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IT'S NOT ROCKET SCIENCE: HUMANITIES, ARTS AND SOCIAL SCIENCES IN THE SPACE SECTOR

Dr Basil P. Tucker & Dr Hank C. Alewine

The space industry is traditionally associated with STEM disciplines, but humanities, arts and social sciences have plenty to offer to the modern space sector. Space accounting scholars Dr Basil P. Tucker and Dr Hank C. Alewine investigate the potential of HASS to address the unique and unprecedented challenges of the New Space Age.

INTRODUCTION

Traditionally, the role of the humanities, arts and social sciences (HASS) in the space sector has been less apparent, less evident and less appreciated than science, technology, engineering and mathematics (STEM). Non-STEM disciplines such as politics, public administration, law, psychology, archaeology, project management, art, marketing, economics, accounting, finance and history are becoming increasingly influential to space exploration, research and policy, and can meaningfully contribute to all these aspects of the space sector. Our progress and achievements in space are influenced by our ability to bring together knowledge from many different disciplinary viewpoints – viewpoints that enable us to see, understand and solve the problems of space travel, exploration and, eventually, habitation. Although much of surmounting these challenges will require impressive technological, scientific and engineering achievements, advancements in space objectives and creating and growing a space economy are by no means the exclusive province of the STEM disciplines. The future advancements realised from overcoming unprecedented and daunting tasks will involve teams of professionals synergistically mobilising both STEM and HASS disciplines.

In this paper, we investigate some of the cross-disciplinary approaches involving HASS disciplines that might more effectively contribute to solving the problems presented by the modern space sector (dubbed the 'New Space Age'). Note that in this paper, we use the term cross-disciplinary to generally encompass multi-, inter-, and trans-disciplinary research. We recognise that there are nuances between these specific types of research, but distinguishing between them is beyond the scope of this paper.

The data used are based on a larger project involving interviews with 21 current and former academics across the globe from a wide range of disciplines who work or have worked within the space sector. What was evident from these interviews was the repeated recurrence of three themes. First, HASS disciplines are perceived to hold an integral role in the New Space Age. Second, cross-disciplinarity is thought to hold many benefits. Principally, the thinking is that cross-disciplinary approaches are likely to address the complexity and unprecedented nature of problems encountered in the New Space Age in ways that are both innovative and creative, and in a fashion that meets the needs and expectations of stakeholders. Third, pursuing a non-conventional field of study as a HASS academic is not without its non-financial costs, these being: the (perceived) lack of credibility one suffers from not having a STEM background in what has been traditionally a STEM field; and pragmatic career considerations – primarily, the absence of a defined and established career path for individuals with a HASS background in this new arena.

The path to a New Space Age

Governments jointly expend about US$80 billion annually on space activities, while the overall space economy may be worth over US$387 billion.[1] This level of expenditure is coupled with several significant developments, such as the increasing engagement of private sector entities in the space economy,[2] lunar plans,[3] the prospect of launching a crewed mission to Mars,[4] and the increasing footprint of global space activities. Seventy-two countries now have active space programs, including 14 with launch capabilities.[5] All this forms what is currently termed 'the New Space Age'.

Another perspective involves the shorter label, 'New Space'. Here, the focal point of the sector has moved away from government agencies bearing sole responsibility for space-faring activities, shifting towards a number of private entities that now provide much of the leadership when it comes to achieving modern space objectives.[6] This shift in the composition and responsibilities of stakeholders opens up opportunities to advance space-related pursuits in previously impossible ways. For example, more competition from the private sector will not only lead to increased innovation in the technologies created for space applications but also help to develop entirely new streams of entrepreneurial activity within the sector, such as space tourism, space launch services and space mining endeavours.

This competition in New Space dynamics may consequently lead to advances that all stakeholders might benefit from. For example, the costs of launching a rocket might be streamlined, making space more accessible to everyone.[7] We might

1. Cross, 2019
2. Crawford, 2021
3. Migaud et al., 2021
4. Kalmbach and Ralston, 2021
5. Cross, 2021
6. Weinzierl, 2018
7. Alewine, 2020

deepen our understanding of how management controls and creativity can coexist in entities that are dependent on innovation.[8] Or we might learn more about how the psychological and sociological factors of New Space impact organisational behaviour and its human involvement. This includes both workers within the space sector and the general public as they emotionally process the consequences of human ventures off Earth and into outer space. Such knowledge creation and its applications will rely heavily on cross-disciplinary efforts, particularly from HASS disciplines. However, for this to materialise, the literature needs to provide insights into how such cross-disciplinary efforts come to fruition in New Space. We aim to help build the literature in this regard.

All of the above developments suggest that space exploration will proceed. This is even though humanity has not ventured beyond low Earth orbit since the original Moon landings of the late 60s and early 70s. This is not an unreasonable assumption since, in the intervening period, we have landed probes on Mars and Venus, conducted fly-bys of the outer planets, built and flown reusable spacecraft, and observed the cosmos via the Hubble Space Telescope. More recently, the James Webb Space Telescope travelled through interstellar space like Voyager 1. Now, we are witnessing the commercial sector become a key player in space by exploring resource mining, tourism, colonisation and national security operations. As we head into the second decade of the 21st century, space activities are increasingly becoming the vanguard of research, development and the global economy.

Mars – a different proposition than landing on the Moon

Most space exploration endeavours in the recent past have been robotic missions. However, now plans are being made to transport humans to Mars by 2033 – a human achievement that might rival the Moon landing.[9] Yet accomplishing such an endeavour will present complex and unique challenges that will test the limits of human ingenuity and organisation. Moreover, overcoming these trials will extend our resourcefulness beyond the considerations many would think of first – that being the scientific and the technological. In fact, there are many other implications of space exploration and its related challenges that need to be resolved, be they ethical,[10] legal,[11] financial,[12] medical,[13] political,[14] environmental,[15] or related to public opinion.[16] Individually and collectively, these challenges represent potentially significant impediments toward a human presence on Mars. For all these reasons, at present, human interplanetary missions not only remain beyond our technological and medical capabilities, they also exceed our social, political, financial, psychological and sociological talents. These considerations represent cogs of a larger, more complex dynamic that must be addressed, acknowledged and resolved before meaningful modern space sector strategic objectives can be realised.

Cross-disciplinarity as a way forward

Overcoming the challenges of the New Space Age will involve often-conflicting perspectives between stakeholders, such as policymakers and private enterprises, entrepreneurs and workers, public sector agencies and private sector organisations. Research and policy circles

8. Tucker, Halkett and James, 2021
9. Szocik, Lysenko-Ryba, Banaś and Mazur, 2016
10. Arnould, 2019
11. de Zwart, 2019
12. Ehlmann et al., 2005
13. Saluja et al., 2008
14. Moltz, 2019
15. Mankins, Mankins and Walter, 2018
16. Kalmbach and Ralston, 2021

increasingly acknowledge that such issues cannot be resolved by any lone discipline independently[17] but, instead, will necessitate alliances, solid cooperation and transparency between an array of researchers and practitioners across multiple disciplinary boundaries.[18] Thus, modern research commonly calls for cross-disciplinary tactics to solve these challenges.[19] However, communicating across disciplines and overcoming the 'silo' mentality so common to research, especially within the academy, has been notoriously difficult to accomplish. This is a significant hurdle on the path to realising the benefits that cross-disciplinary endeavours might provide.

Thus, cross-disciplinarity is not a strange idea nor a tactic to advance research policy either generally[20] or specifically, given arguments advocating the necessity of interdisciplinarity in space and planetary sciences.[21] Over the past three decades, there has been a noticeable increase in the emphasis placed on encouraging cross-disciplinary alliances among various STEM and HASS fields within research policies and funding mechanisms worldwide.[22] Further, there is growing acknowledgement in the literature that the research challenges we face are of such a magnitude that any solutions will need to rely on knowledge created out of a vast range of subjects, some of which we have traditionally perceived as being quite distant.[23] And, moreover, these complicated endeavours are only anticipated to increase in the future, resulting in even more necessary interactions amongst once disparate fields of study.[24]

At first, the above trajectory of complexity in future research seems perplexing in view of the various potential combinations of disciplines that might work together, and the different forms that cross-disciplinarity might potentially take.[25] Thus, cross-disciplinarity may be something of an umbrella term for associated ideas that essentially cut across disciplinary boundaries[26] or, as Schmidt[27] notes, 'problem orientation beyond disciplinary constraints'.

Cross-disciplinary approaches have been examined in a range of environments and contexts involving HASS and STEM.[28] Over the past few decades, more credence has been given to cross-disciplinary methods and, more specifically, cooperative approaches and cross-field understanding.[29] Alexander and Bannova,[30] for example, consider cross-disciplinary research to be vital to future successes in researching, policymaking and actual exploration within the space sector. However, there are very few formal investigations of meaningful, effective and unique cross-disciplinary approaches in the literature. In exploring the perceived hurdles that see cross-disciplinary approaches cast to the sidelines in the New Space Age, we aim to offer tangible views supporting the value proposition that HASS disciplines can help to solve the wicked problems of the modern space sector.

17. Brown et al., 2010
18. Hawkey et al., 2019
19. Ryan and Neumann, 2013
20. Siebert et al., 2020
21. Berea et al., 2019
22. D'Este et al., 2019
23. Cummings and Kiesler, 2014
24. Davies et al., 2018; Lyall and Meagher, 2012; Sardar, 2010
25. Van den Besselaar and Heimeriks, 2001
26. Klein, 2012
27. Schmidt, 2011, p. 249
28. Metcalfe et al., 2006
29. Lee et al., 2018
30. Alexander and Bannova, 2021

The potential merits of cross-disciplinarity within the space sector align nicely with the 'Second Track' process of the Global Access Partners' (GAP) Australian Space Initiative.[31] The 'Second Track' process was designed to'bring together experts from relevant sectors including government, business, non-government organisations and consumers. Working collaboratively, with a positive approach, these groups identify problems, initiate discussions, prepare papers, develop practical solutions and oversee their implementation'.[32] This is the very definition of cross-disciplinarity – collaborations between a multitude of experts, such as academics, researchers and practitioners, in a wide variety of disciplines from across the scholastic spectrum working together to solve complex space-related challenges.[33]

The importance of HASS to the space sector

In the past, researchers and practitioners in HASS disciplines have sometimes found it difficult to effectively communicate the value they can provide in areas that are generally considered to fall under the purview of STEM disciplines.[34] As a counterpoint, though, some space organisations have noticed the potential value of HASS in achieving space objectives. One example is the European Space Policy Institute, which notes that HASS contributions will be integral to future achievements in space.[35] Pell[36] also notes that various HASS areas, such as archaeology, sociology, tourism and law, can play a meaningful role in advancing the space sector. She suggests that HASS disciplines tend to provide frameworks and methodologies that work to cultivate a better understanding of how people will engage with 'space technology, systems and environments' and that this will impact all aspects of establishing and achieving strategic space objectives.

Perhaps a starting foundation to both consider and emulate for cross-disciplinary engagement by HASS disciplines in the space sector is NASA's Human Research Program. This research and technology program, which began in 2005, initiated procedures to manage NASA's research on the substantive elements of human health and performance risk during space exploration.[37] The program acknowledges five key risks of spaceflight: 1) decreased gravity (including gravity transitions and launch and landing loads), 2) increased radiation, 3) a hostile/closed environment (including habitability factors such as atmosphere, microbes, dust, volume/configuration, displays/controls), 4) isolation/confinement and altered light-dark cycles, and 5) distance from Earth. Of note is that only two factors on this list (decreased gravity and increased radiation) would presumably fall almost exclusively within the realm of STEM disciplines. For overcoming issues related to the other factors (hostile/closed environments, isolation/confinement and altered light-dark cycles, and distance from Earth), the program enlists the help of researchers and practitioners from HASS disciplines, such as psychology, organisational behaviour, project management and financial management. Of course, many other HASS disciplines might be similarly involved in neutralising such hazards. Just a few moments' thought should bring to mind the incredible range of subject matter deliberations and reflections needed to plan, research, develop and execute solutions to the myriad components of a space mission. Even disciplines generally considered

31. Global Access Partners, 2017
32. See 30
33. Fritz and Mallory, 2022; Fritz, 2019; Massingham, 2019; Fritz-Kalish, 2019
34. Ankeny and Given, 2018
35. ESPI, 2007
36. Pell, 2021, p. 5
37. Smith et al., 2020

to offer only behind-the-scenes support might be heavily involved with achieving space objectives – disciplines like *accounting*! [38]

On the surface, it makes sense that undertaking these missions would involve a diverse range of subject matter. For example, consider the tasks and short-term goals needed to successfully fly for eight months to reach Mars, let alone the additional plans needed to stay there for an extended time before returning to Earth. Attempting such lengthy missions will involve solving economic, health, psychological and managerial challenges on rarely experienced or appreciated levels. It is clear that a better understanding of the nature and extent to which HASS-related cross-disciplinary approaches can meaningfully contribute to overcoming these hurdles is in order. To this end, we have undertaken a study that aims to identify the factors that surround the potential contribution of HASS-related cross-disciplinarity to the unique and largely unprecedented challenges presented by the New Space Age.

METHODS

Study participants

The study's participants were selected to capture a diverse set of perspectives on the applicability of cross-disciplinarity in the New Space Age. Our overarching selection philosophy followed Parker and Northcott who argue that the participants should be those 'that can best inform the focus of their inquiries and provide the in-depth information relevant to the study's research question'.[39]

Consequently, our sample comprised 21 academics, predominantly from HASS disciplines, from a space research group within a leading Australian university. Comprising scholars from around the globe, including Australia, the US, the UK, China, Italy, Canada and India, the broad mission of this research group is to bring a humanities, arts and social sciences perspectives to the space sector through research, education and consulting. The strategy in selecting these individuals was to bring together a diverse set of academics with multidisciplinary and multilevel perspectives and a range of interests in space matters beyond traditional STEM boundaries. The disciplines represented included finance, accounting, law, ethics, project management, organisational behaviour, marketing, strategy, public sector management, history and archaeology. The experiences of these interviewees help provide quality insights into the ways and means by which cross-disciplinary efforts can address the contemporary challenges presented by the New Space Age.

Data collection and analysis

The data were gathered through semi-structured interviews. The interview questions were designed to help direct the discussions and so were deliberately general and open-ended. This gave the interviewees significant discretion as to the level of detail provided, which helped to capture their genuine views on the subject matter.[40] The questions revolved around our key topic of interest – the hurdles that may prevent the potential value that cross-disciplinary approaches can add to the New Space Age from materialising, particularly those that involve HASS disciplines. The interviewees were asked to provide their opinions on the broader characteristics of cross-disciplinarity as it relates to challenges in the space sector. This method allowed the researchers to consider what the interviewees felt was meaningful without introducing demand effects. It also helped ensure that the data reflected an experience-based view on the part of the participants instead of accidentally involving any preconceived biases the interviewers may have had.

38. Alewine, 2020; Tucker and Alewine, 2022
39. Parker and Northcott, 2016, pp. 1116
40. Kvale and Brinkmann, 2009

The interviews were conducted via Zoom due to the logistical and health considerations stemming from the COVID-19 pandemic. They lasted between 45 and 90 minutes and were audio-recorded. The research team took notes during the interviews. Afterwards, the interview recordings were transcribed and coded in the qualitative software package NVivo. This method efficiently captured specific quotes based on guided search criteria that helped factor out both common and unique themes for consideration and analysis.

Our research procedures included approaches to help confirm 'credibility' and 'dependability',[41] and also to ensure that the processes of data capture, recording and reporting were authentic and genuine.[42] Steps to enhance credibility comprised peer debriefing, with the research team analysing the data as it developed to validate the themes and configurations that emerged. Actions to enhance dependability included transcribing interview notes, preserving the interviewees' contact records, and consistently documenting interview dates, times and venues.[43]

WHAT DID WE FIND?

Our findings are structured around three predominant themes that emerged from our interviews. The first theme concerns the integral role that HASS disciplines are perceived to hold in the New Space Age. The second theme relates to the perceived benefits associated with cross-disciplinarity, and the third theme relates to the perceived costs associated with cross-disciplinarity. These themes are illustrated through the 'voices' of the participants. The quotes reported highlight their primary concerns, uppermost observations and principal experiences. They also represent the consensus of the sample.

The role that HASS disciplines are perceived to hold in the New Space Age

The view that HASS disciplines have significantly contributed to the space sector in the past and will likely contribute more so in the future was unanimous. All interviewees, irrespective of their disciplinary background, location or university affiliation, perceived that the extent and nature of the contribution HASS disciplines have made to the space sector has been highly significant. Regardless of how the interviewing question was phrased or how the data were sliced and considered, there was broad consensus among the interviewees that 'HASS in space' is not a fleeting fad – it has staying power and will continue to contribute substantially to space objectives. In the words of one interviewee:

> **I see the role of HASS disciplines in the space sector as very similar to the common analogy of the duck gliding across the water. To the observer all appears to be calm on the surface, but under the water, the duck is paddling furiously to stay afloat. You don't see what's under the water, and you don't see the influence of non-STEM disciplines in space activities – like marketing, management, financing, politics, teamwork, psychology. I6**

The issue of disciplinary visibility was raised repeatedly in our interviews:

> **The rocket launches and live streams from space is what is most visible – that's all STEM-related. The budgets, public relations, supply chain negotiations, political lobbying, and human resource issues are all HASS-related – that's what you don't see. I9**

41. Lincoln and Guba, 1985
42. Parker and Northcott, 2016
43. Gelman and Basbøll, 2014

The widespread interest in space from disciplines other than science and engineering was an observation made repeatedly by the interviewees:

> You might say that to a hammer everything looks like a nail and that members of this research group are bound to say that HASS has a central role in space. That's the very point though – this research group, which brings together disparate non-STEM based disciplines, has a single common denominator – space. This is the tip of the iceberg insofar as interest in and contribution to space is concerned. I7

Several participants remarked on how the need for a HASS contribution to space has changed over time:

> When you are looking at longer expeditions (like heading for Mars) you have an entirely different ball game – the need to address team dynamics, supply of resources, commodities, psychological issues from being in an artificial environment for so long, the massive financial expense, and managing public expectations are going to be much greater than when we were headed for the moon. I9

This theme of now being a 'different ball game' to the demands of the past was pronounced in the interviews. The participants spoke of the very different demands presented by the New Space Age in comparison to the old days of Moonshots, and how this new context was not only shedding light on the benefits of cross-disciplinary approaches but also necessitating them.

The perceived benefits of cross-disciplinarity

Three perceived benefits associated with cross-disciplinarity were repeatedly stressed in the interviews. First, there was the opportunity to draw on a wide range of disciplines. This was seen to be most amenable to solving what were regarded as the 'wicked problems' the New Space Age presents. One interviewee explains:

> You could say the problems facing us in travelling to Mars fit the definition of wicked problems. They are highly complex, defy complete definition, are intractable and very difficult to formulate and manage. They can't be easily solved by any one discipline but require partnerships beyond traditional disciplinary boundaries. That's why a cross-disciplinary approach is necessary. We'll need all the resources available to us to solve these problems. I8

Second, and expanding on the above benefit, combining diverse disciplines in cross-disciplinary approaches increases our capacity for innovation and creativity. This was perceived to be a particular strength:

> Solving complicated and unprecedented problems will require creativity and innovation. A different perspective is likely to lead you down the creative and innovative path. I12

Another interviewee provided a different view of how diverse disciplinary lenses might contribute to more effective outcomes:

> What is reassuring about the involvement of a diverse range of disciplines is that different vantage points help you to see what's there – and not just a blinkered view of things. I17

The third benefit cited by the majority of interviewees related to diversity – that is, the more 'political' and pragmatic considerations of managing stakeholders' expectations:

> Stakeholders in the area of space are not passive observers – they have agendas and need to be convinced that things are running to their view of what the plan should look like. These expectations need to be managed. I14

When considered, these three benefits represent variations on a theme, which is that HASS disciplines are well equipped to help solve wicked problems synergistically. They can help space missions succeed by effectively navigating the human dynamics associated with space-related frameworks, technologies and organisational behaviours.[44] Similarly, it is well established in the literature that cross-disciplinary approaches can, through diversity, increase innovation and creativity.[45] Cross-disciplinarity capitalises on the diversity of experiences[46] and ways of knowing[47] to support creative and innovative outcomes.[48] This perspective is particularly applicable, given the wide variety of stakeholders working in the space sector, both public and private, that require specialist knowledge – for example, when manufacturing and managing space infrastructure and systems, in space-related R&D, and when developing public policies about space activities.[49]

The perceived costs associated with cross-disciplinarity

The costs of taking a cross-disciplinary approach, as recounted in the interviews, converge on two main themes: the loss of credibility when operating outside the STEM disciplines, and pragmatic career considerations.

The interviewees perceived that a lack of STEM training was detrimental to being accepted as a valued contributor to achieving space-related goals. One interviewee used the analogy of a hierarchy of disciplines in which STEM was rated more highly than HASS:

> **There's definitely a hierarchy of disciplines in effect. Where space is concerned, sciences are the gold standard. Arts and humanities are nowhere near as prestigious or highly regarded – and are not always seen to bring much of consequence to the table. I11**

Another interviewee reinforced the 'second-class citizen' observation and its implications:

> **Without a science or engineering background you won't have much credibility. Social sciences, arts, humanities – anything that isn't technologically linked will have questions surrounding its credibility. I16**

Still another interviewee identifies the potential downside of not developing a degree of credibility:

> **Not only are people not accustomed to dealing with others who don't have a strong knowledge and understanding of the science of space, they won't take those without this understanding seriously. There are as you can see, turf issues at play. I21**

In terms of career considerations, there was definitely a feeling that working as a HASS academic in this field meant one was giving up a defined and established career path. One participant offered a cautionary note on the practical difficulties of HASS researchers working in a STEM field:

> **Non-STEM researchers who do research in STEM areas run the risk of isolating themselves from their original discipline, their peers, their funding sources, and their publication options. It's very high risk. I18**

And these costs are amplified for junior and early-career researchers:

> **Non-science-based researchers trying to forge a career in a science field is a very tall order. It hasn't been done a lot; the precedent has not been set yet. I19**

44. Pell 2021
45. Zhang, et al., 2018
46. Davies et al., 2018
47. Kaufmann and Tödtling, 2001
48. Acar et al., 2019
49. Clark et al., 2014

The perspectives surrounding these costs are consistent with other views that advocate a more cross-disciplinary approach to research.[50] Thus, the reported issues that may currently hinder HASS disciplines from helping to advance the space sector are not unique. This is encouraging news in that, while not perfectly correlated with other challenges found in other contexts, there may indeed be 'lessons learned' from previous studies that can help HASS disciplines to address these costs going forward. What those detailed solutions may look like is not readily apparent. However, with the interviewees agreeing with the overall potential for HASS disciplines to meaningfully contribute to the space sector, future efforts to justify these costs seem very reasonable.

CONCLUSION

In this study, we explored the nature and extent of the contribution that HASS-related cross-disciplinarity might make to resolving the challenges of the New Space Age. From our interviews, it is clear that cross-disciplinarity – and, in particular, the role of HASS in the space sector – plays a prominent role. HASS disciplines can contribute much to advancing space objectives, as our sample of those working in the sector revealed. However, for the academics involved, it also comes at a cost.

This study delivers some notable contributions to the literature. First, the extant literature provides scant insight into how HASS disciplines meaningfully and positively impact strategic space objectives. The findings of this study can be seen as a call for all involved in the sector to reflect more on HASS's potential to help accomplish space objectives going forward. The understated HASS developments of prior decades have laid solid ground from which to develop and execute future space projects. Second, the data suggest the potential for a mutually beneficial partnership between the STEM and HASS fields in the space sector. Finally, the interview data focuses on people as being vital to realising the ability of HASS disciplines to advance space objectives, as opposed to the systems, policies and institutions at play in the sector. This includes a better understanding of how people can overcome complex challenges using their various areas of expertise while navigating the intricacies of the dynamics between stakeholders.

The social implications of having a better understanding of how cross-disciplinarity efforts advance space activities and research abound. Since humanity considers Earth to be its one and only home, the very idea of expanding the only boundaries we have ever known cannot be understated or taken lightly. Why are we pushing these boundaries and extending into space? What are the benefits and costs of the various courses of action we might take for society? And how will we get feedback on the consequences of those actions to inform future plans? With no predetermined trajectory on how to advance development in such a unique sector, it would be prudent to debate multiple perspectives from multiple areas of inquiry. As a result, there is no shortage of opportunities in HASS disciplines to consider when looking for ways to help advance the modern space sector.

Like other studies involving interview data, limitations exist that may impact the study's suggested inferences, but these present opportunities for further research. First, the method used to collect, organise and report the interview data is not immune from subjectivity. Although care was taken to mitigate this possibility, some of the data may be skewed due to misunderstandings between the interviewers and interviewees. If so, this would result in biased inferences. Also, given the lack of extensive analysis, this study is mainly exploratory in nature. This approach should not be surprising in a cutting-

50. E.g., Ashby and Exter, 2019; Pye, 2018; Taebi et al., 2014

edge area of academic inquiry, and, for this reason, we welcome critical analysis and further dialogue on the subject matter of the study. It is our hope to arrive at a more informed perspective on the state of the New Space Age and the potential for integrating HASS disciplines more thoroughly within it. Lastly, the newness of the setting may contain variables and contexts that warrant further investigation so as to enhance this study's internal and external validity. Such inquiries can only further strengthen the initial underpinnings of this exciting new area of space scholarship.

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REFERENCES

Acar, O.A., Tarakci, M. and Van Knippenberg, D. (2019), creativity and innovation under constraints: A cross-disciplinary integrative review, *Journal of Management*, 45(1), 96–121

Alewine, H.C. (2020), Space accounting, Accounting, *Auditing & Accountability Journal*, 33 (5), 991–1018

Alexander, S. and Bannova, O. (2021), University based interdisciplinary space lab: Designing for astronaut health and wellbeing, *Acta Astronautica*, 186, 382–395

Ankeny, R.A. and Given, L.M. (2018), Creating research value needs more than just science – arts, humanities, social sciences can help. The Conversation, June 18, https://theconversation.com/creating-research-value-needs-more-than-just-science-arts-humanities-social-sciences-can-help-97083

Arnould, J. (2019), Colonising Mars. A time frame for ethical questioning. In K. Szocik (Eds.), The human factor in a mission to mars. space and society. Cham: Springer

Ashby, I. and Exter, M. (2019), Designing for interdisciplinarity in higher education: Considerations for instructional designers, *TechTrends*, 63(2), 202–208

Berea, A., Denning, K., Vidaurri, M., Arcand, K., Oman-Reagan, M.P., Bellovary, J., Aydinoglu, A.U., Lupisella, M., Dong, C., Vakoch, D., Messeri, L., Dick, S., Prescod-Weinstein, C., O'Leary, B.L., Strauss, B.E. Domagal-Goldman, S. Billings, L., Wright, J.T., Chambers, L.M., Khullar, G. and Fulmer, L. (2019), The social sciences interdisciplinarity for astronomy and astrophysics – Lessons from the history of NASA and related fields, Astro2020 A.P.C. white papers, *Bulletin of the American Astronomical Society*, 51(7), id. 142

Brown, V.A., Deane, P.M., Harris, J.A. and Russell, J.Y. (2010), Towards a Just and Sustainable Future. In Tackling Wicked Problems through the Transdisciplinary Imagination, edited by V. A. Brown, J. A. Harris, and J. Y. Russell, 3–15. London, UK: Earthscan

Clark, J., Koopmans, C., Hof, B., Knee, P., Lieshout, R., Simmonds, P. and Wokke, F. (2014), Assessing the full effects of public investment in space, *Space Policy*, 30(3), 121–134

Crawford, H. (2021), NASA's Time to Shine: Approaching Procurement in the 'New Space Age', *Air & Space Law*, 46(6), 649–664

Cross, MAKD (2019), The social construction of the space race: Then and now, *International Affairs*, 95(6), 1403–1421

Cross, MAKD (2021), Outer space and the idea of the global commons, *International Relations*, 35(3), 384–402

Cummings, J.N. and Kiesler, S. (2014), Organisation theory and the changing nature of science, *Journal of Organization Design*, 3(3), 1–16

Davies, A., Manning, S. and Söderlund, J. (2018), Why neighboring disciplines fail to learn from each other: the case of innovation and project management, *Research Policy*, 47, 965–979

D'Este, P., Llopis, O., Rentocchini, F. and Yegros, A. (2019), The relationship between interdisciplinarity and distinct modes of university-industry interaction, *Research Policy*, 48(9), Article 103799

de Zwart, M. (2019), South Australia's Role in the Space Race: Then and Now, *Adelaide Law Review*, 40(1), 63–73

Ehlmann, B.L., Chowdhury, J., Marzullo, T.C., Collins, R.E., Litzenberger, J., Ibsen, S., Krauser, W.R., DeKock, B., Hannon, M., Kinnevan, J., Shepard, R. and Grant, F.D. (2005), Humans to Mars: a feasibility and cost-benefit analysis, *Acta Astronautica*, 56(9–12), 851–858

European Space Policy Institute. (2007), Vienna vision on humans in outer space, http://www.espi.or.at

Fritz, P. (2019), Second Track to success, *Journal of Behavioural Economics and Social Systems*, 1(1), 11–28

Fritz, P. and Mallory, N. (2022), The anatomy of bad decision making and the role of neuroscience and the Second Track in improving decision making, *Journal of Behavioural Economics and Social Systems*, 4(1), 50–63

Fritz-Kalish, C. (2019), Twenty years on the Second Track: GAP case studies, *Journal of Behavioural Economics and Social Systems*, 1(1), 44–50

Gelman, A. and Basbøll, T. (2014), When do stories work? Evidence and illustration in the social sciences, *Sociological Methods & Research*, 43(4), 547–570

Glesne, C. (1999), 'Making words fly: developing understanding through interviewing', in Becoming Qualitative Researchers: An Introduction. New York, Longman, 2nd Ed

Global Access Partners (2017). The Australian Space Initiative: GAP Taskforce on Space Industry Report, https://globalaccesspartners.org/Australian_Space_Initiative_GAP_Taskforce_Report_Aug2017.pdf, (accessed 30 June 2022)

Kalmbach, J.A. and Ralston, J.J. (2021), Sights on Mars: Continuity and Change in Support for Space Policy, *Space Policy*, 57, 101446

Kate, H., James, J. and Tidmarsh, C. (2019), Using wicked problems to foster interdisciplinary practice among UK trainee teachers, *Journal of Education for Teaching*, 45(4), pp.446–460

Kaufmann, A. and Tödtling, F. (2001), Science–industry interaction in the process of innovation: The importance of boundary–crossing between systems, *Research Policy*, 30(5), 791–804

Klein, J.T. (2012), Research integration: A comparative knowledge base. In Repko, A.F., Newell, W. and Szostak, R. (Eds.), Case studies in interdisciplinary research (pp. 283–298). Thousand Oaks, CA: Sage

Kvale, S. and Brinkmann, S. (2009), Interviews: Learning the Craft of Qualitative Research Interviewing, Los Angeles, CA: Sage

Lee, T.S., Lee, Y.S., Lee, J. and Chang, B.C. (2018), Analysis of the intellectual structure of human space exploration research using a bibliometric approach: Focus on human related factors, *Acta Astronautica*, 143, 169–182

Lincoln, Y.S. and Guba, E. (1985), Naturalistic inquiry. London: Sage

Lyall, C. and Meagher L.R. (2012), A Masterclass in Interdisciplinarity: Research into Practice in Training the Next Generation of Interdisciplinary Researchers, *Futures*, 44(6), 608–617

Mankins, J.C., Mankins, W.M. and Walter, H. (2018), Biological challenges of true space settlement, *Acta Astronautica*, 146, 378–386

Massingham, P. (2019), Second Track processes: A research agenda, *Journal of Behavioural Economics and Social Systems*, 1(1), 29–43

Metcalfe, J., Riedlinger, M. and Pisarski, A. (2008), Situating science in the social context by cross-sectoral collaboration. In Communicating Science in Social Contexts (pp. 181–197). Springer, Dordrecht

Migaud, M.R., Greer, R.A. and Bullock, J.B. (2021), Developing an adaptive space governance framework, *Space Policy*, 55, 101400

Moltz, J.C. (2019), The changing dynamics of twenty-first-century space power, *Journal of Strategic Security*, 12(1), 15–43

Organisation for Economic Cooperation Development (OECD). (1972), Interdisciplinarity. Problems of Teaching and Research in Universities. OECD/CERI, Paris.

Parker, L.D. and Guthrie, J. (2014), Addressing directions in interdisciplinary accounting research, Accounting, *Auditing & Accountability Journal*, 27(8), 1218–1226

Parker, L.D. and Northcott, D. (2016), Qualitative generalising in accounting research: Concepts and strategies, *Accounting, Auditing & Accountability Journal*, 29(6), 1100–1131

Pell, S.J. (2021), What are the growth areas in domestic STEM skills to support jobs in the space industry, and how can these be addressed by the tertiary (university and relevant VET) sector? Rapid Response Information Report 1 July 2021. Office of Australia's Chief Scientist, Executive Officer of the National Science and Technology Council

Pye, G. (2018), Interdisciplinary research and the early career researcher. In Positioning research, pp. 34–54. SAGE Publications, Inc

Ryan, S. and Neumann, R. (2013), Interdisciplinarity in an era of new public management: a case study of graduate business schools, *Studies in Higher Education*, 38(2), 192-206

Saluja, I.S., Williams, D.R., Woodard, D., Kaczorowski, J., Douglas, B., Scarpa, P.J. and Comtois, J.M. (2008), Survey of astronaut opinions on medical crewmembers for a mission to Mars. *Acta Astronautica*, 63, 586–593

Sardar, Z. (2010), The Namesake: futures; futures studies; futurology; futuristic; foresight – what's in a name? *Futures*, 42, 177–184

Schmidt, J.C. (2011), What is a problem?: On problem-oriented interdisciplinarity, *Poiesis Prax*, 7, 249–274

Siebert, P., Siebers, P.O., Vallejos, E.P. and Nilsson, T. (2020), Driving complementarity in interdisciplinary research: A reflection, International *Journal of Social Research Methodology*, 23(6), 711–718

Smith, M., Craig, D.; Herrmann, N., Mahoney, E.; Krezel, J., McIntyre, N. and Goodliff, K. The Artemis Program: An Overview of NASA's Activities to Return Humans to the Moon. In Proceedings of the 2020 IEEE Aerospace Conference, Big Sky, MT, USA, 7–14 March 2020, 1–10

Szocik, K., Lysenko-Ryba, K., Banaś, S. and Mazur, S.K. (2016), Political and legal challenges in a Mars colony, *Space Policy*, 38, 27–29

Taebi, B., Correlje, A., Cuppen, E., Dignum, M. and Pesch, U. (2014), Responsible innovation as an endorsement of public values: the need for interdisciplinary research, *Journal of Responsible Innovation*, 1(1), 118–124

Tucker, B.P. and Alewine H.C. (2022), Space for accounting and accountability: Realising potential management accounting research contributions to the space sector, Accounting, *Auditing & Accountability Journal*, forthcoming

Tucker, B.P., Halkett, I. and James, J. (2021), Necessity: The mother of invention? The tension between management control and creativity: Lessons from Apollo 13, *Journal of Management Accounting Research*, 33(3), 163–188

Van den Besselaar, P. and Heimeriks, G. (2001), Disciplinary, multidisciplinary, interdisciplinary: Concepts and indicators Proceedings of the 8th international conference on scientometrics and informetrics, pp. 705–716

Weinzierl, M. (2018), space, the final economic frontier, *Journal of Economic Perspectives*, 32(2), 173–192

Zhang, L., Sun, B., Chinchilla-Rodríguez, Z., Chen, L. and Huang, Y. (2018), Interdisciplinarity and collaboration: on the relationship between disciplinary diversity in departmental affiliations and reference lists, *Scientometrics*, 117, 271–291

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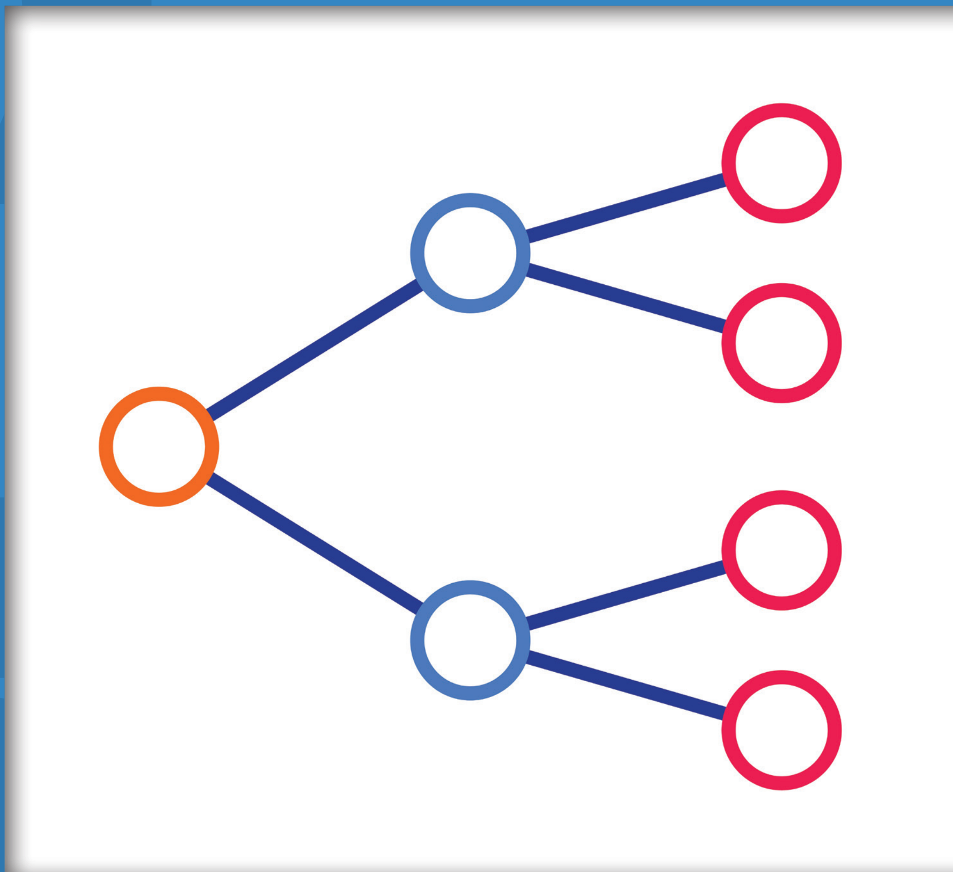

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