

Building Capacity in Satellite-Based Earth Observation and HQP Training: Canada as a Use Case

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Keywords: Geomatics Education, Skills-Gap, Market Needs, Disruptive Technology, GeoAI, GeoFM.

Abstract

Remote sensing (RS) and especially earth observation (EO) have been used extensively for decades in environmental monitoring, infrastructure asset management, urban planning, emergency response, mapping and many others. The pace of technology advancements in big data, cloud computing, Geospatial AI (GeoAI) and Geospatial Foundation Models (GeoFM) causes a paradigm shift on how to and who can maximize the potential of remote sensing technology. This shift challenges traditional geomatics curriculum and pedagogical methods. Additionally, the gap between geomatics graduates' skills and market needs is widening. The pace of disruptive technology advances like GeoAI and GeoFM can be challenging to match with developments in geomatics education content or suitable pedagogical methods and formats. To address these skills gaps in geomatics courses and courseware, an initiative has been developed between the Canadian Space Agency (CSA) and Carleton University, involving more than a dozen different partners spanning industry, government, academia and NGOs. We have been gathering information through qualitative and quantitative techniques to obtain insights about the soft and hard skills that are valuable and/or lacking in contemporary geomatics graduates, to forecast trends and future needs, and plan how to optimize the introduction of new technology and techniques into the educational content. Based on the mapped feedback, university-level geomatics courses are being redeveloped and updated, and novel course modules, mini-courses and micro credential programs are being developed and tested.

1. Introduction

This paper reports on a cross-sector initiative led by Carleton University with support from industrial partners, with financial support from the Canadian Space Agency. The purpose of the project is to enhance Canada's capacity for training in satellite-based earth observation. Recent large influxes of highly available EO data can be attributed to the launches of many new satellite sensors, and the increased availability of data due to open access models and cloud computing platforms. This rapidly increasing availability of earth observation data and their spread to many application areas has contributed to recruitment of personnel with highly diverse backgrounds to design and operate distribution and analysis systems for those data.

Our research team spans industry, government, academia, and NGO partners working in the remote sensing and geomatics fields. The aim of the assembled team is to help address the skills-gap between geomatics graduates and market needs, especially with the need for optimized utilization of the huge amounts of data now available and the rapid pace of disruptive advances in GeoAI and GeoFM domains. The partners' application domains include agriculture, environmental monitoring, conservation, water resources, sea ice mapping, and many others. Within the fields of geography and geomatics, our industry partners have noted that they require trainees to understand how to analyze very large datasets and use technology like cloud computing, machine learning, GeoAI and GeoFM, yet these skills are often not yet taught in undergraduate geography and geomatics programs.

Our current curriculum provides comprehensive training in remote sensing and satellite-based Earth observation through core courses, advanced electives, and specialized experiential learning opportunities. To remain responsive to evolving industry demands and technological advancements, we propose to redevelop and expand geomatics courses to better reflect market needs and emerging skill sets. This initiative will also

explore innovative formats such as mini-courses and micro-credential programs, ensuring flexible and accessible pathways for learners, whether they are engaging in complete programs or seeking opportunities to update individual areas of knowledge and skills. To guide this development and ensure the courses reflect the market needs and skills required, a combination of qualitative and quantitative methods has been used. These methods are being applied to map the skills-gap patterns identified by the initiative partners' insights in addition to the broader Canadian remote sensing community feedback.

In terms of readiness levels, initial consultations suggested that our existing programs and courses included appropriate content and valued approaches, but updates were needed to keep them current; the new courses that are being developed add innovative approaches and content. By the end of the initiative, a mix of traditional university courses along with flexible shorter courses and workshops will be developed and demonstrated, and feedback is being collected in an iterative manner with continued updates. A mix of both professionals in the workforce and university students will be able to access the developed content and teaching materials. In addition, refined training solutions will be disseminated and made accessible through the Open Educational Resources (OER) concept, making training available after our project is completed.

1.1 Related Work

Although geomatics education and training provide the foundation to supply geomatics graduates with knowledge and skillsets meeting market needs, the literature about post-secondary geomatics education in Canada, its evolution, and how it compares to the actual market needs is very limited and fragmented. The most recent government-led efforts to map a cross-country profile dedicated to geomatics is a decade old and was published in 2016 (Hickling et al., 2015). The report profiles

geomatics sector and details the contributions of geospatial information to economy and society. Although not primarily focused on assessing the gap between geomatics education curricula and market needs, it correctly forecasted there would be an insufficient supply of 'data scientists' with the deep analytical skills to exploit the full potential of big data.

LeDrew et.al. (2023) produced a holistic web-analysis to survey remote sensing post-secondary institutions but without addressing the graduates' skills-gap or market needs. A survey by Chasmer et al. (2022) of industry, government and academic trainers and trainees in remote sensing concludes that there is a disconnect between what universities teach and what the job market demands. This is further emphasised by disruptive trends in remote sensing and the growth in cloud-based platforms and big EO data.

Since the breakthrough paper "Attention is all you need" (Vaswani et al., 2017) and its introduction of Transformer architecture, which has since become the foundation of nearly all-modern Large Language Models (LLM), the utilization of these models has become ubiquitous and the pace of its evolution is staggering. The fast rise of GeoAI and GeoFM models is also no exception. Transfer learning (TL) has emerged as a promising strategy to solve key challenges with using machine learning (ML) in environmental remote sensing; the requirement of a substantial amount of ground truth labels for training, and models trained using labelled data from one domain often performs poorly when directly applied to other domains. The rapid increase of TL application in remote sensing is evident by the 10-fold increase in peer-reviewed articles published in 2022 compared to 2017 (Yushi Ma et al., 2024). GeoAI and GeoFM models present a significant paradigm shift in the utilization of big data in remote sensing applications. GeoFM has the potential to reshape GeoAI and spatial data science research, education and practice (Janowicz et al., 2025). The introduction of GeoFM models like AlphaEarth (Brown et al., 2025) by Google DeepMind, Pritivi V1.0 (Szwarcman et al., 2024) and V2.0 (Szwarcman et al., 2025) by NASA, IBM and partners offers completely new avenues on the way environmental remote sensing is applied.

Consequently, the demand has shifted towards skills in algorithm development, optimized machine learning and multimodal data fusion. Smeers et al. (2020) and Darling et al. (2022) highlight the increased need for more technical training in specific emerging fields and the need for a more holistic education approach including the scientific basics behind earth observation, effective communication, and other professional skills. While skills in data science, advanced machine learning and deep learning techniques are becoming common in engineering disciplines, these students often lack the geographical and spatial knowledge to apply these techniques in an earth observation context effectively (Chasmer et al., 2022).

Increasing use of earth observation in industry and government is a trend that is expected to continue, but the rapid growth of both demand for and supply of data and techniques to support this is challenged by disruptive innovation, as non-experts in remote sensing are producing and applying remotely-sensed earth observation data (Chasmer et al., 2022). This shift in expertise provides opportunities for constructive innovation but also possible misinterpretations or misapplications.

2. Methodology

To assess the skills gap between geomatics graduates and evolving market demands—including anticipated technology trends over the next five years—a mixed-methods approach was employed. Qualitative insights were gathered through interviews, while a structured survey provided quantitative data. This holistic methodology enabled a comprehensive mapping of both soft and hard skills currently lacking in the workforce.

A number of in-depth and semi-structured interviews have been conducted with the project stakeholders and with the broader RS community, including experts spanning industry, government, academia and NGOs. The objectives of the interviews were to gather insights about skills-gaps, both soft-skills and hard skills, and a forecast about the technology required in their production and operation environments in the coming five years.

In addition, and guided by the activities above, to assess skills-gap patterns across the target groups quantitatively, a structured survey instrument was designed and administered. The survey aimed to capture measurable indicators of competency levels (soft and hard skills), training needs, and alignment with market demands. The survey was structured into different sections, each with a specific goal, as shown in Table 1.

Section	Goal
Current Skills Requirements	Understand what skills are most in demand in the workplace.
Graduate Preparedness	Evaluate how well academic programs align with real-world needs.
Training & Upskilling	Identify opportunities for bridging the gap.
Industry/Government - Academia Collaboration	Explore how partnerships can improve workforce readiness.
Future Outlook	Anticipate future skill needs.
Final Thoughts	Share any additional comments, reflections, or suggestions that may not have been covered by the structured questions
Respondent Info	Business Type, Section/Role

Table 1. Skills-gap structured survey sections and goals.

The survey was shared with our partners to gather initial feedback, and then with the broader remote sensing community through the help of the Canadian Remote Sensing Society, and personal networks and through LinkedIn.

3. Results and Discussion

Recruitment of respondents is continuing, but at the time of this writing, October 2025, 35 responses had been received. The majority were from experts working in government (57.6%), while the remaining responses were equally split between industry and academia (Figure 1). Figure 2 shows that the respondents' roles were fairly equally split between Research and Development (R&D), Operations and Production, and Management.

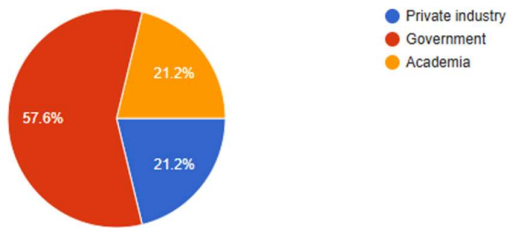


Figure 1. Respondents' organizations sectors.

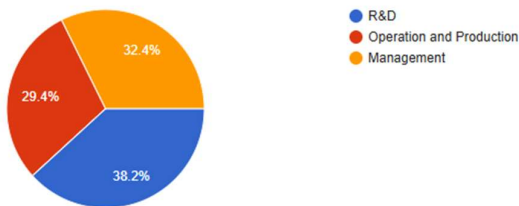


Figure 2. Respondents' sections/roles.

Even with the preliminary response rate so far, clear patterns can be identified. Figure 3 shows the technical skills categories that were most relevant to the organizations' geomatics-related roles namely, GIS, remote sensing, Python, and ML/AI, while GNSS and CAD were ranked lowest—likely reflecting the environmental remote sensing focus of most participants. Figure 3 depicts the distribution of responses, number of respondents (percentage).

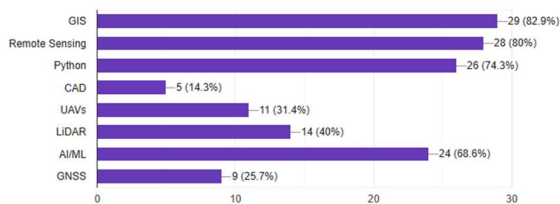


Figure 3. Important technical skills categories.

Respondents identified critical thinking as the most lacking soft skill among recent geomatics graduates, followed by problem solving, communication, and project management. Teamwork was seen as the least deficient, suggesting graduates are generally well prepared for collaborative work (Figure 4).



Figure 4. Important soft skills categories lacking.

To understand the type of tools or platforms and their different modalities (desktop, cloud-based, license type ...) that the respondents use, the feedback collected through the survey was further analysed with the help of MS Copilot [GPT-5] to parse the list of tools and platforms used, and normalize the different variants for the tool family (e.g. ArcGIS/ arcgis/ Esri package/ ArcPro/ Arcmap/ ... were all categorized as Esri ArcGIS). Then

the mentions were tallied, ranked and flagged as either open source or proprietary. Figure 5 summarizes the different categories of tools and platforms.

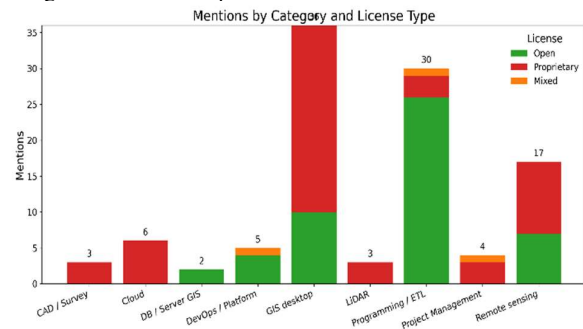


Figure 5. Tools and platforms categories.

A hybrid ecosystem can be noticed as open-source vs proprietary mentions (by count across the list) were:

Open Source: 49 (~45.8%), Proprietary: 54 (~50.5%), Mixed: 3 (~2.8%)

Esri is the dominant proprietary platform, but there is a strong open-source backbone (QGIS, Python, R/RStudio, GDAL/rasterio, SNAP, PostGIS, MapServer) and a growing use of cloud / model tooling (GEE, AWS, Prithvi), in addition to a great emphasis on open source programming. This highlights the importance of providing comprehensive training programs. These programs should combine practical, hands-on experience in programming skills with a strong foundational understanding of cloud computing environments. Such programs will better prepare learners to meet evolving market needs and industry expectations.

The graduate preparedness section of the structured survey aimed to assess how well academic programs prepare geomatics graduates for the workforce. It included questions on technical proficiency, areas of under preparedness, essential skills, and emerging technologies. Responses on how well recent geomatics graduates meet the expectations in terms of technical proficiency revealed a mixed perception: while many rated graduates' technical skills as average or well-suited to the position requirements, a smaller proportion viewed them as either very well-prepared or poorly prepared. These findings are summarized in Figure 6.

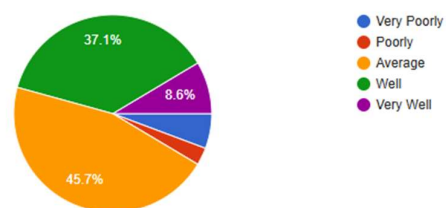


Figure 6. Graduate readiness in technical domains

Most survey respondents indicated that recent geomatics graduates lack sufficient practical experience, highlighting a key gap between academic preparation and workplace expectations. This emphasizes the need to rethink and revisit Work-Integrated Learning (WIL) options such as co-op or practicum learning for geomatics students to better equip them with initial experience that is more practical during their learning journey. This key finding aligns with results of Chasmer et al. (2022)'s survey. As

shown in Figure 7, in addition to practical experience, respondents also identified gaps in technical skills, soft skills, and industry knowledge among recent geomatics graduates.

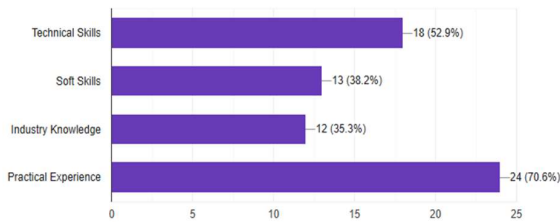


Figure 7. Deficient competencies among geomatics graduates

Some very rich insights have been received through the respondents answer to “Which specific skills do you think graduates need to have?” Analysing the feedback received and categorizing the main takeaways from the received input highlights some skills-gaps. The findings of the needed skills are summarized in Table 2.

Category	Needed Skills
Technical Skills	Python, R, Web GIS, Cloud platforms, SAR techniques, RDBMS
	EO data processing, multi-platform GIS (beyond ESRI), automation, system dev
	GeoAI, ML/DL, computer vision, sensor integration, immersive tech (VR/MR/XR)
Analytical & Cognitive Abilities	Critical thinking, problem solving, systems thinking, scientific reasoning
Real-World & Practical Experience	Co-op and fieldwork, workplace norms, independent work habits
	Awareness of post-grad roles, contextual and market experience
Learning Agility	Communication, presentation, public speaking, leadership
	Adaptability, time management, fast learning, attention to detail
Educational Gaps	Limited deep programming exposure, theory-practice imbalance
	Tool familiarity without mastery, GIS not integrated into IT systems
	Lack of software management training

Table 2. Skills needed and educational gaps

The analysis of the open-ended question feedback shows again the need for practical experience, programming and familiarity of cloud computing along with the new GeoFM models offerings. Moreover, the critical thinking and problem solving constitute a foundational necessity for the geomatics graduates to better align with the market needs.

Regarding emerging technologies, the forecast for the trending technologies in the coming five years and the analysis of the received feedback revealed the need for greater focus on GeoAI, GeoFM, big data handling and optimized processing of large data volumes with scalable workflows development. The main takeaways from the respondents’ feedback and the future-ready geomatics graduate skillset to better align with market needs is summarized in Table 3.

Trend / Technology	Aligned Skills Needed
AI / ML / Deep Learning	AI/ML fundamentals, supervised learning, deep learning, vision transformers
	Understanding foundational models and hybrid approaches
	GeoAI, real-time mapping, selective sampling
	GeoAI for automated feature extraction, object detection, metadata generation
Big Data & Data Infrastructure	Large volume time series analysis, data fusion, cloud computing
	Data cubes, quality control, calibration/validation
Automation & Workflow Optimization	Automated feature detection and extraction
	Workflow automation, quick prototyping of hardware/software
Digital Twins & IoT	Integration of multi-sensor data (SAR, optical, LiDAR, GNSS)
	Intelligent sensing and mapping platforms
	Understanding of digital twin concepts and applications
Cloud & Scalable Computing	Skills in cloud platforms for EO/RS data processing
	Scalable model deployment and analysis
Immersive & Interactive Tech	VR/MR/XR for environmental and climate applications
	Robotic mapping and real-time interaction platforms
Critical Thinking & Data Literacy	Ability to assess AI outputs critically
	Avoiding superficial analysis and promoting innovation

Table 3. Future-ready geomatics graduates skills needed

It is pertinent to observe that critical thinking is again considered one of the key skillsets that is needed to deal with emerging technologies and any future technology trends. This alignment shows a clear shift from traditional GIS tool usage toward custom, modular, and intelligent systems that require strong analytical thinking, coding, and data literacy.

To gauge what type of micro-credential or mini courses are needed for the upskilling of geomatics graduates and help tackle the skills-gap, to better align with market needs, the feedback of the respondents is further analysed. Employers did not note a single "must-have" certification but value continuous learning, exposure to cloud platforms, programming, and workflow management tools. Demonstrated interest through courses or memberships is a strong differentiator among recent graduates. The main takeaways from the respondents' feedback about the upskilling training needed is shown in Table 4.

Area	Details
Conceptual Understanding	Strong grasp of ML concepts, strengths/weaknesses of foundational models and physics-based approaches
Project & Workflow Skills	SCRUM / Agile methodologies, project management (PMP), organizational workflows
Certifications (Optional)	GIS, Applied GIS, Analytics, Data Science, Cloud/AI Practitioner certificates
Technical Specializations	LiDAR (calibration, classification, extraction), RPAS
Analysis & Governance	Big data analysis, cluster processing, information governance, business case development
Emerging Tech Awareness	GeoAI, UAV mapping, Digital Twins, geospatial intelligence

Table 4. Upskilling key needs Identified

As highlighted from the upskilling needs, not only specific focused training (e.g. as in LiDAR calibration, classification, extraction) is needed but it can also be deduced that broader training is important. This holistic approach includes project management fundamentals and some business development familiarity, in addition to a foundational basis of theory understanding and emerging technology awareness.

Although almost (65%) of respondents have partnered with academia for research, co-op, or training programs, the skills-gaps present highlight the need to make this partnership more efficient. Figure 8 shows the percentage of respondents that already collaborated with academia for their research or co-op needs.

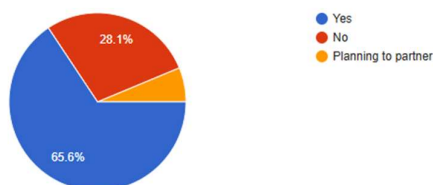


Figure 8. Respondents' partnership with academia.

The feedback from employers on how to make the partnership more efficient in tackling the skills-gap, suggests that longer-term, strategically aligned partnerships with real-world projects and better student preparation are key. Main takeaways for stronger more efficient partnerships are presented in Table 5.

Theme	Details
Real-World Collaboration	Collaboration on real projects
	Co-design of projects, joint supervision, internships
Co-op & Work Terms	Multi-semester co-op or back-to-back work terms
	Longer placements (4–8 months) for better integration
	Co-op as a pipeline for hiring (extended interview model)
Recruitment & Accessibility	Opportunities to showcase industry work to attract candidates
	Address security clearance challenges for government roles
	Ensure equal access for students across institutions
Strategic Alignment	Align research with product roadmaps and ROI timelines (1–3 years)
	Emphasize both monetary and soft benefits of partnerships
Capacity Building	Prepare students with relevant skills before placement
	Assign young researchers and include them in processes
Funding & Shared Resources	Shared funding opportunities for graduate students
	Support for joint projects and research initiatives

Table 5. Stronger Tech-Academia partnership

The suggestions collected for better partnerships highlights the need for longer co-op placements and some strategic alignment for longer periods with shared funding opportunities to make the Work-Integrated Learning (WIL) thrive and increase its potential for all stakeholders involved.

4. Conclusions

With the pace of technological advances in the geospatial world and the paradigm shift introduced with advances in areas such as GeoAI and GeoFM models, we risk a widening skills-gap between geomatics graduates and market needs, so a more holistic approach for geomatics education, upskilling and training is needed. A new initiative encompassing more than a dozen industry, government, academia and NGOs has been implemented. Qualitative and quantitative methods have been carried out to better map the skills-gap between geomatics graduates and the Canadian market needs. In-depth, semi-structured interviews with RS experts spanning industry, government, academia and NGOs have been supplemented by a structured survey to identify some key findings about the current skills-gap; soft and hard skills, and future-ready aligned skills have been mapped. Critical thinking and practical experience are

among the most valued skills, yet they are also the most frequently reported as lacking in recent geomatics graduates.

A combination of updated credit courses and new shorter ones along with micro-credential programs that value continuous learning, exposure to cloud platforms, programming, and workflow management tools are highly recommended.

Upskilling training that focuses on the emerging new technologies like GeoAI and GeoFM, with the proper balance between ML fundamentals and hands-on practical experience, help align the geomatics graduate's skillset with the current emerging technologies required and the forecasted technology trends. Course content and assessment strategies need to place greater emphasis on developing competencies in soft skills such as critical thinking and problem-solving.

In addition, more efficient and stronger partnerships between different stakeholders and academia is paramount to maximize the full potential of Work-Integrated Learning (WIL). Extended co-op placements and establishing strategic, long-term alignment supported by shared funding to maximize the success and value of these programs for all stakeholders are needed.

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