IAC–25–D1.7

TAILORED CAPACITY BUILDING FOR CUBESAT INNOVATION: LESSONS LEARNED FROM NATIONAL PROGRAMS AND PATHWAYS TO SPACE ACCESS FOR ALL

Malaika Malik[a]*, Moervica Anushree Prashant[b], Aydin Yousaf[c], Ayush Roy[d], Isabella Schick[e], Mahsheed Akbari[f], Parneet Saini[g], Niki Mohammadi Bidhendi[h]

[a] *University of Toronto Aerospace Team (UTAT), Canada, malaika.malik@mail.utoronto.ca*
[b] *University of Toronto Aerospace Team (UTAT), Canada, m.prashant@mail.utoronto.ca*
[c] *University of Toronto Aerospace Team (UTAT), Canada, aydin.yousaf@mail.utoronto.ca*
[d] *University of Toronto Aerospace Team (UTAT), Canada, aayushroy.roy@mail.utoronto.ca*
[e] *University of Toronto Aerospace Team (UTAT), Canada, isabella.schick@mail.utoronto.ca*
[f] *University of Toronto Aerospace Team (UTAT), Canada, mahsheed.akbari@torontomu.ca*
[g] *University of Toronto Aerospace Team (UTAT), Canada, parneet.saini@mail.utoronto.ca*
[h] *University of Toronto Aerospace Team (UTAT), Canada, niki.mohammad@mail.utoronto.ca*
* *Corresponding author*

Abstract

CubeSats have emerged as a sustainable and cost-effective alternative to traditional satellites, offering advantages in scalability, resource efficiency, and innovative end-of-life disposal practices. The rapid growth of nanosatellite launches, particularly CubeSats, is accelerating. In the next five years, around 1,900 more launches are expected, nearly two-thirds of the total deployed over the past quarter century. This highlights the exponential expansion of CubeSat technology. A significant portion of these missions are led by undergraduate educational teams, often supported by national or international programs such as NASA's *CubeSat Launch Initiative* (CSLI), the Canadian Space Agency's (CSA) *Canadian CubeSat Program* (CCP), the Japan Aerospace Exploration Agency's (JAXA) *KiboCUBE*, and the European Space Agency's (ESA) *Fly Your Satellite!* (FYS). This paper presents a comparative analysis categorizing CubeSat programs into well-established (e.g. the CSLI, FYS), newer (e.g. the CCP), and emerging (nations exhibiting interest in developing CubeSat initiatives, such as those working with *KiboCUBE*). Drawing from structured surveys and semi-structured interviews with undergraduate teams from each tier, the study evaluates key determinants of program success, such as infrastructure, funding, and deliberate knowledge transfer. These parameters are examined to assess their cumulative efforts on mission success, workforce development, and sustainable economic growth. With the ultimate goal of leveraging concrete capacity-building practices common in high-tech and capital-intensive sectors, the study proposes actionable frameworks for empowering emerging spacefaring nations to develop autonomous and resilient CubeSat programs. Each case study is contextualized within its unique institutional and cultural environment to ensure that recommendations support sustainable and equitable growth across diverse regions in the global CubeSat sector. Key trends indicate that well-established programs provide stable and enduring frameworks through extensive mentorship structures and subsidized launch opportunities, whereas emerging initiatives emphasize adaptability, leveraging international collaborations to compensate for limited infrastructure. The *KiboCUBE* program, in particular, exemplifies a model of equitable capacity building through its partnership with JAXA and the United Nations Office for Outer Space Affairs (UNOOSA), fostering practical skills and local program development in participating nations. Despite the diversity of approach, programs across all maturity levels face similar systemic challenges in securing resources, ensuring continuity, and facilitating knowledge transfer. Aligned with the United Nations Sustainable Development Goals 8, 10, and 17, this study identifies cross-cutting factors which enhance knowledge transfer, promote equitable access and use of outer space, and strengthen international collaboration. The proposed strategies not only cultivate a skilled, globally-connected space workforce, reinforce national CubeSat ecosystems, and support emerging programs in achieving long-term sustainability and competitiveness within the evolving global space economy.

Acronyms/Abbreviations

SDG: Sustainable Development Goal
CSA: Canadian Space Agency
NASA: National Aeronautics and Space Administration
CSLI: CubeSat Launch Initiative
CCP: Canadian CubeSat Program
UNOOSA: United Nations Office for Outer Space Affairs
JAXA: Japan Aerospace Exploration Agency
ESA: European Space Agency
FYS: Fly Your Satellite!

UN: United Nations
CUBICS: CubeSats Initiative in Canada for STEM
IARU: International Amateur Radio Union
ROSPIN: Romanian Space Initiative
URSSA: Undergraduate Research Student Self-Assessment
SPARSO: Space Research and Remote Sensing Organization
EU: European Union
UK: United Kingdom
ITU: International Telecommunication Union
STEM: Science, technology, engineering, and mathematics

1. Introduction

CubeSats—standardized modular nanosatellites—have become a cornerstone of modern space access, offering a sustainable and cost-effective alternative to traditional satellite platforms. Their smaller size, lower mass, and reliance on off-the-shelf components help reduce resource consumption across the development process, which is further streamlined by their short build cycles and minimalist onboard systems. Their evolving end-of-life disposal strategies also support the minimization of space debris and the promotion of responsible orbital practices [1]. Their standardized design, compact size, and low launch costs have attracted significant interest from academic institutions and emerging space nations, enabling participation in orbital missions that were previously out of reach [2, 3]. As of April 30, 2025, a total of 2,730 CubeSats had been launched, comprising approximately 92% of all nanosatellites deployed globally since the early 2000s [4]. This demonstrates the overwhelming dominance of CubeSats in the modern era, as launch activity has followed an exponential growth trajectory since 2020. A growing share of these missions are led by undergraduate teams and supported by institutional programs such as NASA's CSLI [5], CSA's CCP [6], ESA's FYS [7], and JAXA's *KiboCUBE* [8]. These initiatives provide access to launch infrastructure, technical mentorship, and funding support, which collectively foster student-led innovation and strengthen national space ecosystems [1, 9].

Despite the growing number of CubeSat launches worldwide, academic missions continue to face significant challenges in achieving consistent success. According to the Aerospace Corporation, fewer than 50% of university-led CubeSats fully meet their mission objectives, with failures often resulting not from technical limitations but from inadequate project management, inconsistent mentorship, and poor documentation practices [10]. While recent studies have proposed targeted solutions such as clearer mission scoping, embedded mentorship, risk-based assurance, and structured lifecycle documentation, these practices remain unevenly implemented across national programs, including NASA's CSLI, JAXA's *KiboCUBE*, and ESA's FYS [10, 11]. Most existing literature focuses on isolated cases or context-specific recommendations, without systematically examining how national programs implement capacity-building strategies to support CubeSat development. Capacity building refers to developing the long-term technical and institutional capabilities for countries to sustain their own satellite development programs. That includes skills training, mentorship, career advancement, infrastructure, funding, outreach and collaboration, and internal leadership. Capacity building is an essential element to ensure program continuity beyond one launch and development within the global space economy. There is little analysis of how these practices vary across programs with different levels of maturity, or whether they are designed to be generalizable and scalable beyond individual contexts. As a result, there is limited understanding of how student training and mentorship in university-led CubeSat programs, supported by national initiatives, contribute to long-term program sustainability and workforce development, as students gain practical skills that prepare them to contribute effectively to the broader aerospace sector. Thereby, this study addresses this gap by comparatively analyzing national initiatives to identify which practices have the most durable impact on student-led mission success and knowledge retention.

To examine differences in educational CubeSat program design and outcomes, this study conducts a comparative analysis across three tiers of capacity-building initiatives. (1) Well-established programs, such as NASA's CSLI, have supported the launch of over 200 university-led CubeSats and provide long-term institutional frameworks along with robust technical resources [12]. (2) Newer national programs aim to expand domestic space capabilities and educational outreach. For example, the CSA's *CubeSats Initiative in Canada for STEM* program builds on the earlier CCP, introducing a multi-tiered support model for novice, intermediate, and advanced teams. It emphasizes structured mentorship, industry collaboration, and access to shared infrastructure such as centralized testing platforms [13]. (3) Emerging programs often represent initial, internationally supported efforts to build local capacity. A representative example is Saudi Arabia's KAUSTSat team, which was developed in partnership with global stakeholders to catalyze regional CubeSat capabilities [14]. To evaluate these tiers, this study conducted surveys with undergraduate CubeSat teams affiliated with national programs, focusing on key dimensions including technical infrastructure, funding mechanisms, and knowledge transfer practices. Mentorship and international collaboration were also examined, as both are consistently linked to improved mission success and long-term program sustainability. Well-established initiatives such as ESA's FYS and NASA's CSLI exemplifies this through resilient program frameworks that provide extensive mentorship, subsidized launch access, and structured support. In particular, FYS combines technical guidance from ESA engineers and industry professionals with international student collaboration and non-technical training in areas such as soft skills and career development [15]. Meanwhile, newer programs adapt to national contexts by aligning with local industry needs and educational capacities. For instance, *KiboCUBE* epitomizes capacity building via international partnership and tailored training for countries like Kenya and Guatemala, enabling the building and deploying of their first CubeSat [16], while KAUSTSat targeted the national aim of increasing student knowledge and experience with CubeSats [14]. However, efforts like the BIRDS program demonstrate how standard bus designs and mentorship shorten timelines for novice teams [17].

This study translates into offering a structured, comparative framework that shares lessons learned from established and emerging educational CubeSat programs to help student-led teams with long-term sustainability and mission success. By aligning these insights with UN SDGs 8 (Decent Work and Economic Growth), 10 (Reduced Inequalities), and 17 (Partnerships for the Goals), the framework not only empowers university teams to strengthen their capacity-building but also guides educators, funders, and policymakers in assessing current programs and revising them to maximize success. Ultimately, it provides recommendations grounded in real-world successes to help cultivate skilled workforces, foster equitable access to space, and sustain innovation through international collaboration.

1.1 The Rise of CubeSats in Academic and Emerging Space Contexts

CubeSats are a class of nanosatellites built using modular units, where each unit (1U) has dimensions of approximately 10 cm on each side and weighs a maximum of 1.3 kilograms. These units can be scaled into larger forms, with the 6-unit (6U) configuration emerging as the most prevalent model in active use [18]. Their compact form, lower mass, and use of off-the-shelf components have made them particularly appealing for educational use, offering students hands-on experience in satellite design, systems engineering, and mission operations. In academic contexts, CubeSats enable universities to engage in orbital missions at a fraction of the cost of traditional platforms, promoting STEM education and innovation. These missions are valuable not only for the experience they offer but also for the data they collect. For example, the first Romanian educational satellite, ROSPIN-SAT-1, was produced by a student team of the Romanian Space Iniative (ROSPIN), under ESA's FYS *Design Booster* program. ROSPIN-SAT-1 was developed with the aim of detecting health issues in vegetation and potential reforestation areas to combat forest degradation in Romania [19]. Beyond scientific aims, CubeSat missions contribute to capacity building by helping institutions and individuals develop long-term expertise, infrastructure, and opportunities in space science and technology. Through the continuity of such programs, future students and programs benefit from established technical knowledge and accessible pathways to participate in satellite development and operations [20].

1.2 Barriers to Continuity and Scalability in Student CubeSat Programs

The chief risks to continuity and scalability in student CubeSat teams are institutional: fragile knowledge transfer, episodic funding, and underestimated regulatory overhead. A recurring challenge is the loss of institutional knowledge caused by high student turnover and insufficient documentation. Without living onboarding records, or repositories for code and operations, new members must reconstruct the mission from scratch. The University of Colorado's MAXWELL team noted challenges with knowledge transfer, including delayed schedules and forced established teams to repeat work unnecessarily [21]. Beyond money, teams often lack standard access, reusable design/test procedures, and structured onboarding, forcing avoidable rework. Many teams lack consistent access to aerospace standards, reusable design and testing procedures, and laboratory facilities. The APTAS project at Luleå University of Technology found that without clear guidance on adapting international standards to local contexts, teams often repeat avoidable mistakes, degrading reliability and scheduling [9]. Regulatory requirements add another layer; licensing, export controls, and debris mitigation are frequently underestimated in early planning. Programs such as ESA's FYS emphasize starting frequency coordination and compliance work early to avoid costly delays or scope changes [22]. In short, mission success hinges less on a single launch than on knowledge continuity and scalable team practice themes that recur across the project lifecycle.

1.3 Educational and Workforce Development through CubeSat Missions

CubeSat missions provide a low-cost capacity-building platform that enhances workforce readiness and supports a smoother transition for undergraduate students into professional roles. CubeSats are intricate systems that involve direct engagement in disciplines such as engineering, physics, communications, management, and policy, providing a multidisciplinary experience that fosters collaborative systems thinking and technical teamwork skills. Engaging in CubeSat development offers a practical, hands-on learning environment that has been linked to measurable academic benefits. Active learning experiences of this kind can lead to roughly a 6% improvement in examination scores and lower the likelihood of course failure when compared to conventional lecture-based instruction [23]. National programs facilitate such learning for undergraduate students seen through *KiboCUBE*, FYS, and more that allow them to participate in CubeSat projects as well as creating capacity through collaborative efforts with sponsors, other universities, and international collaborators. Many of these initiatives align with the long-term educational goals for capacity building in basic space technologies set by UNOOSA. For example, the well-established BIRDS program empowers students from emerging nations, including Ghana, Mongolia, and Nigeria, by enabling them to participate in the entire lifecycle of a CubeSat mission and launch their country's first satellite [24]. These programs offer an affordable, low-risk pathway for non-space-faring nations to successfully develop their first CubeSats and cultivate experienced local talent capable of sustaining national space programs. Beyond technical capacity building, national initiatives also focus on increasing the participation of underrepresented students and minority-serving institutions to ensure a diverse and inclusive space sector [13].

1.4 Lifecycle of a Student-led CubeSat Initiative

Student CubeSat projects typically span three to five years, but their pacing is governed by semesters and cohort turnover. During the concept and proposal phase teams conduct feasibility studies, wherein students learn to define achievable objectives within resource constraints [12, 25]. Subsequently, during the design phase, students begin developing subsystem architectures and payload requirements under faculty or industry mentorship. NASA's *CubeSat Launch Initiative* (CSLI) describes design cycles as 1–6 months, reflecting expectations for relatively mature proposals [12]. By contrast, case studies such as Hestad et al. (2023) demonstrate that in student-led programs, this stage may extend to 1–2 years due to steep learning curves, cohort turnover, and the integration of coursework into project milestones [9]. Beyond its training in systems engineering, this stage provides training in documentation, which are critical skills for ensuring continuity across graduating cohorts [9]. Payload development usually has the most direct student contributions, requiring the design of instruments or experiments to balance mass, power, volume, and data constraints. This process builds interdisciplinary collaboration, communication skills, and experience in design reviews [23]. Early regulatory planning is vital to mission success; NASA's CSLI advises submitting the IARU coordination requests 10 months prior to integration into the launch vehicle, while amateur bands must coordinate through the IARU Satellite Frequency Coordination Panel, which meets every two to three weeks [26, 27]. The environmental testing and integration should take up the majority of the schedule, as vibration, thermal-vacuum, and EMC tests often reveal anomalies, making test campaigns and iterative development crucial aspects of a CubeSat mission [28]. Finally, during the launch and operation phase, students gain experience in telemetry and data analysis and can hand over valuable skills to younger cohorts, embedding knowledge transfer into the mission lifecycle [10]. Each stage thus functions as both a technical and capacity-building milestone, producing graduates who are well-trained in the complexities of real-world space systems.

1.5 Global Impact and Alignment with UN Sustainable Development Goals

By giving students hands-on experience in aerospace design, testing, and operations, educational CubeSat programs directly advance SDG 8 by creating skilled talent pipelines for high-value technology sectors [29]. National policies such as Canada's Space Strategy and the African Union's Space Strategy recognize small satellites as catalysts for resilient, collaborative innovation systems, as per SDG 17 [30, 31]. UNOOSA's Space2030 Agenda and Access to Space for All initiatives position space education as a means to reduce inequality, especially for low- and middle-income nations without domestic launch capabilities, in direct support of SDG 10 [20, 29]. For instance, the Joint Global Multi-Nation Birds Project has enabled universities in underserved countries to build and operate their first satellites. Expanding such access is both an economic priority and a matter of global fairness. To meet these global targets, it is essential to compare how national CubeSat programs deliver on the SDGs in practice, identifying structures that most effectively turn policy into measurable educational, technological, and socioeconomic gains.

1.6 Rationale for This Study and Need for Comparative Insight

This study addresses a central question in CubeSat program design: what consistently works across national initiatives to ensure not only mission success, but also long-term capacity-building and workforce development. While numerous countries have launched university CubeSat programs, there is limited comparative research evaluating which structural and institutional features contribute most effectively to sustained outcomes.

A comparative approach is necessary to identify which elements are transferable across contexts and which are specific to national conditions. Such an approach also enables the evaluation of how program maturity, institutional support, and resource availability influence outcomes. In doing so, this study moves beyond isolated success stories to develop a more comprehensive understanding of effective program design.

To support this analysis, the study focuses on three core analytical pillars. The first is knowledge transfer, which refers to the processes through which technical, organizational, and experiential knowledge is retained, documented, and shared between project cycles. The second is technical infrastructure, which encompasses both physical infrastructure, such as integration and testing facilities, and non-physical infrastructure, such as software tools and institutional support systems. The third pillar is funding models, which include the structure, sources, and timing of financial support available to university teams.

By examining knowledge transfer, technical infrastructure, and funding models across well-established, newer, and emerging national programs, this study clarifies which program features most effectively contribute to mission success, long-term skill development, and sustainable program growth. These three analytical pillars provide a focused lens for identifying transferable strategies while recognizing the importance of local context. In doing so, the study supports the design of national CubeSat initiatives that promote equitable access to space, strengthen educational outcomes, and build lasting capacity within the global space ecosystem.

2. Methodology

The methodology is outlined in detail here to ensure transparency and provide a clear point of reference for replication and future comparative studies.

2.1 Data Collection and Outreach Procedure

Participants were selected through purposive sampling and included former and current undergraduate or graduate students, as well as leaders of predominantly undergraduate CubeSat teams across diverse regions, institutional contexts, and levels of national program involvement. All participants were above 18 years of age, had the capacity to provide informed consent, and held an active or former role within their CubeSat team. This eligibility served as the baseline criteria and was complemented by a database in which information on prospective teams was compiled and reviewed for relevance. For each invited participant, a rationale was established based on their role and contributions within the CubeSat team, their affiliation with an academic institution or national program, and the scope of their team's activities as documented through registries, conference proceedings, organizational websites, or professional networks. Additional verification was supported by publicly available information such as team websites, press releases, or LinkedIn profiles, ensuring that all participants were directly engaged in their CubeSat initiative.

Each identified team was contacted through email, LinkedIn, or university website forums and received a personalized invitation along with documentation to ensure that participation was fully informed. Participants were provided with: an abstract of the paper, which introduced the research idea, outlined the objectives, and described the expected outcomes of the study; a Participant Information Statement, which detailed the study purpose, the voluntary nature of involvement, potential risks and benefits, confidentiality, and data storage procedures; and a Consent Form, which confirmed that participants understood their rights and agreed to take part in the survey, with an optional item to participate in a follow-up interview, and included contact details of the research leads for any inquiries or concerns.

2.2 Procedure of Surveys and Interviews

Data collection was conducted in two sequential stages designed to combine broad coverage with detailed, context-specific insights. The first stage involved an online survey administered through Google Forms. Before receiving access to the survey, participants were required to return a signed consent form via email, which confirmed that they understood their rights and agreed to participate. This step ensured that participation in both stages remained voluntary and fully informed.

The second stage comprised semi-structured interviews with participants who had consented to further contact and whose survey responses contained anomalies, unexpected findings, or particularly thought-provoking perspectives. These interviews were conducted over Zoom, typically lasting thirty to forty-five minutes. Each session was led by a trained co-investigator who conducted background research by reviewing the participant's survey responses in detail prior to the interview. This preparation enabled the interviewer to design tailored, open-ended questions directly linked to the participant's prior input.

Interviews followed a standardized protocol. Each began with an unrecorded introduction in which the study was explained, consent was revisited, and the structure and expected duration were outlined. Once recording began, participants were reminded that they could indicate "off the record" at any point. With permission, sessions were recorded and auto-transcribed, allowing the interviewer to remain engaged while ensuring accuracy. At the conclusion, the co-investigator summarized the discussion, expressed gratitude, and explained next steps, including transcript review and amendment opportunities.

We reached out to 120 participants involved in undergraduate-level CubeSat initiatives across national and international programs. Of these, 19 completed the survey, and 4 were subsequently interviewed in greater depth due to the distinctiveness of their responses. Participants self-classified their teams into three categories of national program maturity: **Emerging** (early-stage or pilot programs in nations just beginning CubeSat development), **New** (recent initiatives with limited cohorts, such as CSA's CCP), and **Established** (long-running programs with consistent support and multiple launch cycles, such as NASA's CSLI or ESA's FYS), guided by these explicit definitions and examples provided in the survey. The final distribution included 5 Established, 7 New, and 7 Emerging teams. In addition to program maturity, the survey captured a geographically diverse set of responses. A total of thirteen regions were represented, spanning from Canada and the United States to Portugal, Saudi Arabia, and beyond, covering four continents (Asia, Europe, North America, and Oceania). This distribution ensured that the study reflected a wide range of institutional and regional contexts. This methodological design not only ensured rigor and comparability but also aligned with broader international priorities, particularly the SDGs on Decent Work and Economic Growth (SDG 8), Reduced Inequalities (SDG 10), and Partnerships for the Goals (SDG 17). By foregrounding student experiences, institutional contexts, and cross-regional collaboration, the study contributes to understanding how CubeSat programs serve as pathways to workforce development, greater equity in space access, and international capacity building.

2.3 Question Design and Development

Survey questions were developed through an iterative process informed by a review of global CubeSat literature and by drawing on validated approaches to educational program evaluation, particularly the Undergraduate Research Student Self-Assessment (URSSA) framework [32]. URSSA was selected because of its emphasis on capturing student experiences, including skill development, knowledge transfer, and career impacts, making it especially relevant to the context of undergraduate-led CubeSat programs. The aim was to capture both measurable trends and nuanced experiences, enabling meaningful comparisons across regions. Questions reflected the study's guiding objectives: knowledge transfer, funding and resource challenges, project management practices, outreach, and the influence of CubeSat participation on educational and career trajectories.

The final survey contained 54 questions organized into sections aligned with these objectives. Specifically, the instrument consisted of 6 multiple-choice items, 32 Likert-scale items, 2 "select all that apply" items, and the remainder open-ended prompts, including questions capturing participant background information. This distribution provided a balance of structured comparability with opportunities for elaboration. The language of each item was refined to avoid leading phrasing and remain accessible to participants from diverse cultural and educational contexts. All survey questions were reviewed and verified by the University of Toronto Research Ethics Board for neutrality, clarity, and compliance with ethical standards. The design process emphasized precision and fairness, ensuring that responses reflected the participants' perspectives rather than researcher expectations.

Interview protocols were constructed to build directly on survey findings. Each participant's responses were reviewed in advance by a trained co-investigator, who identified anomalies or particularly rich commentary. Semi-structured guides were then tailored to these focal points. While anchored by a set of core themes, the guides remained flexible, allowing participants to expand on reasoning, clarify ambiguities, and provide concrete examples.

Survey and interview data were analyzed using a combination of statistical and qualitative methods. Quantitative responses were examined using non-parametric tests, including the Kruskal–Wallis test with Bonferroni corrections for post-hoc comparisons, while qualitative data from open-ended responses and interview transcripts were analyzed through thematic coding and comparative analysis. This mixed-methods approach enabled both statistical validation of observed patterns and deeper interpretive insights into the lived experiences of CubeSat teams.

This dual approach ensured that the survey provided broad, structured coverage, while interviews generated deeper, context-specific insights that enriched and validated the quantitative findings.

2.4 Ethics and Participant Protection

Although no physical, psychological, or legal risks were anticipated given the voluntary and noninvasive nature of the study, deliberate safeguards were embedded in the research design to ensure participant comfort and protection. Before completing the survey, each participant received a consent form and an information sheet outlining the objectives of the study, the scope of participation, and their rights as contributors. These rights included the freedom to decline any question, withdraw from the study at any time without penalty, and request clarification whenever necessary. They were also reiterated at the beginning of every interview to reinforce transparency and understanding.

To minimize social risks that could arise from participants sharing personal or institutional experiences, all data were anonymized and only aggregate findings were reported. Participants were also provided with copies of their survey and interview transcripts and were explicitly invited to redact or amend any content they did not wish to include in the analysis. By granting participants meaningful control over the use of their data, the study minimized the possibility of unintended disclosure while strengthening trust and openness between researchers and contributors.

The study was reviewed and approved by the Research Ethics Board at the University of Toronto, ensuring that all procedures met established international standards for informed consent, confidentiality, and participant welfare.

Taken together, these measures ensured that participation was voluntary, respectful, and protective of individual autonomy throughout the research process. Participants could therefore engage candidly and meaningfully, confident that their perspectives would be handled with integrity.

3. Theory and calculation

3.1 Ordinal Analysis Theory

This section details the rationale and statistical procedures used to analyze ordinal responses in our survey. We aimed to determine whether self-reported outcomes differed across CubeSat program categories—Emerging, New, and Established—using methods appropriate for ordinal data. These tests were chosen to align with the nature of Likert responses and our sample characteristics.

3.1.1 Why use Ordinal Tests

Our survey employed 5-point Likert-style items to capture constructs such as funding, training, collaboration, and institutional engagement. These responses yield ordinal—not interval—data. As emphasized in the literature, "parametric statistics should not be used with ordinal data, especially for small samples" [33]. Treating ordinal responses as continuous risks violating assumptions about spacing and distribution [34]. Non-parametric tests, by contrast, do not assume normality or equal intervals and are therefore well-suited to survey evaluations in space program contexts where sample sizes are modest and category counts are imbalanced.

3.1.2 Kruskal–Wallis H Test

To test for statistically significant differences in outcomes across the three program types, we applied the Kruskal–Wallis H test. This test is a rank-based alternative to one-way ANOVA and is appropriate for comparing more than two independent groups on an ordinal variable [35, 36]. It does not assume normal distributions or equal group variances.

The Kruskal–Wallis statistic is calculated as:

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(n+1) \qquad [1]$$

where:

- n = total number of observations,
- k = number of groups,
- n_i = number of observations in group i,
- R_i = sum of ranks in group i.

The H statistic measures the extent to which the distributions of ranks differ between groups. A larger H value indicates greater differences between group medians, relative to the variation within groups. Under the null hypothesis that all groups are drawn from the same population (i.e., their medians are equal), the H statistic approximately follows a chi-squared distribution with $k-1$ degrees of freedom.

3.1.3 Post Hoc Comparisons

For survey items with statistically significant omnibus test results ($p < 0.05$), we conducted post hoc pairwise comparisons using Dunn's test with Bonferroni correction. The Dunn test computes a standardized z-score for the difference in mean ranks between groups i and j:

$$z_{ij} = \frac{\bar{R}_i - \bar{R}_j}{\sqrt{\frac{N(N+1)}{12}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}} \qquad [2]$$

where N is the total number of observations.

To control for the family-wise error rate across multiple comparisons, raw p-values were adjusted using the Bonferroni method:

$$p_{\text{adjusted}} = \min(1, m \cdot p_{\text{raw}}) \qquad [3]$$

where m is the number of comparisons.

This allowed us to identify which pairs (e.g., Established vs. Emerging) drove the observed differences, while minimizing false positives. In borderline cases (e.g., $p = 0.0697$), we interpreted the trend directionally rather than drawing firm conclusions, consistent with the exploratory nature of our study.

3.1.4 Methodological Justification

This analytic approach was selected to match the data characteristics and research aims. Specifically:

1. **Ordinal measurement:** Likert-type items reflect subjective judgments, which are ordered but not necessarily equidistant [33, 34].
2. **Distributional concerns:** Program-level data may be skewed or contain outliers. Kruskal–Wallis is robust to these issues [35].
3. **Comparative interpretation:** Non-parametric tests allow for meaningful intergroup comparisons even when group sizes differ or variances are unequal [36].

This combination of Kruskal–Wallis and Dunn post hoc testing allowed us to test hypotheses about maturity-related differences in program outcomes without violating core statistical assumptions. We present the resulting test statistics and significance levels in Section 4, along with post hoc pairwise comparisons where applicable.

4. Results

We reached out to over 120 CubeSat teams, of which a total of 19 completed the survey. Four of these participants also engaged in follow-up interviews. The dataset included Likert-scale items, multiple-choice and select-all responses, as well as open-ended questions. Given the modest sample size, statistical power was limited, and the results are best understood as exploratory indicators of patterns and experiences rather than definitive conclusions. The strength of the study lies in the combination of quantitative measures, which provide structured points of comparison, and qualitative insights, which highlight the institutional and cultural contexts behind recurring themes.

4.1 Ordinal Analysis Results

From the 32 Likert-scale questions in the survey, we conducted a detailed analysis of 10 items to assess whether participants' reported capacity-building outcomes differed across CubeSat programs of varying maturity. These 10 were selected for their statistical significance or thematic relevance, capturing outcomes related to funding, career alignment, infrastructure, knowledge transfer, and collaboration. Programs were grouped into three categories—Emerging, New, and Established—based on self-reported classifications guided by explicit definitions and examples provided in the survey.

Although only a subset of questions reached statistical significance, the inclusion of non-significant but thematically relevant items provides important context. These measures exhibit where outcomes were broadly similar across program types, such as collaboration and infrastructure, indicating that in these areas participants reported comparable experiences regardless of program maturity (evidence of convergence). While the significant items highlight areas where program maturity shaped outcomes, the non-significant items illustrate domains of shared experience across all program types. Presenting these items alongside the significant results ensures that the quantitative analysis reflects the broader landscape of CubeSat capacity-building, while leaving detailed interpretation to the discussion section. To account for the ordinal nature of the data, we applied the Kruskal–Wallis H test to each question. For items with statistically significant omnibus results ($p < 0.05$), we conducted Dunn's post hoc pairwise comparisons using Bonferroni correction.

4.1.1 Summary of Key Results

Two survey items demonstrated statistically significant differences across program categories, while the others indicated broadly similar outcomes across programs. Ten items were selected for presentation based on their statistical relevance or thematic alignment with the study's analytical pillars.

Table 1. Kruskal–Wallis H test results for selected ordinal items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
Did the CubeSat program provide financial support/funding access?	9.371	**0.009**
Did participation influence your career goals or interests?	7.327	**0.026**
Did space agency/regulators provide licensing guidance?	5.886	0.053
How difficult was obtaining key licenses (launch, spectrum, export)?	5.482	0.065
Did the project help you gain practical job/academic skills?	4.694	0.096
Did participation improve your team's long-term financial capacity?	4.395	0.111
How would you rate your team's STEM skill growth (coding, systems, orbital mechanics)?	4.041	0.133
Did national policies need to be adapted/created for the mission?	3.409	0.182
Should teams allocate time/resources for outreach?	3.343	0.188
Have skills/knowledge from your CubeSat project been useful beyond the project?	3.334	0.189

Across the 10 items presented, two reached statistical significance: national financial support (Q_{finance}) and career goal alignment (Q_{career}). 8 additional questions, while not significant, are included for their relevance to infrastructure, knowledge transfer, and collaboration themes. These patterns provide a quantitative baseline for the subsequent post hoc analyses and qualitative interpretation.

4.1.2 Post Hoc Comparisons

Table 2. Presents Bonferroni-adjusted p-values from Dunn's test for pairwise comparisons across program maturity categories on perceived access to national financial support (Q_{finance}) . A significant difference was observed between Established and New programs ($p = 0.0135$), with Established teams reporting greater access to support, ($Median_{\text{finance\_new}} > Median_{\text{finance\_established}}$). No significant differences were detected between Emerging and Established programs ($p = 1.0000$) or between Emerging and New programs ($p = 0.0697$).

	Emerging	**New**	**Established**
Emerging	1.0000	0.0697	1.0000
New	0.0697	1.0000	**0.0135**
Established	1.0000	**0.0135**	1.0000

Table 3. Presents Bonferroni-adjusted p-values from Dunn's test on the perceived influence of CubeSat participation on career goals (Q_{career}). A significant difference was found between Emerging and New programs ($p = 0.0265$), with New programs reporting a lower median influence score than Emerging programs ($Median_{\text{career\_new}} < Median_{\text{career\_emerging}}$). No significant differences were observed between Established programs and either Emerging or New programs.

	Emerging	**New**	**Established**
Emerging	1.0000	**0.0265**	0.4166
New	**0.0265**	1.0000	0.4166
Established	0.4166	0.4166	1.0000

4.1.3 Full Ordinal Results

The complete set of Kruskal–Wallis H test results for all 32 ordinal Likert-style items is provided in **Appendix A**, with interpretation of these findings presented in Section 5 (Discussion).

4.2 Open-Ended Analysis

The open-ended survey responses reveal important descriptive patterns in how CubeSat programs at different stages of maturity prioritize outreach, skills, collaboration, and funding. These trends highlight how program maturity shapes not only resource challenges but also strategic priorities, offering insights that complement the quantitative findings.

4.2.1 Outreach Activities

Distribution of reported outreach activities by CubeSat program maturity category. Emerging and New programs emphasized school-based outreach and STEM events, while Established programs were unique in reporting public events, suggesting broader community engagement.

Table 4. Engagement types reported by CubeSat teams across program maturity levels. Sample sizes: Emerging ($n = 6$), New ($n = 6$), Established ($n = 5$). Results demonstrate that media outreach and school visits were the most frequently reported engagement strategies, while environmental agency involvement was rare.

Engagement Type / Audience	Emerg.	New	Estab.	Total
Media / Public outreach	4	3	3	10
Workshops / STEM fairs	1	0	1	2
Young students (school visits)	3	2	3	8
Scientific community	1	0	3	4
Environmental agencies	0	0	1	1
Universities	2	2	1	5
International community	3	0	1	4
Total	15	8	11	34

4.2.2 Skills Development

Table 5. Skill development areas reported by CubeSat teams across program maturity levels. Sample sizes: Emerging ($n = 6$), New ($n = 6$), Established ($n = 5$). Project management and problem solving were most frequently cited, while design and operations were less commonly identified.

Skill Type	Emerg.	New	Estab.	Total
Systems engineering	1	1	4	6
Project management	0	4	4	8
Operations	0	0	2	2
Programming	3	2	1	6
Problem solving	3	5	1	9
Design (technical)	1	1	0	2
Total	8	13	12	33

4.2.3 Collaboration Patterns

Table 6. Collaboration patterns reported by CubeSat teams across program maturity levels. Sample sizes: Emerging ($n = 6$), New ($n = 7$), Established ($n = 5$). Results indicate that universities and national space agencies were the most common collaborators, while partnerships with government agencies and industry were less frequently reported. Public contributions, including crowdfunding, donations, and student levies, were also noted by some teams.

Funding Source	Emerg.	New	Estab.	Total
Universities / Academic institutions	4	2	4	10
National space agencies	1	7	1	9
Government agencies	2	0	0	2
Industry partnerships	0	2	2	4
Public contributions[a]	0	2	2	4
Total	7	13	9	29

[a] *Includes crowdfunding, donations, and student levies.*

4.2.4 Support

Table 7. Support types identified by CubeSat teams as most beneficial for STEM skill development. Sample sizes: Emerging ($n = 6$), New ($n = 7$), Established ($n = 5$). Workshops and mentorship were most frequently cited, while targeted funding opportunities were less commonly reported.

Support Type	Emerg.	New	Estab.	Total
Curriculum integration	1	1	1	3
Multidisciplinary collaboration	2	0	2	4
Targeted funding opportunities	0	1	1	2
Workshops and work experience	3	3	1	7
Support and mentorship	1	4	0	5
Total	7	9	5	21

4.3 Nominal Data Analysis

This section presents the results of the nominal analysis of survey responses. To interpret the findings, a cross-sectional study was conducted, with program categories (emerging, newer, and well-established) represented on the rows, and the survey questions along with their responses displayed on columns. This structure enables clear comparisons across program types, highlighting patterns and differences in responses. The multiple-choice data are further organized into four key categories: funding and budgeting, Policy and Licensing Regulations, knowledge transfer, and infrastructure and testing. These data are presented directly through visual analyses, allowing for a structured comparison of responses across program categories. The study reports frequency distributions of responses, broken down by program type, ensuring transparent interpretation of the nominal data.

4.3.1 Funding and Budgeting

Survey results indicate that funding shortages were not a significant limitation, with 79% respondents reporting no delays caused by insufficient funding (Fig. 7: Appendix A). Although financial resources themselves were not identified as a barrier, the findings underscore the importance of financial management skills in ensuring effective budgeting and resource allocation. A significant proportion of participants, particularly those from well-established teams, reported receiving little or no support in developing these skills before project implementation.

4.3.2 Policy and Licensing Regulations

Policy and Licensing Regulations Policy and licensing requirements were consistently identified as one of the most significant challenges for student teams, mainly due to the absence of clear guidance or institutional support. This was assessed by reporting the frequency of delays attributed to policy challenges, broken down by program type. Although some well-established programs reported access to structured policies and licensing instructions, emerging and newer programs frequently lacked such frameworks.

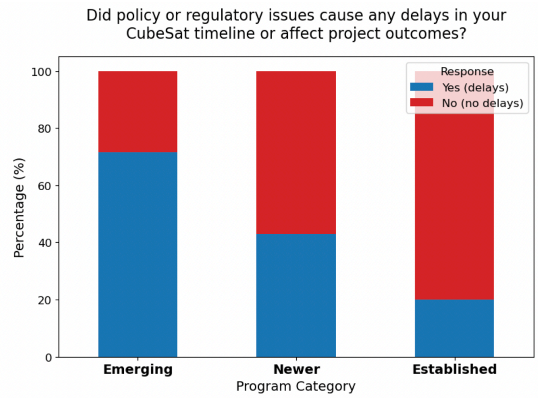

Fig. 1. Reflected in the survey results, 71.43% of emerging programs and 42.86% of newer programs reported delays due to policy-related obstacles. The most frequently cited regulatory barriers included radio frequency allocation, warranty coverage, spectrum access, and radio licensing, all of which were reported as major contributors to project delays.

4.3.3 Knowledge Transfer and Institutional Memory

Although outreach was not an explicit requirement or goal for nearly half of the surveyed projects, the majority of CubeSat initiatives demonstrated substantial efforts in this area. This was measured by the proportion of teams reporting outreach activities as part of the survey. Specifically, 94.7% of projects reported engaging in outreach activities, which included campus presentations, conference participation, media coverage, and involvement in broader STEM events. The data further highlight strong engagement with younger student populations, with 84.21% of respondents indicating targeted outreach to this group.

4.3.4 Infrastructure and Testing

Infrastructure availability and testing capacity emerged as critical determinants of project outcomes. Survey data demonstrates that 36.8% of respondents experienced post-launch issues; this figure increased substantially among newer programs, where 71.4% teams reported post-launch complications, as shown in Figure 1. Responses were analyzed by tallying the types of tests performed and the reported issues, disaggregated by program type. The most common tests performed were vibration testing, followed by thermal, structural, integration, radio frequency communication, and power system testing. More than 79% of teams reported conducting these types of testing. Well-established programs reported the broadest range of testing, reflecting stronger access to institutional infrastructure. Notably, 66.7% of respondents indicated that testing processes revealed key issues (Figure 5). Furthermore, emerging programs demonstrated the highest reliance on external or shared facilities, with 85.7% of respondents reporting significant dependence on such resources. Similarly, 71.4% of newer programs indicated frequent use of external facilities.

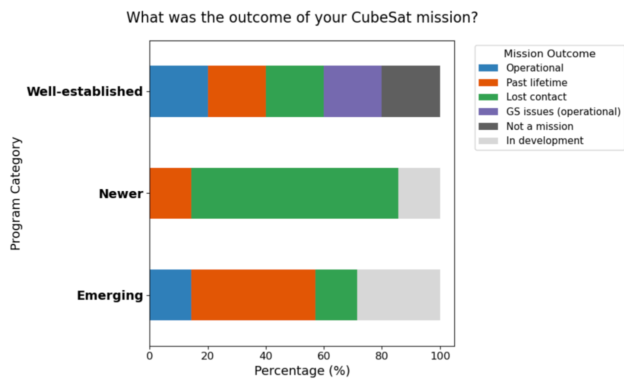

Fig. 2. Outcomes of CubeSat missions across program maturity levels. Well-established teams most frequently reported operational or past-lifetime missions, newer programs had a mix of completed and ongoing missions, and emerging teams reported a higher proportion of projects still in development.

4.3.5 Collaboration and Outreach

International collaboration was identified as a notable strength across CubeSat programs. Overall, 47.4% of survey respondents reported partnerships with international collaborators. Emerging programs demonstrated the highest participation rates in such collaborations (71.43%), followed by newer programs (42.9%), as shown in Figure 3.

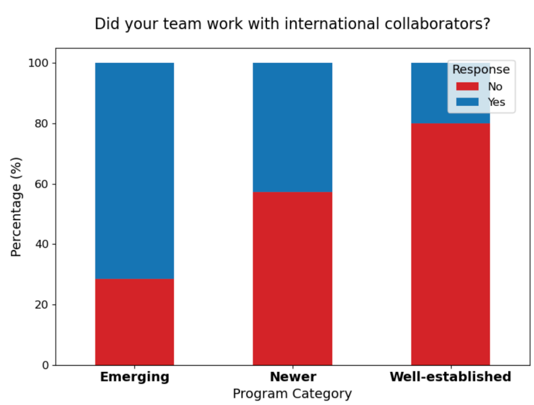

Fig. 3. Survey responses on international collaboration by CubeSat program category. Emerging programs showed the highest collaboration rates, followed by newer and well-established teams.

5. Discussion

5.1 Financial Support

While most CubeSat teams do not perceive funding shortages as a barrier, our findings suggest that the real challenge lies in financial literacy and planning. Funds may be available which is a common trend across all maturity levels, but mismanagement, underbudgeting, and lack of training consistently undermine project sustainability. As shown in Figure 1, more than 79 percent of teams indicated that they did not experience significant delays due to funding shortages. However, the Likert-scale results in Table 1 provide a more detailed picture. The item "To what extent did the national CubeSat program provide financial support or help your team access funding?" yielded a p-value below 0.05, indicating significant differences among categories.

Post-hoc results Table 2 suggest that while all programs receive some form of support, the way funding is managed differs with emerging teams receiving more support than established. Emerging programs often benefit from national or university backing, sometimes due to the novelty of their projects. In a personal interview with Dr. Mojammel Haque Shourobh from a Bangladesh CubeSat team called BRAC Onnesha at BRAC University, it was noted that because the project was novel, the university directly covered the costs. By contrast, established programs are expected to manage costs through their institutions or external sources regardless of novelty. NASA's CSLI illustrates this pattern, as it provides only launch costs while leaving operations and development to be covered by universities otherwise the project will risk losing the opportunity to launch [5]. As the number of CSLI projects has grown, competition for launch opportunities has increased, placing greater pressure on established teams to be creative in securing additional resources. This challenge is compounded by our survey results (Table 8), where 80 percent of teams reported receiving no support in developing financial management skills, a pattern consistent across all maturity levels.

This aligns with broader findings that financial literacy and management are rarely foregrounded in CubeSat education. Effective budget and time planning requires early consideration of expenses such as labs, testing equipment, and launch costs, as well as a margin for unforeseen expenses [9]. There is an emphasis that funding applications require substantial effort, and that knowledge gaps in management often extend and negatively impact project phases beyond initial expectations. This is further supported by a personal interview with a CubeSat team member at Concordia University, SC-ODIN, who explained that although funds were available, miscommunication in the budget plan and underbudgeting of certain aspects such as the ground station led to negative impacts on the project. Taken together, these results suggest that while teams may not perceive funding itself as a barrier, the lack of structured support for financial literacy and planning has a direct impact on project timelines and sustainability. Addressing these gaps aligns with the objectives of SDG 8, which emphasizes strengthening financial management capacity as part of promoting sustainable innovation and economic growth, thereby ensuring the viability of future CubeSat projects.

5.2 Infrastructure and Resources

Access to infrastructure is a critical enabler across design, verification, and operations; without it, teams face delays, higher costs, and dependence on external providers. Survey items on access before (p = 0.59) and during projects (p = 0.63) demonstrated no significant differences across maturity levels, indicating that infrastructure is a systemic bottleneck rather than a stage-specific constraint. Here, infrastructure refers to clean-rooms, environmental testing laboratories, integration spaces, and ground stations.

Nominal responses indicated that many teams relied on external facilities especially for testing and ground segment needs often through shared or rented arrangements. Likert ratings also showed a noticeable increase in perceived improvements from before to during participation in CubeSat programs, including in countries with established space heritage (e.g., the United States and Japan). This pattern may reflect that CubeSat development remains comparatively nascent within larger space ecosystems, or that rapid sectoral growth has intensified demand for limited resources.

Interviews reinforced these access constraints. A member from Romania's ROSPIN-SAT-1 team, emphasized the role of institutional support in bridging gaps: "Professors allowed us to use their electronic or structural laboratories and conference rooms for meetings." By contrast, a member of Concordia University's SC-ODIN team described bureaucratic hurdles: "Concordia facilities existed, but getting approval was slow, and student groups weren't prioritized." Case examples further illustrate the issue: RADSAT-SK "had to create their own clean-room for testing purposes" [37], while KAUSTSat depended on private partnerships with Spire Global [38]. Even where established frameworks exist such as ESA's FYS providing shared facilities [22] survey scores suggest persistent barriers. Post-launch issues were more frequently reported by newer and emerging programs, consistent with the idea that limited infrastructure access undermines risk management.

Overall, these findings indicate that infrastructure challenges are not resolved by maturity but remain a shared vulnerability across CubeSat ecosystems. The absence or inaccessibility of facilities restricts innovation and reinforces inequality in participation, ultimately constraining contributions toward SDG 8's objectives of productive employment and sustainable economic growth.

5.3 Policy and Regulation

Results depicted that one of the greatest barriers to CubeSat programs is policy and regulation, with a trend seen across the maturity gradient of program levels. Regulation here refers to the legal and procedural environment around CubeSats, including licensing, spectrum allocation, export control, and national oversight.

In Table 10, 47.37% of all team members surveyed reported policy-related issues. Out of this, 66.67% surveyees highlighted frequency allocation delays, while others noted the lack of clarity in their nation's licensing frameworks. Existing literature agrees with this finding, noting that licensing is a lengthy process, where just registering a CubeSat's radiofrequency with the International Telecommunication Union (ITU) can take up to 2 years [39].

However, approval times are not the only difficulty in regulatory processes: lack of updated documents and unclear regulatory environments also result in delays. For example, in a personal interview with a team member of SC-ODIN revealed "the Canadian government's regulations weren't straightforward" for amateur radio licensing, and they had to refine and resubmit applications to get approval due to not being familiar with the licensing procedure. Likewise, a team member of ROSPIN-SAT-1 from Romania described how they had to rely on outdated reference books to secure amateur radio licenses. These similarities across programs illustrate that the barrier of regulatory delays and ambiguity is prevalent across programs of all levels of maturity. The ordinal analysis results, seen on Table 10, on policy clarity strengthened this finding. There was no statistically significant difference between program maturities on the policy-focused Likert questions, such as Q3 having a p-value of 0.0645 depicting that all programs found it difficult to obtain licenses. Hence, in capacity-building terms, even technically capable teams cannot progress without predictable, transparent, and timely legal frameworks. The persistence of regulatory barriers underscores that national governments play a decisive role in enabling or limiting participation in, and thus causing inequitable access to, the space sector.

While this indicates no relation between regulation as a barrier and program maturity, nominal analysis demonstrated a different trend: as program maturity increased, fewer teams faced policy-related delays 1. Some emerging teams, like KAUSTSat from Saudi Arabia, had started before their national space agency had been established while others, such as BRAC Onnesha from Bangladesh, had little support from their national CubeSat programs. Personal interviews demonstrated that KAUST-Sat depended on UK's Spire Global for licensing processes, while BRAC Onnesha had to navigate the complex regulatory system of the Bangladeshi space authority Space Research and Remote Sensing Organization (SPARSO) alone. Meanwhile, teams in established programs like CSLI or FYS generally operate within more predictable and developed legal frameworks, sometimes benefiting from step-by-step guidelines, institutional memory or longstanding agreements with national authorities [12]. Overall, though policy-related delays are experienced by many teams, maturity can partially dissolve regulatory barriers. Addressing this systemic divide connects directly to SDG 10, which calls for reducing structural inequalities, and demonstrates that equitable access to space requires more than technical training or financial resources.

Ultimately, regulatory hurdles may serve as hidden barriers that constrain participation in the global space sector. Seeing as this domain was somewhat differentiated across maturity levels in the results, guidance is crucial for navigating around legal frameworks to ensure more equitable access to CubeSat development for younger teams.

5.4 Career Goals and Workforce Development

CubeSat programs play a formative role in shaping student career trajectories. They are more than technical training exercises. They function as entry points into the space workforce, with their impact shaped by the maturity and institutional support of the program.

Survey results underscore this point. The item on career preparedness exhibited a statistically significant difference across maturity levels ($H = 6.47$, $p = 0.039$), with participants from established teams more likely to report that their CubeSat experience prepared them for careers in aerospace. In contrast, items measuring STEM skill growth ($p = 0.12$) and job readiness ($p = 0.13$) did not show significant differences (Appendix A), indicating that technical learning occurs across all program types. This indicates a critical distinction: while students gain skills regardless of program maturity, not all teams are equally positioned to convert those skills into workforce outcomes.

This gap is acknowledged in national program design. NASA's *CubeSat Launch Initiative* frames CubeSat engagement as a catalyst for career interest. As CSLI program executive Jeanie Hall explains, "Working with CubeSats is a way to get students interested in launching a career in the space industry…It's hands-on experience that enables students, teachers, faculty, and NASA to conduct scientific investigations and technology demonstrations" [40]. This perspective reinforces the idea that interest is the first step. However, our findings indicate that turning that interest into employment requires more than technical engagement. It depends on institutional structure, mentorship, and alignment with workforce pathways, which are more common among established teams.

Interview data illustrate how structural factors shape outcomes. A member from Romania's ROSPIN-SAT-1 team, explained that his interview at Deimos Space focused on "ESA report writing and documentation," and noted that around 20 teammates "now work in the space sector." Dr. Shourobh, from Bangladesh's BRAC Onnesha team, said CubeSat participation "shaped [his] industry intent" and enabled him to stay in-country while pursuing embedded systems. A member from Canada's SC-ODIN team, said "lots of our team members got internships at MDA in Montreal because of their CubeSat experience," and highlighted the importance of soft skills like communication and teamwork. These outcomes reflect the design goals of national programs. The Canadian Space Agency identifies workforce development as a primary aim of its CubeSat Project, preparing "Canada's next generation of space innovators" [6]. Interview responses suggest this goal is realized when technical training is paired with clear career pathways.

Open-ended survey responses support these findings. Emerging teams tended to highlight technical and problem-solving skill development, while more mature programs emphasized project management, communication, and soft skill acquisition (Table 5). Newer teams also more frequently reported needing external mentorship and legal guidance (Table 6), indicating that support structures are essential for translating experience into employment. This aligns with the European Space Agency's *Fly Your Satellite!* program, including lessons synthesized from the SmallSat community [22]. ESA's approach demonstrates how formal support mechanisms can help early-stage teams overcome institutional gaps and strengthen workforce outcomes.

In this context, CubeSat programs emerge not just as educational projects but as mechanisms for workforce integration. They support SDG 8 (Decent Work and Economic Growth) by creating employment pathways through hands-on training, and SDG 10 (Reduced Inequalities) by offering comparable technical experiences to students in both established and emerging programs. Although career outcomes vary, the consistency of skill acquisition across teams suggests that with targeted support, CubeSat programs can serve as scalable tools for equitable workforce development in the global space sector.

5.5 Knowledge Transfer and Continuity

The sustainability of CubeSat programs depends not only on technical execution but also on how effectively knowledge and skills are transferred across cohorts. Survey results confirm this as a systemic weakness: questions on institutional knowledge preservation (p = 0.28) and turnover management (p = 0.77) did not reach significance, indicating that continuity challenges affect teams across all maturity levels. As shown in Table 12, Likert-scale responses on knowledge transfer were low across the board, with open-ended responses describing a recurring "reinvention" effect where new cohorts repeated prior mistakes due to poor documentation.

Interview findings reinforced these survey patterns. A team member from SC-ODIN emphasized that "the best handovers happened when a replacement shadowed for six months," underscoring the effectiveness of mentorship in bridging turnover gaps. A member from Romania's ROSPIN-SAT-1 team noted, "Our knowledge transfer is not yet perfect; we achieve about 80% effectiveness in some areas… most effective approach has been organizing in person workshops," highlighting how face-to-face interactions and leadership roles help consolidate institutional memory. Dr. Shourobh described both technical improvements and broader advocacy as part of knowledge transfer: "Some of the software systems at the Space Agency have been improved… I introduced them to MATLAB for better simulations and research… Additionally, in collaboration with [the Bangladesh Telecommunication Regulatory Commission], we advocated for ham system licensing." Beyond national contributions, his team extended capacity building internationally: "From Bangladesh, we conducted workshops with Nigeria and Nepal... capacity building isn't just within our nation — it's also affecting surrounding countries." Similarly, the KAUSTSat team institutionalized outreach through national space camps and international conferences, though acknowledging that "the knowledge transfer was mainly theoretical."

Taken together, these results suggest that continuity is not maturity-dependent but a shared vulnerability across CubeSat ecosystems. Informal yet impactful practices like shadowing, workshops, outreach camps, technical advocacy, and regional mentoring demonstrate that student-driven mechanisms can effectively compensate for the absence of formal handover protocols. External literature reinforces this interpretation: ESA guidelines stress that "larger-scale team interactions and documentation of meeting minutes" are essential for mitigating turnover risks [22], while Hestad et al. [9] and Kim [17] similarly highlight mentorship and documentation as central to building lasting capacity.

This evidence points toward the need to institutionalize adaptable knowledge transfer mechanisms within CubeSat programs. By combining formal structures like documentation and mentorship frameworks with the flexibility of peer-driven approaches, teams can reduce reinvention effects, safeguard program sustainability, and contribute to broader capacity building directly supporting SDG 8's emphasis on stable institutions and sustainable growth.

5.6 Outreach and Collaborations

Nominal survey responses identified outreach and collaboration as critical dimensions for ensuring the sustainability and broader impact of CubeSat programs. Beyond the dissemination of project outcomes, outreach activities were found to foster public engagement with space research while simultaneously strengthening inter-cohort knowledge transfer and institutional memory. Interview findings suggested that outreach also functioned as both an educational tool and a form of professional development. A participant from Bangladesh described how, inspired by outreach models in Japan, he returned to his rural village to engage schoolchildren in water rocket construction: "They made their own versions and flew them... it was eye-opening to see how much they could learn through practice." This example illustrates how outreach can act as a vehicle for STEM education, community-building, and legacy creation both within academic institutions and in the wider public sphere. Similarly, a student from Concordia emphasized the professional value of outreach: "Outreach gives visibility, builds presentation skills, and fulfills the program's goal of growing Canada's space sector… great professional development."

Collaboration emerged as a fundamental mechanism for addressing resource constraints while enabling technical and knowledge exchange [22]. International partnerships frequently allowed Emerging CubeSat programs to access expertise, facilities, and networks that would otherwise have been unattainable. A participant from Bangladesh noted: "All test facilities regarding the satellite were in Japan... our lab capacity in Bangladesh is limited." Members of the KAUSTSat initiative echoed this reliance on external partnerships: "Spire Global handled the testing," and "licenses were handled by Spire Global in the UK."

Patterns in outreach and collaboration further revealed how maturity shapes dependency on external expertise. Newer programs leaned most heavily on mentorship and legal support, underscoring their reliance on outside partners during the growth phase. Romanian respondents pointed to the limits of institutional involvement: "Our university only provided the necessary signed paperwork for the *Design Booster* program and could not allocate funds or focus on our project," contrasting this with other European teams that received active faculty support and close mentoring. Dependency on outsourcing was also evident in Emerging contexts, with Syrian participants explaining: "Spire Global handled the testing." By comparison, Established programs reported far less mentorship, relying instead on institutionalized arrangements with agencies. One Canadian participant observed: "In CCP and CUBIX, launch contracts and costs are fully handled by the CSA… the CSA took care of negotiations, shipping, customs." These cases highlight UNOOSA's emphasis that sustained institutional experience is crucial for continuity in student-led programs [20].

This is built on nominal results with Figure 3 indicating that as programs advance along the maturity gradient, CubeSat teams report fewer international collaborators. This is due to emerging teams often relying on external partners for training, funding, and capacity-building, while mature programs tend to become more self-sufficient. Formal mentorship and structured training further reinforced these collaborations. A participant from Romania's ROSPIN-SAT-1 explained: "The Romanian Space Engineering company, whose team developed Romania's first CubeSat in 2012, has been mentoring us, providing valuable knowledge and access to equipment and laboratories." ESA support through the *Design Booster* program was described as particularly impactful, offering subsystem-specific training, access to technical documentation, and direct specialist feedback: "We also gained access to various ESA documents and research through their platforms and received direct feedback from their specialists during workshops." Similarly, ESA Academy workshops, such as the *2024 CubeSat Concurrent Engineering* Workshop, provided opportunities for around 50 students to gain expertise in areas including space communication, law, and cybersecurity.

Open-ended survey responses provided additional evidence of how collaboration patterns varied by program maturity (Table 6). While all teams reported receiving technical and testing support, Newer programs highlighted mentorship and legal support more often than other groups, suggesting a heightened need for structured external guidance as they expand. By contrast, Established programs reported less reliance on mentorship, reflecting greater internal self-sufficiency.

Only one program, EIRSAT-1, stood out for its extensive media presence and public communication efforts. This limited emphasis on formalized outreach across most teams points to an underexplored area of capacity building. Strengthening public-facing and cross-sector engagement aligns with Sustainable Development Goal 17, which emphasizes inclusive partnerships that mobilize knowledge, expertise, and resources across institutional and national boundaries. Taken together, outreach, collaboration, mentorship, and structured training collectively enhance program visibility, technical capability, and capacity-building in CubeSat initiatives.

6. Conclusions

This study examined educational CubeSat programs at varying maturity levels to identify which parameters most effectively support capacity-building and sustainable mission outcomes. Drawing on international responses from 19 teams across 13 regions, our findings show that program maturity alone does not explain differences in performance. Of the 32 Likert-scale items analyzed, only national financial support and career influence displayed statistical significance, while the other 30 revealed similar experiences across maturity groups. When combined with nominal indicators, open-ended responses, and personal interviews, these results suggest that the barriers shaping outcomes are cross-program rather than maturity-dependent, providing a more comprehensive picture of the challenges facing educational CubeSat initiatives.

A consistent set of barriers emerged across survey and interview data. Regulatory bottlenecks, particularly unclear licensing procedures and delayed frequency allocation processes, proved the most persistent constraint, limiting equitable access to space and reflecting broader structural inequalities addressed in SDG 10. Inadequate documentation, high turnover, and weak knowledge-transfer practices further impeded program continuity, underscoring the importance of sustained collaboration and partnerships emphasized in SDG 17. Financial barriers were less pressing, stemming less from limited funding and more from mismanagement and insufficient training, highlighting the need for financial literacy and sustainable practices in line with SDG 8.

While this study is limited by a relatively small sample size, it represents a novel first step in systematically examining educational CubeSat programs across multiple national initiatives and regions. By capturing perspectives from undergraduate-led teams in 13 regions, it begins to map barriers within a sector that is rapidly expanding but remains underexplored in the literature. Future research should increase the number of respondents to strengthen statistical power and ensure more balanced regional representation, as some categories in this study were dominated by a single country. A broader scope could also include longitudinal tracking to monitor turnover, the evolution of teams over successive cohorts, and challenges across different project phases. Integrating institutional and regulatory data would further complement self-reported experiences, while cross-national comparisons and in-depth case studies could highlight how policy environments and program structures shape outcomes. Additional work could also examine equity dimensions and the role of collaboration networks. Building on these directions, future studies could enable the creation of a clear framework of recommendations that guides emerging teams and informs national program design.

By prioritizing regulatory readiness, financial literacy, and robust knowledge transfer practices, all student CubeSat programs regardless of their maturity can achieve sustainable success while cultivating skilled workforces, reducing structural barriers to participation, and building international partnerships.

Acknowledgements

The authors thank Dr. Maurice Bitran, Munk School of Global Affairs and Public Policy, University of Toronto, for his support on the Research Ethics Board application and his advisement, which helped refine the research design and methodological approach. We also extend our gratitude to the professionals who generously contributed their time to participate in surveys and interviews, including members of CubeSat teams and other stakeholders, whose insights were invaluable to this study. No funding was received from the University of Toronto Aerospace Team (UTAT) or the University of Toronto to conduct this research. The authors declare no conflicts of interest.

Appendix A

Ordinal Analysis Results

This appendix provides the full results of the Kruskal–Wallis H tests conducted on the ordinal survey items analyzed in this study. Survey questions are grouped by thematic domain—Financial Support, Infrastructure and Resources, Policy and Regulation, Career Goals and Workforce Development, Knowledge Transfer and Continuity, and Outreach and Collaboration. Each table presents the full text of the item, the H statistic, and associated p-value, with statistically significant results ($p < 0.05$) **bolded**. These results supplement the discussion of capacity-building outcomes presented in Section 5.

Financial Support

Table 8. Kruskal–Wallis H test results for Financial Support-related items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
To what extent did the national CubeSat program provide financial support or help your team access funding? (Q4)	9.3709	**0.0092**
Did participation in the CubeSat program help improve your team or institution's long-term financial capacity for future missions? (Q5)	4.3948	0.1111

Infrastructure and Resources

Table 9. Kruskal–Wallis H test results for Infrastructure-related items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
Rate the adequacy of your software tools and IT systems during/after the CubeSat project (Q13)	2.6925	0.2602
Rate the adequacy of your software tools and IT systems before the CubeSat project (Q14)	2.2488	0.3248
Rate your team's access to physical infrastructure before the CubeSat project (Q20)	1.3124	0.5188
Rate your team's access to physical infrastructure during/after participating (Q21)	0.9428	0.6241
To what extent did the CubeSat program lead to lasting improvements in infrastructure at your institution or country? (Q24)	0.5261	0.7687

Policy & Regulation

Table 10. Kruskal–Wallis H test results for Policy & Regulation items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
Did your national agency or regulator provide guidance during licensing? (Q2)	5.8860	0.0527
How difficult was it to obtain licenses (e.g., launch, spectrum, export control)? (Q3)	5.4818	0.0645
To what extent did existing policies need to be adapted for your team to carry out the mission? (Q7)	3.4093	0.1818
How clear were CubeSat-related policies and regulations when your project began? (Q19)	1.4305	0.4891

Career Goals / Workforce Development

Table 11. Kruskal–Wallis H test results for Career Goals and Workforce Development items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
To what extent did the CubeSat project influence your career goals or interests? (Q1)	7.3268	**0.0256**
Did this project help you gain practical skills relevant to a job or academic opportunity? (Q4)	4.6945	0.0956
Rate your team's growth in STEM skills as a result of the CubeSat program (Q6)	4.0408	0.1326
Did the CubeSat help develop STEM skills that wouldn't have been developed otherwise? (Q17)	1.5662	0.4570
Were technical skills developed hands-on or through prior training? (Q18)	1.5424	0.4625
Were STEM skills integrated into university coursework? (Q23)	0.5546	0.7578
How prepared did you feel to enter a professional/academic environment? (Q31)	0.3873	0.8239

Knowledge Transfer & Continuity

Table 12. Kruskal–Wallis H test results for Knowledge Transfer and Continuity items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
Have the skills/knowledge from your project been useful beyond the timeline? (Q9)	3.3339	0.1888
How important is mandated knowledge-sharing in national programs? (Q11)	2.8929	0.2354
How effectively was institutional knowledge preserved (e.g., mentorship)? (Q15)	1.9033	0.3861
Did the CubeSat program improve knowledge transfer to future cohorts? (Q32)	0.3675	0.8321
Did the program facilitate knowledge exchange across teams? (Q29)	0.4575	0.7955

Outreach & Collaboration(s)

Table 13. Kruskal–Wallis H test results for Outreach and Collaboration items. Significant differences ($p < 0.05$) are **bolded**.

Survey Question	H	p-value
Would you recommend allocating time and resources for outreach? (Q8)	3.3429	0.1880
How essential was collaboration to your project's success? (Q12)	2.8034	0.2462
How frequently did your team interact with collaborators? (Q22)	0.5769	0.7494
How many CubeSat missions has your team been involved in? (Q25)	0.5156	0.7728
How satisfied was your team with the collaboration experience? (Q26)	0.4956	0.7805
Did collaboration contribute to long-term capacity (e.g., workflows)? (Q27)	0.4727	0.7895
Did your team collaborate with institutions to promote space awareness? (Q28)	0.4589	0.7950
Did your team engage in external collaboration during the project? (Q30)	0.4286	0.8071

Open-Ended Analysis Results

Table 14. Methods of Community Outreach reported by CubeSat teams. Sample sizes: Emerging ($n = 7$), New ($n = 7$), Established ($n = 5$).

Engagement Style	Emerg.	New	Estab.	Total
Activities & Workshops	4	2	4	10
Elementary Classroom Visits	3	5	2	10
Presentations to the Scientific Community	1	0	0	1
Undergraduate Events	1	0	0	1
Total	9	7	6	22

Table 15. Direct Outcomes of Collaborative Efforts. Sample sizes: Emerging ($n = 7$), New ($n = 7$), Established ($n = 5$).

Support Type	Emerg.	New	Estab.	Total
Technical Support	5	3	1	9
Legal Documentation Support	1	0	0	1
Test Equipment Support	1	1	1	3
Project Management and Success Support	3	3	3	9
Total	10	7	5	23

Table 16. External and Shared Facilities. Sample sizes: Emerging ($n = 7$), New ($n = 7$), Established ($n = 5$).

Facility and Usage	Emerg.	New	Estab.	Total
Ground Station Communication Support	4	0	1	5
Test Equipment Environmental Testing	4	4	2	10
Clean-room Electromagnetic Compatibility Facilities	2	0	3	5
Industry External Partner Support	0	1	0	1
Total	10	5	6	21

Nominal Analysis Results

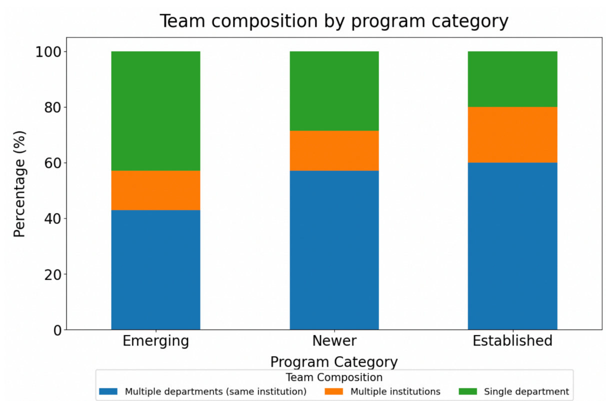

Fig. 4. Chart shows team composition across maturity levels, revealing a consistent trend along the maturity gradient.

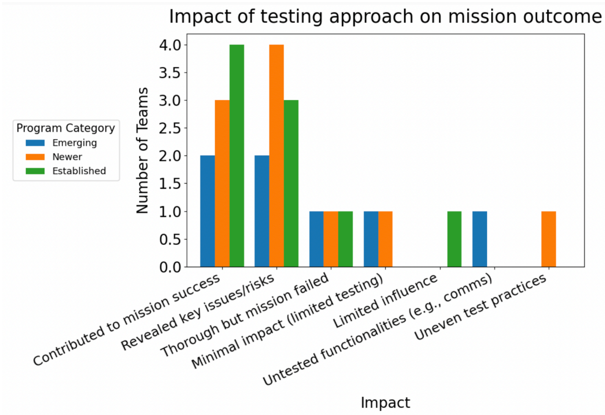

Fig. 5. Impact of testing approaches on mission outcomes across CubeSat program categories. Teams from Emerging, Newer, and Established programs reported varying outcomes, with testing most often contributing to mission success or revealing key risks, but in some cases highlighting limited testing influence or uneven practices.

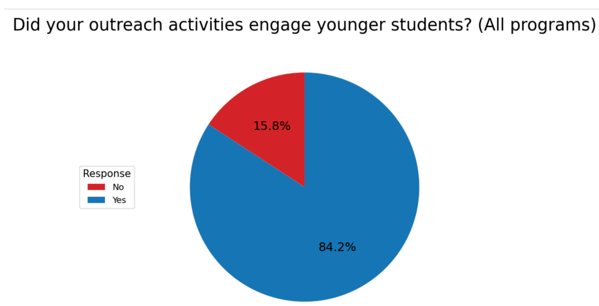

Fig. 6. Outreach activities reported by CubeSat teams and their engagement with younger students across all programs. Most teams (84.2 percent) indicated that their outreach successfully engaged younger students, while 15.8 percent reported no such engagement.

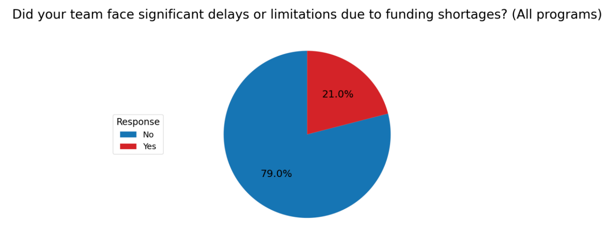

Fig. 7. Survey responses on whether CubeSat teams faced significant delays or limitations due to funding shortages. Across all programs, the majority (79.0 percent) reported no delays, while 21.0 percent indicated funding shortages had a significant impact.

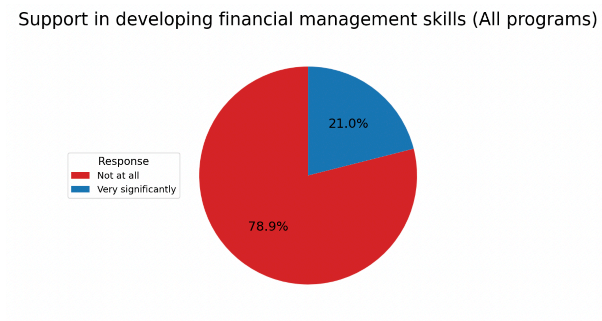

Fig. 8. Survey responses on support received in developing financial management skills across all CubeSat programs. A majority of teams (78.9 percent) reported receiving no support, while only 21.0 percent indicated that support was provided very significantly.

References

[1] K. P. Bouzoukis, G. Moraitis, V. Kostopoulos, and V. Lappas, "An overview of cubesat missions and applications," *Aerospace*, vol. 12, no. 6, p. 550, Jun. 2025. DOI: `10.3390/aerospace12060550`. [Online]. Available: `https://doi.org/10.3390/aerospace12060550`.

[2] A. Wuerl, "Cubesats: Cost-effective science and technology platforms for emerging and developing nations," *Advances in Space Research*, vol. 47, no. 4, pp. 663–684, 2011. [Online]. Available: `https://www.sciencedirect.com/science/article/abs/pii/S0273117710006836`.

[3] United Nations Office for Outer Space Affairs, *Access to space for all*, Online; accessed 2025-08-20, 2025. [Online]. Available: `https://www.unoosa.org/oosa/en/ourwork/access2space4all/index.html`.

Table 17. Mission success factors reported by CubeSat teams across program maturity levels. Sample sizes: Emerging ($n = 6$), New ($n = 6$), Established ($n = 5$). Knowledge and skills, launch and deployment, and operations were the most frequently cited contributors to success, while capacity-building training and mission objectives fulfilled were less commonly identified.

Success Factor	**Emerg.**	**New**	**Estab.**	**Total**
Knowledge & Skills	5	3	3	11
Capacity Building & Training	1	1	0	2
Launch & Deployment	4	4	1	9
Operations, Data Return & Tech Demo	4	4	3	11
Mission Objectives Fulfilled	0	1	1	2
Total	14	13	8	35

[4] E. Kulu, *CubeSats and Nanosatellites 2024*, Nanosats Database, 2024. [Online]. Available: https://www.nanosats.eu/assets/CubeSats-Nanosatellites-2024_ErikKulu_IAC2024.pdf.

[5] NASA, *Cubesat launch initiative*, 2024. [Online]. Available: https://www.nasa.gov/kennedy/launch-services-program/cubesat-launch-initiative/.

[6] Canadian Space Agency, *Canadian cubesat project (ccp)*, 2023. [Online]. Available: https://www.asc-csa.gc.ca/eng/satellites/cubesat/default.asp.

[7] European Space Agency, *Fly your satellite!* 2024. [Online]. Available: https://www.esa.int/Education/CubeSats_-_Fly_Your_Satellite.

[8] United Nations Office for Outer Space Affairs, *Kibocube programme*, 2024. [Online]. Available: https://www.unoosa.org/oosa/en/ourwork/access2space4all/KiboCUBE/KiboCUBE_Index.html.

[9] T. Hestad, V. Barabash, and R. Laufer, "The aptas student cubesat mission: A case study for reflective practitioner in education and student teams," *Advances in Space Research*, vol. 72, no. 6, pp. 2245–2258, Sep. 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0273117723004623?via%3Dihub.

[10] C. Venturini, B. Braun, and D. Hinkley, *Improving mission success of cubesats*, Presented at 32nd Annual Small Satellites Conference, 2018. [Online]. Available: https://s3vi.ndc.nasa.gov/ssri-kb/static/resources/Improving%20Mission%20Success%20of%20CubeSats.pdf.

[11] A. Alanazi and J. Straub, "Engineering methodology for student-driven cubesats," *Aerospace*, vol. 6, no. 5, 2019. DOI: 10.3390/aerospace6050054. [Online]. Available: https://www.researchgate.net/publication/333057399_Engineering_Methodology_for_Student-Driven_CubeSats.

[12] NASA, *Cubesat 101: Basic concepts and processes for first-time cubesat developers*, [Online; accessed 2025-09-08], 2017. [Online]. Available: https://www.nasa.gov/wp-content/uploads/2017/03/nasa_csli_cubesat_101_508.pdf.

[13] Canadian Space Agency, *Cubesats initiative in canada for stem (cubics)*, 2022. [Online]. Available: https://www.asc-csa.gc.ca/eng/funding-programs/funding-opportunities/ao/2022-cubics-cubesats-initiative-in-canada-for-stem.asp.

[14] KAUST, *Kaust satellite to deliver advanced earth observation data*, 2023. [Online]. Available: https://www.kaust.edu.sa/en/news/kaust-satellite-to-deliver-earth-observation-data.

[15] European Space Agency (ESA), *Fly your satellite! programme*, ESA Education Office, 2022. [Online]. Available: https://www.esa.int/Education/Fly_Your_Satellite.

[16] H. Mori, J. Del, W. Zhang, and L. St-Pierre, "United nations activities for enhancing access to space," in *Small Satellite Conference*, Accessed: Jul. 20, 2025, 2022. [Online]. Available: https://digitalcommons.usu.edu/smallsat/2022/all2022/70/.

[17] S. Kim, T. Yamauchi, and H. Masui, *Birds bus: A standard cubesat bus for an annual educational satellite project*, 2021. [Online]. Available: https://jossonline.com/wp-content/uploads/2021/07/Final-Kim-BIRDS-BUS-A-Standard-CubeSat-BUS-for-an-Annual-Educational-Satellite-Project.pdf.

[18] S. Kuzin *et al.*, "Euv telescope for a cubesat nanosatellite," *Applied Optics*, vol. 62, no. 31, p. 8462, 2023. DOI: 10.1364/AO.501437.

[19] Romanian Space Initiative, *ROSPIN-SAT-1*, 2023. [Online]. Available: https://www.old.rospin.org/rospin-sat-1/.

[20] United Nations Office for Outer Space Affairs, *UNOOSA Annual Report 2024*, Accessed: Aug. 20, 2025, 2025. [Online]. Available: https://www.unoosa.org/res/oosadoc/data/documents/2025/stspace/stspace93_0_html/UNOOSA_Annual_Report_2024.pdf.

[21] A. P. Aboaf *et al.*, *A methodology for successful university graduate cubesat programs*, 2020. [Online]. Available: https://digitalcommons.usu.edu/smallsat/2020/all2020/31/.

[22] C. del Castillo-Sancho, G. Grassi, A. Kinnaird, A. Mills, and D. Palma, *Lessons learned from aiv in esa's fly your satellite! educational cubesat programme*, 2021. [Online]. Available: https://digitalcommons.usu.edu/smallsat/2021/all2021/232/.

[23] National Academies of Sciences, Engineering, and Medicine, *Achieving Science with CubeSats: Thinking Inside the Box*. Washington, D: The National Academies Press, 2016. DOI: 10.17226/23503.

[24] UN Office for Outer Space Affairs, *Open-sourcing of cubesat bus for capacity building aimed at space exploration*, 2021. [Online]. Available: https://www.unoosa.org/documents/pdf/psa/activities/2021/UNIAF/2_03_maeda.pdf.

[25] Frances Zhu, *A guide to cubesat mission and bus design*, [Online; accessed 2025-09-08], 2022. [Online]. Available: https://pressbooks-dev.oer.hawaii.edu/epet302/chapter/2-1/.

[26] NASA Spectrum Management Program, *Spectrum guidance for nasa small satellite missions*, [Online; accessed 2025-09-08], 2015. [Online]. Available: https://www.nasa.gov/wp-content/uploads/2020/03/spectrum_guidance_smallsats_cubesats_27aug2015_0.pdf.

[27] International Amateur Radio Union, *Satellites*, [Online; accessed 2025-09-08], 2025. [Online]. Available: https://www.iaru.org/reference/satellites/.

[28] R. Nugent, *Cubesat/small satellite lessons learned*, [Online; accessed 2025-09-08], 2017. [Online]. Available: https://unisec-global.org/pdf/uniglo5/day2/Group_Discussion/Group3_intro_output.pdf.

[29] United Nations Office for Outer Space Affairs, *Space2030 agenda: Space as a driver of sustainable development*, [Online]. Available: https://www.unoosa.org/res/oosadoc/data/documents/2024/stspace/stspace88_0_html/st_space-088E.pdf, 2024.

[30] Government of Canada, *Exploration, imagination, innovation: A new space strategy for canada*, [Online]. Available: https://www.asc-csa.gc.ca/pdf/eng/publications/space-strategy-for-canada.pdf, 2019.

[31] African Union Commission, *African space strategy*, [Online]. Available: https://au.int/sites/default/files/documents/37434-doc-au_space_strategy_isbn-electronic.pdf, 2019.

[32] T. J. Weston and S. L. Laursen, "The undergraduate research student self-assessment (urssa): Validation for use in program evaluation," *CBE—Life Sciences Education*, vol. 14, no. 1, pp. 1–10, 2015. DOI: 10.1187/cbe.14-11-0206. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC4710391/.

[33] S. Jamieson, "Likert scales: How to (ab)use them," *Medical Education*, vol. 38, no. 12, pp. 1217–1218, 2004. DOI: 10.1111/j.1365-2929.2004.02012.x. [Online]. Available: https://www.researchgate.net/publication/8160021_Likert_Scales_How_to_ab_Use_Them.

[34] J. Carifio and R. Perla, "Resolving the 50-year debate around using and misusing likert scales," *Medical Education*, vol. 42, no. 12, pp. 1150–1152, 2008. DOI: 10.1111/j.1365-2923.2008.03172.x. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2923.2008.03172.x.

[35] C. Mircioiu and J. Atkinson, "A comparison of parametric and non-parametric methods to analyse likert scale ordinal data," *Journal of Educational Sciences*, vol. 38, no. 2, pp. 21–28, 2017. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC5597151/.

[36] R. Eiselen, "A comparison of statistical tests for likert-type data," *Journal of Open Humanities Data*, vol. 9, p. 18, 2023. DOI: 10.5334/johd.132. [Online]. Available: https://openhumanitiesdata.metajnl.com/articles/10.5334/johd.132.

[37] University of Saskatchewan Space Design Team, *Cubesat updates*, [Online], Nov. 2021. [Online]. Available: https://usst.ca/cubesat-updates/.

[38] Spire Global, *Three spire global satellites successfully launch on spacex transporter-7 mission*, [Online], Apr. 2023. [Online]. Available: https://ir.spire.com/news-events/press-releases/detail/160/three-spire-global-satellites-successfully-launch-on-spacex.

[39] A. Novak et al., *The Rise of Cubesats: Shifting Standards to Expand Use*, 2022. [Online]. Available: https://www.wilsoncenter.org/blog-post/rise-cubesats-shifting-standards-expand-use.

[40] NASA, *NASA Announces CubeSat Launch Initiative Opportunity*, 2023. [Online]. Available: https://www.nasa.gov/general/nasa-announces-cubesat-launch-initiative-opportunity.