provide data must be allowed to determine the benefits, harms, and potential future uses based on their own values and priorities.

Questions

- In your field, what steps are being taken to increase openness, and what stands in the way?

Steps being taken are usually posting on applications like YouTibe, Reddit, or public forums for aerospace, rocketry etc. What stands in the way is the density of the information, and what we can actually talk about based on fuzzy ITAR lines.

- What could help to increase openness?

I think it would be beneficial for our generation of engineers to get more into video documenting and record how and what they do. After all, many people learn best by seeing.

- What stands in the way?

It's certainly a lot easier to solve a problem or make an action and then move on in engineering. Recording the process, documenting it and capturing the details are difficult, and add to the strain of solving the problem at hand.

Short term gain is less work, but the clear long term loss is failing to practice open science and dooming yourself and others to fall into the same problems, with little resources available for solutions. This of course creates hurdles that hinder progress, solving problems that have already been solved.

A note from NASA on documentation:

Doing open science not only lets other people understand and reproduce your results, but lets you do so as well! Implementing open science principles such as good documentation and version control helps your future self, potential collaborators, and anyone else to understand your results

- **Open science is a good practice as much as it is an important learning tool. By documenting the process you keep it open for yourself, which means research that takes place over time doesn't allow for early progress to be forgotten. Science in industry isn't like in school where you prioritize mass information memorization for tests, we will often as engineers need to go back and look at our notes from before. This is okay and is how we develop great things!**

L'Space NPWEE Note- Funding agencies have begun to realize that openly sharing research products can increase the reuse of work and encourage higher citations, resulting in a better return on investment.

More than just results can be "open" - your slides, discoveries and resources may help others in the field too, and should also be considered as your contribution to the community.

Questions

- Can you find your own previous work, post-publication and/or pre-publication? Can you bring your research materials (data, code, results) with you if you change institutions?

I can find a portion of my previous work, but large portions of what I did in highschool were turned in for grades and essentially left alone. This is really relevant with my work in dissection and in microbiology. Since college I've tried to document much more of what I do, and by having my own page, and creating accounts for open sharing (like with github, at registering with ORCID) using my personal credentials, I can access this work as I change institutions.

- Can you find the work of your collaborators? Of researchers in other fields that you find interesting? Have you reached out to others to collaborate with them after finding interesting results?

This is a really pertinent question for me right now as I've been working on a lot of aspects of high power rocketry lately. It is definitely much harder to find information that I'm looking for (of course with ITAR regulations this is understandable) but not impossible to review the work of others. Mostly I read the technical reports of other university rocketry teams. I find the research done in avionics and aeronautical systems fascinating, and love when I can read about it in a "hand on" perspective. This means that the person whose work I'm reading is really tired of the things they are talking about, and at a level of access and funding that are really similar to my own, meaning their Ideas aren't behind a wall of impossibility for me or my team at Lehigh. A few times our team has reached out to other universities about their reports, but often with little luck. "Cold-emailing" other groups who you will often compete against in competition usually has its issues. Nevertheless, the competitions we all participate in require good documentation as a judging criteria, and for this documentation to be publicly available to those involved. These standards allow a lot of information to be learnt from others in the field of rocketry.

- Are people in your field giving and getting credit for work done?

Yes, while I am new to the technical documentation side of things, it seems that those who work on projects are really thanked and attributed. In higher level institutions however, there is a limit to these attributions, as of course ITAR has regulations on the sharing of sensitive information. I think this is okay, and doesn't mean open science needs to stop, It means that at certain levels it happens in a more selective way. By this I mean that just like with security clearance in the U.S. if

you are working at a level that needs this information, you should be able to get it in a community form. I understand that there are levels to this I don't understand, but an optimistic Junior can hope this is what industry looks like.

A note on getting unexpected results or no results- Scientific journals have traditionally faced the issue of publication bias, where journal articles overwhelmingly feature novel and positive results, according to a 2018 study. (DeVito and Goldacre, 2018)

Open science allows for people of different disciplines, career and skill levels, and backgrounds to collaborate and create new results that come from varied perspectives, and validate OR disprove results based on wider knowledge.

A patent is an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem. Patents are another way to make your work open while protecting your intellectual property.

So should I share it all? - No, so lets cover how to share safely
Sharing ITAR/EAR-regulated data, equipment, resources, or research without clearance to do so can put the country's national security at risk and may bring about both severe criminal and administrative penalties.

- It is important to plan for the release of your data and results from the very beginning of your research project. Investigate and obtain all permits, approvals, and/or certifications needed to ensure you can share your research products. (some journals may not even accept your work if you don't document this!)

Some good questions to ask about your publishing of research:
Check you have the right to do so by asking...

1. What does your supervisor or Principal Investigator say?
2. What does your grant/contract say?
3. What does your institution say?

4. What does your funding agency say?
5. If you are planning to publish, what does the publisher say?

Questions

- What are some reasons you would NOT want your research to be open?

It would be best to restrict publication of items that jeopardize the research itself in harmful ways For example, if working on a drone project, giving away the keys to the server would potentially result in bad actors taking advantage of people, or myself who are using the research properly. Alternatively, work in fields that could be used by malicious organizations or by terror groups should be reviewed and only published if cleared by someone very familiar with ITAR/EAR regulations.

- How would you balance openness with privacy/security/control?

I think the best way is to document as best I can through an entire process, asn then go back and review the content. Selecting sections to be re-written or removed for sensitivity, while still providing as much of the original research as possible for a project. It also seems helpful to have a third party step in, allowing you to have eyes who dint work on a project to objectively look at your research and in their lens decide what to remove or even what to put back.

Interesting note on concerns with open science practice:
What if I make a mistake on publicly shared work?

- To make open science work, we will need to be more open to finding and fixing mistakes or inefficiencies. It's true that in many science communities, a mistake is considered a failure, or a certain style may be considered lackluster. However, open science practices can change the perception of mistakes from that of failure to a step in the discovery process that can be aided with open community feedback.

My work won't be useful to anyone else.

- You never know how materials might be used. In one example, individuals who contributed to all different types of software projects ended up helping NASA fly a helicopter on Mars!

The challenge of over valuing novelty - Especially important when you are trying to learn!

- Awards (e.g. prizes or funding) are often given to those who make big, new scientific discoveries or those who create a new, exciting tool. This practice overlooks the community that wrote code, curated datasets, maintained fundamental existing tools, and many other important steps that enabled these novelties.

How to work in a team according to NASA

Presume that everyone you work with is doing the best they can at the time.
Attempt collaboration before conflict.
Listen carefully and actively.
Encourage other people to listen as much as they speak.
Practice empathy and humility.
Ask questions that seek to understand your colleagues' context.
Participate in an authentic and active way that supports the health and longevity of your community.
Exercise consideration and respect in your speech and actions.
Make an effort to say people's names correctly.
Be mindful of your surroundings and of your fellow participants, and take action if you notice a dangerous situation or someone in distress.

Part of good goal-setting at the beginning of engineering projects is to define your places for storage and sharing of your work. For example, at the beginning of a new project, it is a great course of action to define the Repository for your software (if there is) or locate the journals that you would like to see your work published in for future reference. These actions, when taken early, will not only increase your ability for funding, but also gaining and giving credit, and distinguishing the guidelines of what to and not to share with the scientific community. (For the case of Lehigh Rocketry ITAR)

"Much of responsible open science may seem to be related to outputs - such as data, code, and publications - but preparing and organizing work for these in advance is critical"

"In recent years, many have included an Open Science and Data Management Plan (OSDMP) as a requirement for part of a proposal or project plan."

- Describe your management workflow for data and related research. Other elements, such as code or a publication, have their own lifecycle and workflow which needs to be in the plan.
- Plans that are successful typically include clear terminology about how information is made findable, accessible, interoperable, and reusable. This can include licenses, repositories, formats, and governance of the project.
- Researchers must arrange steps for preservation and accessibility to ensure work is not lost after a research interaction ends.

Create a plan of dissemination- how will you engage with your peers and the community to vest interest in your research.

Questions

What data, code, or publications do you currently use or would like to use? Are they open or closed?

I use a lot of data from university rocketry teams, and code from the open source code community. Open source code is huge for me since i'm not a software engineer, and having the ability to leverage open source libraries is huge for the development of projects like AETHER and LAIKA.

What are the tools and processes that you currently use? Is it easy to include others in collaboration?

I use github a lot. I also use the open source documentation of organizations like ROS.org My tools to disseminate information are through google docs, my own webpage, and socials like linkedin. It's easy to share work, but hard to find the right motivated team. It helps to form the team first, then the project.

How is your work shared or planned to be shared? Can anyone access your results?

Anyone will be able to access the result of AETHER and LAIKA, I'm hoping to have LAIKA be a fully documented process, by doing something I only started late with on AETHER, the technical docs. Since then I've learnt how to use git repositories more fluidly, and write more compelling, and friendly documentation. Being a TA has helped me stay grounded on what stuff is new and needs to be explained and documented.

I Published work on LAIKA after that last comment -
https://github.com/jjk-star-bash