Removing Roadblocks from the UK space skills pipeline: A student and young professional perspective

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***Abstract*—This paper presents a student and young professional perspective on developing the space skills pipeline. Developing the space skills pipeline is critical in ensuring the government's space sector growth target, £40 billion by 2030, is achieved. The limitations of the current pipeline are identified, including places that government policy, industry and universities are falling short. These can be generally categorised as the lack of awareness of the space sector, lack of opportunities to develop experience, and the mismatch between teaching useful knowledge in universities. Several methods for solving each of these issues are suggested, drawing from activities of UKSEDS, and examples from both national and international institutions and organisations.**

Keywords—skills; education; careers; growth; space

I. INTRODUCTION

The UK government's National Space Policy [1] recognises the potential benefits of space to society and the UK economy, and identifies that space is part of today's national critical infrastructure. It codifies the government's ambition to grow the UK space sector to £40 billion (~10% of the global market) by 2030 and sets the path to meet this goal. It lists four key principles that should be supported by the national space strategy, including "supporting the growth of robust and competitive commercial space sector".

A critical component of a growing and healthy industry is the availability of a skilled and educated talent pool. This has been repeatedly identified by government and industry alike as the number one issue facing the sector at present [2-3]. The importance of the availability of this pool cannot be understated. Silicon Valley's success demonstrates the vibrant entrepreneurial environment that can be attained with high numbers of skilled individuals and access to investment capital. Previous national space strategies [4] have stated the importance of ensuring the existence of a sufficiently large and diverse talent pool, and the UK Space Agency (UKSA) has created its own Education, Skills and Outreach [5] strategies to address the issue. However, only a few initiatives to improve the skills of graduates and promote interest in space among higher education students are identified in the UKSA's policy, such as the Space Placement in INdustry (SPIN) scheme and Higher Apprenticeship qualification.

This paper presents a new perspective of the skills pipeline issue, based on the experiences of students looking for career opportunities in the space sector and of young professionals working in the sector. This evidence has been gathered by UKSEDS (UK Students for the Exploration and Development of Space), the UK's student space society, and includes the results from surveys, interviews and experiences of the organisation's membership over several years. Potential roadblocks preventing the growth of the talent pool required for the government's targets are identified. Several potential solutions are described and evaluated based on their efficacy. Some, such as the SpaceCareers.uk website, are currently being implemented by UKSEDS, and others have been identified from the work of other organisations from the UK and around the world.

II. APPROACH TO DATA COLLECTION

A. Aggregated UKSEDS event surveys

UKSEDS collects survey data as part of the registration process for all its events, including the annual National Student Space Conference, the largest event of its kind in the UK.

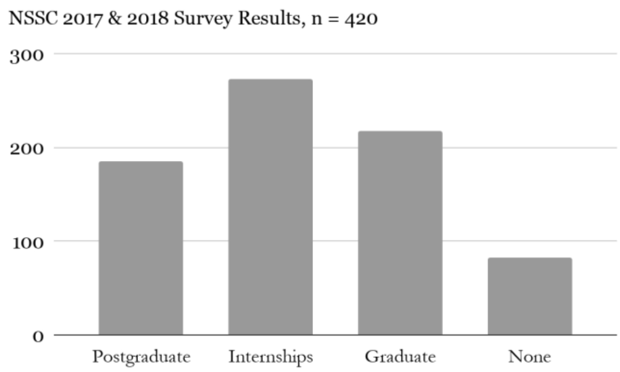

FIG I Results from survey question: What opportunities are you looking for?

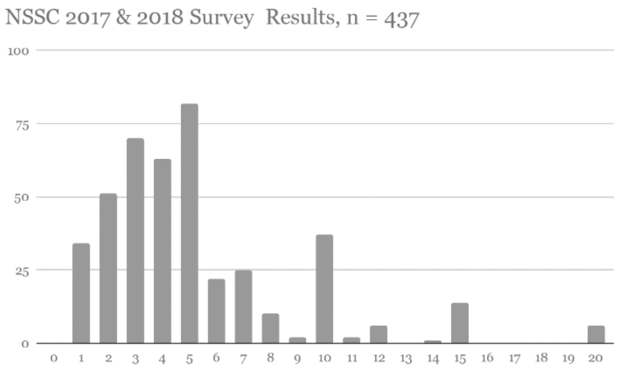

FIG II Results from survey question: How many UK space companies can you name off the top of your head?

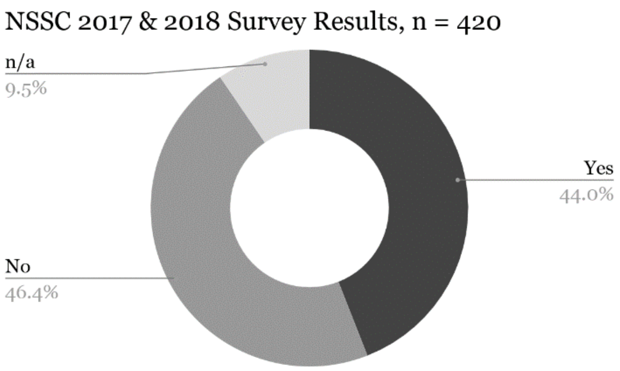

FIG III Results from survey question: Have any space companies exhibited/spoken to you at your university?

Note that these data are from a self-reported survey, which cannot be independently verified. They also represent a spectrum of students from first year undergraduates to PhD students, in a range of technical and non-technical disciplines (approximately 42% engineering, 25% physics, 19% other sciences/mathematics and 14% other or non-disclosed).

B. SpaceCareers.uk job postings and web traffic

The second main source of primary data is from the careers website, SpaceCareers.uk. This site was set up by UKSEDS in 2015 to provide a single place for students and young people to search for jobs and other opportunities in the space sector. The number of job adverts for various opportunity types, and the associated average views per post are shown in Table I. The jobs in question are primarily UK-based positions but include several European openings.

These data provide a useful source of information on the types of adverts that are most attractive to the students who use SpaceCareers.uk. There are a few caveats to the data, notably it is based on jobs that are either sent to SpaceCareers.uk to be advertised (currently a free service) or opportunities found by the SpaceCareers.uk team. Although it is likely to capture a good cross-section of the opportunities available, there will be some that have not been included. Additionally, several of the adverts will be a single advert for multiple opportunities.

	March 2017 - March 2018		
	Posts	Opportunities	Views per post
Internships	71	115	595
Direct Entry	95	106	492
Graduate	32	33	411
PhD	47	60	265
Post Doctorate	10	10	194

TABLE I Number of adverts per year of each category of job and viewing figures

C. Additional sources of data

Finally, some data used in this paper has been taken from 3rd party reports. Specifically, SSPI (Space & Satellite Professionals International) commissioned the *2016 Satellite Industry Workforce Study* [6], performed by recruitment consultancy Korn Ferry. The authors of this report used two main sources of information: 14 telephone interviews with HR executives at companies (including Arianespace, Airbus and SES) and an online employee survey distributed globally through SSPI's membership and other avenues, which received 1060 respondents. The report also notes that the survey is self-reported with no independent verification and should therefore mainly be used to identify trends.

II. Roadblocks to a large talent pool

A. Awareness of the space sector

The first roadblock identified is the lack of awareness of the breadth of activities of the space sector among further and higher education students.

From the UKSEDS survey data presented in FIG II, the median number of firms students know of is 4. These are generally government bodies and the largest upstream companies. The average number of attendees that knew of the downstream employers at the NSSC 2016 was 38%, but was 64% for upstream companies and 70% for government bodies. This does not represent the actual composition of the space sector, where the upstream segment accounts for only 12% of revenue [7].

There are several reasons why this lack of awareness is a roadblock. Firstly, it limits the pool of potential candidates to the small number of students who already know about the sector. While many tech companies such as Facebook, Google and Amazon have strong presences on university campuses in addition to being household names, the same cannot be said of space companies (see FIG III). The result is that many capable students do not consider applying to space jobs. For a sector that is competing for top science, engineering and computing talent this is a major obstacle to growth.

Secondly, one of the key areas of growth for the space sector is downstream applications, which overlaps with many other sectors. Many potential users of space data come from disciplines such as computer science and GIS, which are not traditionally associated with space, and as a result they are not typically made aware of the value the space sector has to offer to their speciality. The Space Innovation and Growth Strategy Skills Themes Report noted that "(sought after) graduates were not aware that they could seek specialist employment as space specialists within their own industry (for e.g. in the water industry)." [8]

B. Opportunities to develop experience

The second roadblock is the lack of opportunities to develop experience. The value of experience is obvious: it differentiates the veteran from the recruit, the professor from the student and is one of the key traits sought by employers. For example, SpaceX filters applications based on:

- *"Hands on hardware/software development exp - i.e. What problems have you actually encountered and solved?"*
- *"Experience with engineering competitions, and placement in top positions/ brackets at those competitions"*
- *"GPA/ SAT - other hard scores"*
- *"Drive/ Grit"*

SpaceX sends a recruiting mission to the Formula Student competition each year, competing with the automotive industry for the top performers [9].

For undergraduate students, opportunities to gain experience are limited. Readily available non-technical part time jobs are a good way of gaining 'soft' skills – teamwork, responsibility, timekeeping etc. – but it is the more valuable technical skills that are most difficult to come by. These are most easily obtained through hobbyist activities, summer internships/research placements and extra-curricular activities, such as engineering research projects run by student societies. However, most STEM courses have a large number of contact hours (15+h/week) [10], which leaves students with little spare time in which to pursue these extra-curricular activities for which they typically receive no credit. The most common reason cited for not volunteering with UKSEDS is lack of time. Additionally, many opportunities to gain experience are unpaid or low-paid, disadvantaging students from low-income backgrounds who cannot afford to work for free [11].

In this regard, the space sector compares poorly with other STEM sectors. For example, Formula 1 teams support Formula Student, while other sectors run challenges like Barclays Launchpad Business Challenge, Shell Ideas360, Babcock Telegraph STEM Awards, IMechE Formula Student and Unmanned Aerospace challenges for Mechanical and Electrical Engineering students. Though there are some similar competitions in the space sector, these tend to be lower profile (which reduces their attractiveness to students), and less well publicised.

Data collected from delegates to the National Student Space Conference in 2018 and 2017 (FIG I) shows that there is a large demand for internships and research placements. 56% (273) of attendees reported that they were searching for internship or research placement opportunities. This is a larger number than for both the postgraduate research/courses (i.e. master's or PhD programmes) or graduate roles (graduate schemes or direct entry). Additionally, the demand from delegates at these events alone far outweighs the number of opportunities that are advertised on SpaceCareers.uk (TABLE I), demonstrating the significant shortage of entry-level opportunities.

British degrees are significantly shorter than many other European countries, with the vast majority of courses taking 3 years for an undergraduate bachelor's, 4 years for an integrated master's, and 3 + 1 years for an undergraduate bachelor's and a postgraduate master's. A significant disadvantage of the speed of this system is that it reduces the time available for students to gain experience before starting work.

The serious impact of this issue is highlighted in the *2016 Satellite Industry Workforce Study* [6], which focuses primarily on North America. It identifies that the "industry relies heavily on a cadre of experienced workers ages 45-54, who make up 42% of employees". Many gained their initial experience in the military before moving to the commercial sector later in their careers, something which is rarer today due to a relatively smaller defence industry. The report additionally states that "the voluntary attrition rate - people leaving their jobs by choice - for employees with 1-5 years of service is a shocking 67%" and concludes that the "industry is failing to invest in careers paths that retain younger talent". If the UK's space sector grows as predicted, there will be a major shortage of experienced professionals in a few decades.

C. Mismatch between teaching and skills employers are looking for

The third roadblock we have identified is the mismatch between the specific skills employers are looking for and what is taught at universities. Many entry level positions available in industry require experience in a specific software package such as ESATAN, STK, and Catia, which are not readily accessible to students because of the high cost of licences.

Universities must teach a broad range of skills and knowledge to equip their graduates to work in many different sectors, and although there are space master's courses available to try to bridge this gap, they rely on students being able to afford the cost of an additional degree. Tuition fees for the International Space University's one-year MSc in Space Studies are €25,000 (£22,200) [12].

Additionally, many disciplines are multidisciplinary, often requiring a mixture of skills and knowledge normally available across different degree courses. This is particularly an issue in the field of space applications, where space data is applied to everything from agriculture to oceanography. It is important not only to know how to manipulate data, but also to understand the source of the data, such as the type of imagery, the orbit of the satellite and its revisit time, as well as the specifics of the problem that is being solved. As a result, applicants are expected to have well-developed programming skills, a good knowledge of Earth observation techniques, and domain specific knowledge for the application in question.

III. Removing the roadblocks

The following section contains several recommendations for government, industry and universities, along with examples of similar existing programmes from around the world.

A. Encouraging organisations to create internship or placement programmes

Internships and placements are the most valuable way in which students can gain experience before committing to a career. Until recently only the largest organisations had formal internship and graduate placement programmes. While opportunities were available at SMEs, these were typically on a more ad-hoc basis, and only accessible to those with connections in the sector. The UK Space Agency's Space Placement in INdustry (SPIN) scheme, launched in 2013, has helped encourage companies to take on students, and made placements with SMEs much more readily available to those without connections.'Spinterns' get 8 weeks of paid summer work experience at a space company, and host organisations are persuaded to host them on the basis that they bring an "injection of fresh ideas and enthusiasm" and a "chance to informally 'interview' a potential employee of the future" [13]. A greater expansion of this programme would further benefit the sector.

Perhaps the best examples of summer internship programmes can be found in the US. SpaceX, Blue Origin and ULA all have large paid internship programmes, and often recruit from within their intern graduate pool. They have found a way to benefit from providing experience-gaining opportunities, and this model should be adopted by more firms in the UK.

An alternative example is the longstanding Summer Undergraduate Research Experience (SURE) programme [14] at the University of Leicester, which provides funds for undergraduate students to undertake research within the department. In the past SURE students have used the programme to further research in extra-curricular projects, such as Leicester's CubeSat programme. There are similar approaches to this at several universities, including the Scotland-wide Carnegie Scholarships, and Imperial College London's Undergraduate Research Opportunities Programme (UROP) [15].

B. Encouraging self-organized technical projects

Rocketry, robotics and CubeSat projects provide excellent opportunities to develop experience and skills, and many students can perform novel and original technology development or research in the process. Many of these projects will be presented at the SSEA 2018 conference.

Despite this, many students are put-off from organising such projects because of their perceived complexity. Competitions provide a good way of encouraging large numbers of students to start their own technical projects by providing a clear structure, technical support, and funding. Existing competitions include the Mars Society's University Rover Challenge, the UK Space Agency's SatelLife Challenge, ESERO-UK's CanSat competition, and UKSEDS' National Rocketry Championship (NRC) and Lunar Rover Competition (LRC). The latter challenges students to design, build and test small rovers based on a set of requirements, passing through an industry-led review process to progress to the competition final. Many competitions addressed at students, including the NRC and LRC, and undergraduate paper/presentation competitions such as those run by Airbus and the British Interplanetary Society have a relatively small number of applications from eligible students. There are two actions that could help to solve this:

1) Universities should encourage their students to engage with opportunities like this by offering extra credit or other benefits

2) Companies should emphasise in their recruitment materials how involvement with competitions makes students more employable

NASA and ESA have both created hackathon initiatives which encourage students and others to create a technical and/or business project in 24 hours. In addition to developing technical skills, hackathons help to bring awareness of the space sector and its activities to a different group of people: computer scientists, developers and entrepreneurs, a key recruitment target for space application SMEs. The NASA Space Apps Challenge 2017 saw hackathons in 160 locations with over 15,000 participants [16].

Industry should be providing more support for these projects and competitions. Offers of funding or resources, such as engineering advice or lab space are incredibly valuable for student-run projects. In many places, particularly in Europe, this is already being done. For example, the WARR Hyperloop team at TU Munich has significant financial support from Airbus, and dozens of other companies have provided expertise, components or facilities. CubeSat programmes in other nations are heavily sponsored by government (DLR, NASA programs), industry and universities. Similar financial support has simply not been available for UK projects. For companies, getting employees involved as competition judges or on review panels improves the learning experience for the participants and can help to boost a company's profile amongst its potential future employees.

To maximise the value and uptake of such competitions, it is important the tasks involved are:

1) relevant to the industry's needs
2) implicitly or explicitly supported by industry and universities
3) accredited or recognised with course credit, certification etc.

C. Outreach with high education students

The space sector should have a greater presence on university campuses and at careers fairs in secondary and tertiary education. Not only will this broaden the talent pool, but it can help to find potential users of space data and technology. The UK's aerospace sector is about 95% SMEs [17], which typically lack the resources to exhibit on multiple university campuses and career fairs. An efficient way for such organisations to maximise their impact would be to combine resources to fund a general space sector stand at such events, perhaps under the banner of the UKspace trade association or another similar body. This would raise the profile of the sector, benefiting all the companies involved. Companies could also create and maintain links with local universities, providing support or guest speakers to relevant departments and societies.

D. Development of training courses for specific skills

The shortfall in skills, and to some degree experience, can be offset by introducing more paths for students to gain them. One method of doing this is to introduce specific postgraduate degree courses. For space engineering, several have existed for many years (Cranfield University's MSc in Astronautics and Space Engineering, and the University of Surrey's MSc in Space Engineering), whilst other have been introduced more recently (the University of Leicester's MSc in Space Exploration Systems). Universities have also identified topics where specialist courses may be required, with the development of master's courses in space data at the University of Strathclyde and in Earth observation at Leicester. However, committing to the financial and time cost of a postgraduate degree is not feasible for all.

The second method is to introduce short training courses. Industry-standard courses, such as the *Continuing Education: Space Systems Engineering* [18] course run by University of Southampton (£2100), or the *Space Missions Operations Course* [19] run by Catena Space at Goonhilly (£300 students rate) are prohibitively expensive for students [20]. The ESA Academy has introduced an excellent range of affordable training opportunities ranging from concurrent engineering to spacecraft communications [21]. However, these are primarily based in Redu, Belgium, and there is still a lack of courses teaching specific software packages or systems engineering techniques (such as CAE). In the UK, UKSEDS have worked directly with software companies to provide students with opportunities to learn and practice with industry-standard products (MSC Software). The most important consideration in providing workshops is to ensure that they are short, affordable and modular.

Conclusions

We have presented several roadblocks to the successful growth of the space sector, supported by a collection of primary, secondary and anecdotal data, as well as a summary of approaches to overcoming these roadblocks. The key takeaway is that the industry should be encouraged to engage with students through events, projects, and competitions, and for government and universities to enable students to gain further experience and skills.

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