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Discussion: The future is our future

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Abstract. The last day of the Kavli-IAU symposium featured a fourth discussion, which was about the future. The discussion focused on the changing landscape of scientific research and the allocation of funding and their implications for the ideal scientist of tomorrow. It was chaired by H. Landt, who was joined by the four panellists E. Chatzichristou, J. R. A. Davenport, M. G. Edmunds and D. H. Grinspoon.

Keywords. research funding, science communication, multi-disciplinarity, data science, astrobiology

1. Introduction

Maybe not all of you but hopefully some of you are aware that things are changing in the way we do science, and also in the way funding, not just in the sciences, is distributed and allocated in order to encourage certain activities. The way we do science is changing because we have many expensive facilities producing large data sets that cannot be satisfactorily exploited by just a few people. The direct consequence is that large consortia need to be established, first in order to get the funding for these facilities and then to exploit them. By necessity, these consortia are both international and multi-disciplinary. Since they also work like an 'organism', a most positive outcome of this development is that it leads to a continued 'democratisation of science'. A similar development can also be observed in the work of international collaborations that create global networks of smaller facilities and in the movement towards Open Science. Open Science, which aims at providing researchers with an unprecedented amount of publicly available data, has the potential of making the scientific process more transparent, inclusive and democratic. The UNESCO Recommendation on Open Science provide an internationally agreed definition as well as a set of shared values and guiding principles for it.

At the same time the landscape of academia is changing. Because governmental funding agencies are encouraging more and more interactions with the private sector, a further emphasis is placed on 'multi-disciplinarity'. The motivation is that academia should increasingly participate in the economic cycle in order to lead to economic growth for the benefit of society, thus justifying the investment of tax-payers money made in them and their often large projects. Therefore, the CV of the ideal scientist is changing. Experts are now sought after who have crossed disciplines during their careers and have gained experience in different sectors such as, e.g., industry, academia and policy-making. It is

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believed that encouraging such cross-pollination of expertise between different kinds of working environment will be beneficial to all in the long-term.

The way funding is allocated is also changing. An increased emphasis is put on public engagement and science communication as a measure of the impact of scientific research. However, at the same time, we see more and more philanthropic funding being distributed by more and more individuals. We have an increased number of wealthy individuals in society who would like to make their money available to science. The scientific research funded in this way is usually high-risk/high-reward and is always non-democratic because its allocation is determined solely by the funder.

What do these developments mean for the future of science and for the future of the scientist? Dr Eleni Chatzichristou (Research Policy Analyst at the European Research Council (ERC)), Prof James Davenport (Associate Director of the DiRAC Institute at the University of Washington), Prof Michael Edmunds (Emeritus Professor of Astrophysics at Cardiff University and President of the Royal Astronomical Society (RAS)) and Dr David Grinspoon (Senior Scientist for the Astrobiology Strategy at NASA) were invited to debate this question.

2. The panel discussion

Hermine Landt (HL): I'd like to start with the non-funders. So, David, you and Eleni are the funders on this panel, and Mike and Jim are the scientists and learned society representatives. So we start with you, Jim. You work at the DiRAC Institute, which is an inter-disciplinary data-intensive astronomy research institute. At the same time, you are heavily involved in the LSST, the Legacy Survey for Space and Time, which will produce 500 petabytes of data. For those who cannot grasp this large number, it is equivalent to 500 million gigabytes. And the SKA will then make us enter into the exabyte era. We will only be able to extract useful information with AI methods. I would like to pose a provocative question: Does the future belong to the machine? But please talk us also through the workings of the DiRAC.

James Davenport (JD): Thank you. So, DiRAC stands for Data-intensive Research in Astrophysics and Cosmology. We are a hybrid institute in terms of our funding strategy. We do have private philanthropic funding sources, and then, of course, like all others, we also apply for public funding through NASA and the National Science Foundation (NSF). As such I actually do believe that I'm very keen to talk to the funders and talk to you all about the methods of funding and how they influence the work we do. One of the advantages we've seen with a private funding sometimes leading the way is that it allows for a lot of possibilities, whereas the NSF or the massive funding sources can be critical to doing big projects. They are relatively slow. And even though I think we've seen a lot of advances in taking high-risk/high-reward projects forward or looking for exotic objects, they can be very difficult to pursue out of fears of time and where they might lead. Whereas, having the control of an endowment or private funding resource can give you a level of flexibility that is really key.

Your question was about AI, and "Is the machine in control of our future?". I think, it is definitely true that such as in our inter-disciplinary institute we see a huge value in our students learning to become better programmers, partnering with data scientists and computer programmers and such. We see a lot of return on behind the questions they ask, the data they can interrogate and the amount of work we're able to do. We're still a relatively small institute, with only about 40 people in total, and the majority of that is students, of course. What I haven't seen any evidence of is that machines ask very good questions. And the thing that I'm most drawn to in this area is that Machine Learning (ML) is very boring, and AI is extremely stupid. It's extremely good at answering the

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question you ask it, or interpolating the data that you give it, or clustering things into clumps. But it doesn't ask good questions. This may change, I don't know, I am not a computer scientist. I love using ChatGPT to sketch our ideas, to mock up code and to even write my topics. It's brilliant, but it doesn't ask good questions. And so I'm extremely heartened by the idea that we can shoot through petabytes and terabytes of data per night in real-time data streams from the Rubin observatory in the search for a million interesting objects per night that we don't have to sit through. There's no way that the capacity of all of us in this room or all of the astronomers on this planet can get through that data. So it's an exciting frontier. But, what will not change, and what we have to speak for us humans, is that we can ask good and better new questions of these data with this new hammer we have in our toolbox.

HL: Thank you very much. I would like to stay on this subject of 'multi-disciplinarity' and go next to Mike. Science was historically developed by polymaths. The current drive to multi-disciplinarity seems to bring researchers, as a group, back to the kind of individuals they once were. What do you think about this concept, from the point of the learned society and from the science history that you know? Are we moving backwards to the future - in a positive way?

Michael Edmunds (ME): I don't know. I'll just make an observation. It's obviously in the history, certainly of theoretical physics, that you do get particular individuals who seem to be particularly good at pushing boundaries forward. That's established. And I assume within science that will always be true. There'll be certain individuals, of a particular intelligence or whatever it is, maybe a bit of ego and in certain cases also luck, who make very fundamental discoveries. But the majority of research will be, I might say, at a lower level, perhaps also less inspired, but it's still very necessary and useful to reinforce those views, theories, and so on.

The drive that you're talking about, towards inter-disciplinary research, I think, is a different question and I'm not sure where that will go. You could argue that one way to get an inter-disciplinary scientist is to give them a physics degree, then give them a chemistry degree, then give them a biology degree, then give them a linguistics degree, probably a philosophy degree, by which time they're ready to retire. Obviously, it is a good thing to have some transition between different roles, as you say, interact through pollination, but I'm not sure that that's the best way to do inter-disciplinary research. I had experience with very large inter-disciplinary projects. And that worked, not because everybody became an expert in the different fields, i.e. everybody tried to become an expert in A, B, C and D, but because we had experts in A, experts in B, experts in C, experts in D, and for once we were prepared to talk to each other. And it seems to me that for inter-disciplinary studies the best thing is, if you can get people who know a bit about the science but are not experts and they'll get the expert advice from the expert, and others will rally around and do the communication. That's the way I think that you do inter-disciplinary science and I suspect that will continue. Because if you look at the big projects, just read the list of names, not all of those scientists can be inter-disciplinary. There are probably all sorts of people in there, experts and non-experts. But it's rather a matter of having different talents, with the most important talent actually being able to communicate to each other.

HL: That's that's very good point. So let's now go over to the funder representatives here on the panel. Eleni, 'Life Beyond Earth', as I personally see it, is a high-risk/high-reward scientific endeavor; high-risk in the sense that we do not know if there is life beyond Earth and high-reward in the sense that, if we do find it, then it will be a most profound discovery. The European Research Council (ERC) say that they are funding

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high-risk/high-reward science and thus differentiate themselves from the rest of the funding program within the Horizon Europe programme. I would like to know your take on this. Would 'Life Beyond Earth' fall directly into the ERC remit? So, should we rush and write Advanced Grants and Synergy Grants on this subject? We need your advice on this.

Eleni Chatzichristou (EC): Okay, thank you. First of all, when we talked about 'high-risk/high-gain' and you gave the interpretation of what this could be, that's exactly the problem that the ERC has eventually addressed. That is, they changed this formulation, because, indeed, there was a mis-interpretation. So, as of the Work Programme 2024, this does not exist anymore in the formulation of the 'high-risk/high-gain' and it has became actually something that is more easy to agree upon, which is 'excellence'. Then, it's 'excellence' as far as research projects go, and 'excellence' as far as the PIs go. So, instead of the words 'high-risk/high-gain', now we talk about 'groundbreaking research', about 'foundation research' and about 'physical research', which, again, needs to be explained in a sense. And then, as far as the PIs are concerned, the 'excellence' is about intellectual capacity, about creativity, and about commitment, as you already know, probably. The CV of the PIs is not really only judged upon, say, by publication record or research age. But it's actually a more holistic way of viewing the series of the applicants. We have this actually, in two levels, a generic level at the stage stage one and then a more qualitative, let's say, approach of this. In this respect as well as in the respect of inter-disciplinarity that you were talking about before, I think that the assumption is that you really know a field, actually a combination of fields, obviously within the remits where the PIs are funded.

Space Sciences by ERC is funded within two panels in the domain of Physical Sciences & Engineering (PE), namely, P9 (Universe Sciences) and P10 (Earth System Sciences). I did a very quick search on terms such as, for example, 'Life beyond Earth' and astrobiology. And then, when you combine these keywords, we end up with a pretty high number of proposals funded in this area since the beginning of the ERC's existence. I can't remember now, but I think we had more than 80 projects in the PE domain alone, and then we had another 10 or 12 in the Life Sciences domain, and then we even had some proposals with these keywords in the Social Sciences & Humanities domain.

HL: I would like to stay on the ERC. The ERC is a relatively new institution. It was incepted in 2007, so I would like to call it 'new'. But its budget has steadily increased and has been now doubled. Your website states that it currently stands at 2.3 billion Euro per year. But, as I just said, we are moving from the individual to the consortia in many of the sciences, and definitely in astronomy. Can you have a take on this or even give an explanation? What is the reason that the budget has increased significantly for individual research? Because the ERC, as you can expect, is not funding consortia, it is funding individuals who have a large team. Can you comment on where the movement is from here?

EC: So, basically there are two questions in one. Regarding the budget, you are right. So, we started with 7.5 billion, then we went up to 13 billion and now it's at 16 billion over the entire Horizon Europe period (2021 - 2027). But this always represented something like 16% or 17% of the overall funding programme. And, indeed, this amounts to more or less 2 billion a year. The point is that from the very beginning of the ERC until now, we have funded over 30,000 PIs with teams that included another 100,000 researchers and professionals and covered over 900 host institutions. If you know a little bit about the evaluation process, you know that we have two steps, except for the Synergy Grants, where you have three separate steps. The proposals that make it through the first step, i.e. they are scored A, let's say, then move on to the second stage. And there you actually

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proceed with a more detailed evaluation of the whole proposal, according to the criteria I was mentioning before. And then you end up funding some projects. The point is that, even with this quite huge number, I think, of standards for funding proposals, we leave outside many, many proposals scored with A, which means that they are excellent. This is simply because we do not have enough funds. This is the reason why we're requesting the doubling, not only of the ERC funding, but of that for the entire programme to exceed 200 billion. So, the ERC is actually keen to fund more research, more excellent projects, and that is the reason why we're looking for higher funding. Also, another problem is that the amount of grants remains more or less the same over the years.

The second part of your question was about individual research funding versus consortia. So, I do think that the ERC totally recognises the fact that nowadays more and more science is inter-disciplinary. That's why the funds are hardly ever disciplinary, i.e. they don't have hard disciplinary boundaries. But you also have the Synergy Grants. So, the Synergy Grants exactly address the issue of having more than one PI. Actually, you need to have 2 - 4 PIs, and 4 PIs is the maximum that can be funded. This, in a sense, addresses the issue of consortia. And, also within the so-called Individual Grants, when a project is intensively across panels, then the PI has the possibility to ask for different expertise to be funded from the different panels.

HL: Thank you. So, let's go over to David now. Effective communication of research results is encouraged, in particular if you want to write some funding proposals. Now, especially for astrobiology, communication is a vital component in its research endeavor. I would like to claim that we cannot have one without the other. We know that in early March NASA conducted under your auspices a workshop called "Communicating Discoveries in the Search for Life in the Universe", a three-day workshop, for particularly this reason, because more skills need to be developed within the community. I would like to invite you to give us a briefing on that. Thank you very much.

David Grinsponn (DG): Sure. Thank you, first of all, for inviting me to participate. And it's a lovely meeting, and I really regret not being able to be there in person. Various events in Washington this week prevented me. I have been sort of ducking in and ducking out and participating when I can, and following the Slack chats. And it's obviously a vibrant and really interesting meeting. And I appreciate that you're doing that. And I appreciate you're including me like this.

So, we've had this longstanding goal at NASA, which very much dovetails to the goals that you've been describing and working on at your meeting, so there's a lot of overlap, for trying to pro-actively think about how we should communicate about discoveries in the area of extraterrestrial life and possible signs of extraterrestrial life, and how we characterize partial or incremental discoveries, and categorize them both within the scientific community and then for the public, and avoid some of the pitfalls that one can see coming. You know, to some extent one can't prevent over-sensationalizing or the public getting burnt out on thinking they've heard the same announcement over and over again. So, there was this past activity a couple of years ago that you've probably heard of, the "Biosignatures Standards of Evidence Workshop", a virtual worskhop that involved a lot of members of the astrobiology community. One of the upshots of it was to come up with a list of questions to ask and categorize a discovery, e.g. 'Have you detected an authentic signal?', 'Have you adequately identified the signal?' and so forth. I'm not going to go through all of them, since I think you're probably familiar with this. I think it was a productive exercise. There was some pushback and critique, which is good of the way this was done. In particular, we had a National Academy of Sciences review of this report and that report was mostly positive, but had some critique as well, which was much appreciated. One of the critiques was pointing out the necessity

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to really separate out how we think about communicating with the public and how we think about communicating within the scientific community, and another questioned the legitimacy or seriousness of the standards of evidence, or what is sometimes called the CoLD scale, that came out of that, i.e. this idea of a numerical scale to categorize how definitive or non-definitive is a potential discovery. Putting that on a scale, there was some pushback on that. And the idea that came out of this National Academy of Sciences report was that perhaps that scale is more appropriate for how we talk within science to each other about discoveries, but wasn't really adequate for thinking about how we talked to the press. And there was a recommendation in this report that we involve more journalists and more communicators in our deliberations about this, and really try to understand that sort of ecosystem of scientists working with communicators, so that we can anticipate and develop best practices and develop more understanding of how these communities work together. So, on the basis of that recommendation, we planned this recent workshop "Communicating Discoveries in the Search for Life in the Universe", which actually happened last month.

What was different and innovative, I think, about this workshop, which was a multi-day virtual workshop, was the way that we incorporated the participation of a lot of journalists and other professional people in the communication space with the participation from scientists. And I'm happy to note that there's some good overlap between the participants of our meeting and the participants of your Kavli-IAU symposium there, both in terms of some of the journalists and some of the scientists, since it's important that we treat this as a coherent effort across oceans and decades in order to do this well. We had roughly a hundred participants, with about half of them professional scientists in astrobiology and related fields, and the other half journalists and other people in the communication space. We set it up so that we had a sort of modified Chatham House rules so that you could not report on the sessions. If you were a journalist, you were participating in those sessions not as a journalist, you were participating as somebody who was there to learn and listen and teach mutually. And that led to a really extraordinary set of conversations. And I've gotten a lot of great feedback about this, because it was kind of unusual for the journalists to be there not as journalists, sort of by rule. By the way, they were allowed to interview people outside of the sessions and make connections and so forth, you could just not report on what was said in the actual sessions. And there's already been some reporting, e.g. Sarah Scoles just had a piece that came out a couple of days ago in Scientific American about this. So, it wasn't like there's got to be media silence about this meeting. It was just simply the sessions themselves, or you're not on the record. And that meant that people were really able to let their hair down. And I saw that working. And I think a lot of other people experienced that working a kind of magic where, even though a lot of these journalists had spoken to a lot of the scientists before, it had always been in this sort of more carefully guarded way of 'You're interviewing me. I'm being interviewed by you. I'm gonna watch what I say. We're gonna sort of follow these rules.' And in this setting that did not apply. There was a lot of discussion about the mutual needs and expectations of the two groups and I just saw, and other people reported, the value of that kind of getting those groups together with that kind of understanding that that was what was going on.

We split it up and had a session of a day of past case histories, reviewing famous relevant examples like the ALH 84001 Martian meteorite discovery and reporting and fallout, and the arsenic life episode, and we did one on relevant examples from the climate debates and communication and miscommunication, and how all that played out. Then we had a day of imagining future scenarios where we played out a few different kinds of discoveries; one had to do with bringing samples back from Mars, and that was fun, one had to do with an exoplanet discovery, and so forth. And we even did some role playing

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where the scientists got to play journalists and the journalists got to play scientists, and, you know, had some fun, and I just saw a lot of light bulbs going on and off and good connections being made. Then we had a day of starting to write a report, and the report writing is still under way, and so I can't give you a neat set of bullet points of what are the results. And I want to be careful to not even try, because, as the NASA ex-officio person on the organising committee, I am determined that this should be a community-based report. We facilitated these conversations, but I deliberately tried to kind of shut up as much as possible during the actual discussions, being from NASA, because this is not a NASA report, it's a community report. So, the writing is under way and we expect it to come out this summer. We're pretty excited about that, and we'll publish it either in a journal and/or widely on-line. Obviously, some of the themes emerging are advice for agencies like our own, best practices for journalists and best practices for scientists. One of my particular concerns is how we avoid some of the mistakes that NASA has made in the past with sort of over-hyping results in what seems to be a repetitive way. So, there's the old joke about 'NASA discovered water on Mars, again'. And we don't want to have that kind of pitfall where every possible biosignature found somewhere is reported in such an over-hyped way that, by the time we find something that's really more significant, the public sees the story and thinks 'Oh, we've already heard that ten times.' Of course, we recognize that we don't have control over stories once they're out there in the mediaverse. But there are aspects of the process that we, meaning 'we' as NASA, 'we' as a scientific community, and 'we' as a broader community of scientists and journalists, do have control over. And so it seems like a really worthwhile effort. I'd love to be more specific about the results, but I'm deliberately letting the process play out. So that's probably all, in terms of specifics, that I can report about that workshop now. But I can tell you that the feedback we've received is that it was a really good experience. And just the experience of doing it and getting that community convened and the connections made, and the efforts already happening to continue those conversations in various ways seems like its own reward. And then, hopefully, the report about the actual results that comes out will add to that.

HL: I have a question, if I may. You just said that, although you want to change some of the things that NASA did wrong in the past, you still cannot speak now about this. So it seems that some of the NASA procedures are still there and unchanged. Now, we had our Kavli-IAU symposium and we do not have that kind of environment and we can freely speak. And what has come out of this symposium is that in the communication with journalists they do not want to see another scientific paper. They want a very short answer like 'Yes, we found it', 'No, we didn't find it.', 'Yes, it has three eyes.', 'No, it has four eyes.', so very, very concise. So, I think it will be very interesting to read your report. Can you tell us if a similar result was reached during your workshop, since this is something that I, as a scientist, didn't know about science journalism, and I don't mean 'science communication' but 'science journalism'. I wonder if similar results have come out. Can you just say 'yes' or 'no'?

DG: Let me make sure that I understand. So, you're saying that you're hearing from journalists that they don't want you to give them a paper and say 'Read this, it has our results.' They want you to tell them in a few sentences 'Here's what we found', and simplify with 'Here's the headline'. Is it that?

HL: Correct.

DG: Yes, I think we did hear some of that. Honestly, there was probably a self-selection of the particular kinds of journalists who chose to spend their time at this meeting. Maybe this is the failing of what we did. It would be interesting to do a meta-analysis of what we left out. But, I think, there's a selection effect that the people who showed up are the

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people who are concerned with these questions. So, probably they have a somewhat more sophisticated understanding and the desire to dive deeply and tell the stories and have some past experience with the subject. So, I wouldn't say that I heard a ton of that at our meeting. And so it's interesting. I'd love to talk more about the differences and how we selected, who showed up and the way they participated, and how that perhaps led to somewhat different messages being received. Because that would be a valuable thing to learn about as well.

HL: Yes, I think summer is also a good point in time for us to talk about it, because our proceedings will be published soon thereafter. So there's another space race, but this time it's about who publishes first. I will go now to the next question, but I'll come back to you later and ask you more questions. Jim, back to you. We are entering the era where we can now make discoveries with outlier science. We always allowed for serendipity, but I think now serendipity will take more and more centre stage. But we still don't allow ourselves to name 'serendipity' or 'outlier science' as the driver for funding, because we believe no one will want to fund this. However, as we said, we have all these large data sets, we will make a lot of the discoveries with the help of AI, probably even automatically and not knowingly and the scientist will just show up and say 'Oh, what's that? That's interesting. I'll publish it.' Do you think that the funding landscape will need to adjust to the way we will make significant discoveries with the help of the machine? And, in this respect, do you think that we need to redefine what we call the 'freedom of research' and the boundary to 'crazy research', if the human factor gets more and more pushed out of the discovery process?

JD: I quite like what Eleni had said about redefining from 'high-risk/high-reward' to something more about 'excellence'. I like this idea to use the probability of feasibility, one of the categories which out of the many categories is especially unique about the 'Search for Life beyond Earth'. I really dislike the term 'high-risk/high-reward', because the search for SETI, which I'm involved in with my colleagues at Breakthrough Listen, is a search for outlier science and as such is extremely low-risk. But, although the likelihood of finding the one particular signal is perhaps low, the likelihood of finding something interesting is very, very high. And, in fact, that's what we have learned every time we step into a new wavelength regime or time coverage or area of the sky coverage, anytime you deploy a new telescope, we are guaranteed to make easy discoveries that the Universe has not yet gotten. And so it's very low-risk, and it's a great endeavor for students that way.

That being said, it can be very difficult to be specific since you don't know what you will find and only that you will find it. Therefore, it can be very difficult to get funding. And this is again right back to the comment that non-profit funding can be leveraged here to take forward high-risk projects, or maybe more ambitious or more nebulous projects. But we have seen, I think, progress, at least from the grant writers perspective, in terms of NASA being more open to the good measurement of this, if you will, open form of collaborative funding structures. This, I think, is really good. What remains the challenge for us is to convince our colleagues. Well, here's my hot take for the panel; I think there's no evidence that scientists are any good at picking out which grant proposals are good. We've done a whole lot of effort on this, you know, split it in several streams from 'garbage' to 'spectacular'. But other than that, it's bit of a dice role. I think that if we embrace that sort of futility, then we can become a little more generous with our funding, or maybe have a little more 'social spare funding' or some other model. There needs to be a little less focus on 'excellence' and more focus on 'equity'.

HL: Very good. Thank you very much, Jim. I would like to go now to Mike and ask another question. Now, we do expect that the first Life beyond Earth will be detected

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in the UK and that's why we're doing the Kavli-IAU symposium in the UK. And we have heard earlier from Chris Impey that it's very likely that aliens do speak English. So now, let's assume this has happened, and, of course, the UK government will come to the Royal Astronomical Society, bypassing the Astronomer Royal, and ask you for advice as a learned society rather than as an individual, although they will ask both sources, if they're wise. You've learned from the Kavli-IAU symposium quite a bit, I hope. Would you like to give us a summary of what you would tell the UK government or warn about?

ME: Well, no. I'm afraid I'll have to shoot you if I told you! Seriously though, I don't think I am in a position to be able to tell you what we would say. What I'm interested in at the moment is setting up a mechanism for deciding how we would work out such a strategy. And it would be impossible to be definite, since we don't know what the threat is going to be. What we can do, though, and I think we need to do, is to think about - for when the government does ask for advice - how are we going to give that?, what is going to be our mechanism for providing such advice? It may be that we'll be able to write some of it down before anybody asks. It may be just a matter of saying "Oh well, we're going to contact A, B, C and D, and that will be the small panel, or whatever, who will work in the same circumstances that would apply if we were to see the antenna waving outside our window." I think one would hesitate (after this symposium) to say what alien life going to be like. Should we have the nukes ready to blast it? We just don't know. I'm sceptical that we have any consensus on the nature of alien life, and I suspect it would be just as difficult to reach a consensus among ourselves for action if actually confronted with an outside threat. But simply getting a consensus on what would constitute a confirmation that extraterrestrial life exists would be a fundamental advance.

So, I'm backing off from saying I could immediately give advice. What I think what we need to decide what is the best strategy is for working out what that advice would be. And, hopefully, that's not something we will need in a hurry. I get the feeling, this is just a gut feeling, that it is not that likely that the alien will knock on our door next week and provide an existential threat. It looks to me as if the biomarkers are not going to be nearly as reliable as we thought they were going to be. Any confirmation of a discovery of Life beyond Earth is going to take a fair bit of time. That means we have time to work on the reception of it, or the perception of it, which we can do. And I do think we need to set up something so that we know how to give advice.

But I will ask you one question back, if I may, which to me is an elephant in the room to some extent. We heard a statistic earlier that about 60% of the public believe there are aliens. Well, what do you want them to believe? Do you want there to be aliens, or do you not want there to be aliens? I'm asking because you're wanting money to go and detect them. So, what is it, in your overall public education or whatever you call it (and I might call it coercion) that you want to achieve? Now, what I should perhaps have said is that 60% of people believe that aliens have visited or are still here, because then you could work on that in a in a different way. But I don't think we've really established what it is that you want this overall education program to do. My suspicion is that we would like people to keep open minds, watch the evidence, make judgment on the evidence, and not to believe that we have found it yet. But I'm open to questions on that.

HL: Well, because of this reason the public probably thinks "Oh, yes, but I already knew that." if you indeed had a discovery of a Life beyond Earth and were telling them about it. But I see that you have not mentioned in your response the Astrobiological Society of Britain, who are, I wouldn't say a rival, under your auspices at the moment. Would you go and talk to them?

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ME: Just to be clear, nobody has asked us anything. If the Government did suddenly want to ask somebody, the first people they are going to ask are the Royal Society. It would certainly ask the Astronomer Royal, then it might cascade down to us, I don't know. But again, it's those relationships that are not set in stone yet. I'll make some inquiries after this meeting as to what, for example, the Department of Science and Technology had by way of subcommittees, developed committees, that it would call in such an event. We will offer advice. We will say that we would like to help with this, if we can. But obviously, as you say, that would hopefully involve several societies. As you mentioned, the astrobiology one would be an obvious one. So far as I know, it isn't set up at the moment.

HL: So, contrary to the U.S., we do not have an Astrobiology Strategy in the UK, which brings me back to you, David. Now, you do have an Astrobiology Strategy and you are the senior scientist of it. But probably funding within NASA is also an issue, as we see cuts, more recently at JPL, for example. Can you imagine that in the future NASA will outsource astrobiology, maybe to some philanthropic funder who would like to take it on and make a name for themselves?

DG: That's a really interesting question. I certainly can't imagine our entire astrobiology programme being outsourced. There are obviously roles for private companies that are working with NASA, and that's very high profile now. But, of course, that's always been the case throughout the entire history of the space programme that we've worked with contractors and companies and so forth. And there are, you know, some obviously very high-profile launch companies that we've become sort of co-dependent upon, for better or worse. And we see that some of these private endeavors, like the Venus mission by Rocket Lab, fill an interesting niche. And, ideally, companies like that are doing things that NASA can't quite do, but is supportive of. And so, for instance, with the Rocket Lab mission, we, NASA, are helping them out in various ways with the deep space network, with their entry, descent and landing technology and so forth. So, that's really a private astrobiology mission that we are supportive of and trying to help, and very much hope that they can succeed. I can see more happening in that category. I can't see our very large flagship or new frontiers class missions becoming outsourced. I think those are very key to NASA and our process for selecting and funding large missions. I can't see us just turning over some big contract to some company, but certainly, again, the involvement of contractors and all that has always been there, and it will continue and will shift. So, I guess I do see an increasing role for private companies at the fringes of astrobiology and some of the missions. And, of course, that raises some concerns. If companies are actually doing missions, then how do we ensure that they keep to our standards of planetary protection, for example? So, I see potential there and I see some concerns that we have to try to stay on top of.

HL: Thank you very much. I think all panellists have been very honest in this discussion and I would like to thank them all with a big applause before we go on to the audience.

3. Audience engagement

Instead of taking questions for the panellists, the audience was invited to say what they wished for the future.

Martin Dominik (University of St Andrews, UK): I think it might be worth having a fundamental rethink of how we assess applications for responsive-mode funding. It is extremely striking that some funders who recently switched part of their decisions to a lottery system found that working better. There's very little evidence to show that certain procedures that we use actually meet the intended goals. If it cannot be demonstrated that they do better than a lottery, then they don't have any justification. I would like

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to question whether disciplinary panels are good idea. To what extent do we even need experts to assess those things? What is it that experts actually should form an opinion on? We should not forget that the only person who tends to fully understand all details of the research proposal is the applicant. I think there are some very interesting jobs for social scientists. I think we can do much better than we do right now.

Julie Nekola Nováková (Charles University, Czech Republic): I wish for more citizen science, greater transparency and accessibility, more engagement and greater trust in science and greater funding for this research. And I'm prepared to try to work on all of that.

Erik Persson (Lund University, Sweden): I actually wish for time to be able to do research.

Kathryn Denning (York University, Canada): I wish for greater integration of social sciences and humanities and science communication research, and all these things, because we can accomplish so much if we actually work together on these issues that are very pressing for the intersection of astrobiology and technosignatures and society. What matters is that we have the expertise, we just need to be marshalling it. What I really like to see is sustained, focused attention to safety for scientists and science, journalists and science communicators, and everybody who's in the public eye because of the interesting work that they do. So that means sustained institutional attention to keep everybody in the community safe.

Jacob Haqq-Misra (Blue Marble Space Institute of Science, USA): I'm an optimist in the room usually, and I felt all the concerns that everyone has raised. But we're studying astrobiology. This is amazing. We had a whole great week. So I want to do more of what we're doing. We could do some things better, but let's find life, let's keep SETI. I think this is great. I'm having so much fun.

Leen Decin (KU Leuven, Belgium): I wished that more people would have attended this kind of multi-disciplinary conference. Since I'm listening, I have been motivated to go beyond my own horizons.

Conor Kennedy (Dublin City University, Ireland): Just a comment. If it was the case that 62% of the public are scared in their beds at night for fear of the monsters that live below, then it is the responsibility of all of us to turn the lights on.

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