REVIEW OF PHOTOGRAMMETRY, REMOTE SENSING, AND GEOSPATIAL SCIENCES REQUIREMENTS BY VARIOUS ACCREDITATION BODIES

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ABSTRACT:

Technological advancements in the fields of Photogrammetry, Remote Sensing, and Geospatial Sciences continuously alter the way we collect, process, and interpret datasets. Accreditation bodies and institutions often need to respond to those changes and make timely modifications to stay current with technology changes and industry needs. However, it can be generally stated that the industry can adapt and adopt technological changes faster than accreditation organizations and institutions, because the process of modernizing curricula can be time consuming and slow based on organization / university / college policies. In addition to industry demands, institutions must adhere to and follow accreditation requirements. This paper reviews several accreditation requirements related to Photogrammetry, Remote Sensing, and Geospatial Sciences. The accreditation bodies that are reviewed focus on organizations in Northern America and Europe due to ease of access to information. The review provides insights about their curricula criteria, their level of detail, if they can be considered current based on industry needs, and if they provide enough flexibility for modernizing curricula without violation of accreditation policies and criteria.

1. INTRODUCTION

The fields of photogrammetry and remote sensing have experienced tremendous technological changes in the last 10 to 20 years (Masum et al. 2019; Gillins et al. 2017; Bolkas et al. 2022; Staiger 2023). These changes have altered the way that we collect, process, and interpret datasets. For instance, consider the changes brought by point cloud technologies such as terrestrial, airborne, and mobile laser scanning (TLS, ALS, and MLS, respectively), and small unmanned aerial vehicles (sUAS), as well as the changes brought by satellite remote sensing, and geographic information systems (GIS). Nowadays, we are able to acquire a wealth of geospatial data that exhibit diverse characteristics, different advantages and disadvantages, necessitate different theoretical foundations, and advanced processing strategies. Across the geospatial industry, businesses and professionals, who are the end users, are often eager to adopt and utilize the most recent technological advancements (either in hardware or software) because they often reduce the time needed for data acquisition and/or data processing (and hence cost), they allow the production of higher quality products, or provide information that was not previously attainable. These benefits are key for companies to remain competitive, and the adoption of these technologies promises a quick return on investment. However, academic institutions often have difficulty in following rapid technological changes and assimilating them in their curriculum. Updating course descriptions and/or creating new courses can be a long and complex process for most institutions that can take months to years (Masum et al. 2019). In addition, it is challenging for institutions to frequently invest in expensive instruments to stay current with industry needs, considering that their return on investment is considerably slower compared to the one of a company.

Furthermore, surveying / geomatics / remote sensing and related programs are often required to be accredited and follow accreditation requirements (e.g., Bolkas and Gouak 2020). Accreditation provides an assurance to the community that graduating students received quality education that meets certain standards, and that they are qualified to contribute to their profession. Many institutions would have to shut down their programs if they were to lose their accreditation, highlighting the importance of staying current and maintaining accreditation. As part of the accreditation requirements or criteria, there are also requirements related to curriculum. Some of the accreditation bodies are more detailed in their curriculum requirements for photogrammetry and remote sensing than others. This paper reviews the accreditation requirements related to Photogrammetry, Remote Sensing, and Geospatial Sciences for Northern American and Europe. A total of four accreditation bodies are reviewed (Table 1). The accreditation bodies that we review are: (1) ABET, Accreditation Board for Engineering and Technology, Inc.; (2) United States Geospatial Intelligence Foundation (USGIF); (3) Canadian Engineering Accreditation Board (CEAB); and (4) EURopean ACcredited Engineer (EUR-ACE®) with a focus on Italy. In addition, we review the licensing requirements for surveyors in the USA regulated by the National Council of Examiners for Engineering and Surveying (NCEES), and in Canada regulated by Canadian Board of Examiners for Professional Surveyors (CBEPS). The review and comparison of the different bodies considers the following factors (1) detail curricula requirements, (2) currency in curricula requirements, (3) flexibility for changing curricula, and (4) a system / framework for updating the curricula.

Through this review, we can understand the emphasis placed on curricula by the different accreditation bodies, their level of detail, and if they can be considered current with today's industry needs. In addition, this review provides insights about

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guidelines and flexibility for modernizing curricula without violation of accreditation criteria.

Accreditation / Licensing body	Program focus	Country
ABET	Engineering, Engineering Technology, Computing, Applied and Natural Sciences	USA & worldwide
USGIF	Geospatial Intelligence (GEOINT) [GIS & Analysis Tools / Remote Sensing & Imagery Analysis / Geospatial Data Management / Data Visualization]	USA
CEAB	Engineering programs in Canada	Canada
EUR-ACE® (QUACING)	Engineering programs in Europe	Europe
NCEES	Surveying	USA
CBEPS	Surveying	Canada

Table 1. List of the reviewed accreditation and licensure bodies.

2. ACCREDITATION BODIES

2.1 ABET

ABET has a long history of accreditation (since 1932), currently accrediting 4,564 programs at 895 colleges in 40 countries (ABET 2023). ABET accredits programs through four commissions, namely the Applied and Natural Sciences Accreditation Commission (ANSAC), Computing Accreditation Commission (CAC), Engineering Accreditation Commission (EAC), Engineering Technology Accreditation Commission (ETAC). Surveying / geomatics/ geospatial programs are often accredited by the ANSAC, ETAC, and EAC commissions. ABET has eight general criteria and criteria related to each discipline, termed program criteria. The criteria are: (1) students, (2) program educational objectives, (3) student outcomes, (4) continuous improvement, (5) curriculum, (6) faculty, (7) facilities, and (8) institutional support. Program criteria are established by the professional society representing a given discipline covered by ABET. The curriculum requirements are very broad. They set a minimum number of credits for mathematics and basic sciences, and courses focusing on discipline content. They request a broad general education component and culminating experiences that are based on the knowledge of prior work. ABET relies on the program criteria set by the representing professional societies to set more specific curricula criteria. For surveying / geomatics / geospatial and similar programs, the requirements with respect to photogrammetry and remote sensing are also very broad. All three commissions have similar wording, which can be summarized as follows (ABET ANSAC 2023; ABET EAC 2023; ABET ETAC 2023): Graduates of a baccalaureate degree in surveying/geomatics possess a strong foundation in geodesy, geodetic science, photogrammetry and remote sensing, professional land surveying, mapping, geospatial data science, and the ability to select modern equipment and techniques to design, construct or locate products through the surveying/geomatics workflow. In addition, programs can select added depth in a minimum of four subject areas consistent with the program's educational objectives chosen from the following: (1) boundary / land surveying, (2) engineering surveys, (3) photogrammetry and remote sending, (4) geodesy and geodetic surveying, (6) mapping including map projections and coordinate systems, (7) geospatial data science and land information systems. ETAC also adds drainage and roadway design, while EAC adds civil engineering topics that assist students in meeting the licensure requirements in the state or region. As part of the accreditation process, ABET sends trained representatives for an on-site visit. The visiting team usually consists of a team chair from outside of the discipline, one or two program evaluators from the discipline. They are tasked with reviewing the self-study material, conducting interviews with students, faculty, staff, and the administration, visiting classrooms and labs, and determining compliance with the applicable ABET criteria and policies. Based on the findings of the visit, the program can receive initial accreditation (for new programs) or re-accreditation (for already accredited programs) for a period of 6 years. In the case where shortcomings are found (weaknesses and/or deficiencies), then an interim /show cause report or interim / show cause visit may be needed, with a typical duration of two years. In the case where deficiencies after the show cause report or show cause visit still exist then an action not to accredit the program is taken.

ABET has very broad curriculum requirements with respect to photogrammetry, remote sensing, and geospatial sciences. This allows programs to modify and change curriculum and courses as needed. ABET accredited programs often establish an advisory committee that may include representatives from alumni, professionals, local companies, government agencies, and instrument manufacturers. This advisory committee reviews the program educational objectives for their currency and often provides feedback on the program, the curriculum, instruments, software, and other things that need to be updated to stay current with industry needs. Through the continuous improvement process, ABET creates a mechanism for identifying issues that can lead to programmatic changes and curricula updates. As part of this continuous improvement process, instructors collect student work (projects, assignments, and exams) and assess the level of compliance with respect to the identified student outcomes. The assessment process is repeated periodically (often every two years), allowing for programs to identify issues, take any necessary action, and close the loop by evaluating whether the actions taken had an effect or if there is need for further action.

2.2 USGIF

Founded in 2004, the United States Geospatial Intelligence Foundation (USGIF) is a nonprofit educational foundation in the United States dedicated to promoting the geospatial intelligence tradecraft and developing a stronger GEOINT (Geospatial Intelligence) community within individuals, government, industry, academia, and professional organizations (USGIF 2023). As part of its efforts to advance the GEOINT community in academia and establish a common operating picture across USGIF accredited academic institutions, USGIF has developed a robust accreditation and reaccreditation program. As of 2023, 20 academic institutions in the United States have met or exceeded USGIF's accreditation standards.

Central to USGIF's accreditation structure is the USGIF Universal GEOINT Essential Body of Knowledge (EBK) last updated in 2019 and the 2018 Collegiate Geospatial Intelligence Accreditation Policies and Procedures informational document. To be considered for accreditation through USGIF, institutions must adhere to the following criteria: (1) submit a Letter of Intent, (2) conduct a rigorous self-review in accordance with USGIF accreditation standards and the EBK, and (3) complete a peer evaluation of the program. Additional requirements for individual academic program eligibility include, but are not limited to: (1) the programs mission is consistent with the USGIF focus of facilitating growth and innovation within the

GEOINT field, (2) curriculum designs meet the standards and expectations outlined in the EBK (an example of standards outlined by the EBK are available in Figure 1), (3) programs are engaged and actively involved in the GEOINT community and are committed to the professional development of both faculty and students (USGIF 2018). USGIF also requires an in-person site visit by the USGIF Vice President of Academic Affairs and one GEOINT subject matter expert to gauge each individual programs classroom, laboratory, and faculty capabilities with the purpose of determining if designated spaces and faculty design structure currently and in the future facilitate a cohesive GEOINT learning environment. Upon the completion of the accreditation packet and certification of accreditation, programs remain accredited by USGIF for five years. Subsequent reaccreditation involves a similarly robust reaccreditation packet with programs highlighting changes in the program and how programs curricula have evolved to meet new industry demands and expertise since the last accreditation period.

To better understand the level of detail of USGIF’s accreditation process it is worth expanding on the self-study report and EBK matrix completed by each academic program seeking accreditation. The program self-study report consists of several categories and criteria. Criteria for program self-evaluation currently include: (1) students, (2) program educational objectives, (3) curriculum, (4) faculty, (5) facilities, (6) institutional support and monetary resources, (7) recruiting/retention, (8) partnering with industry/professionals, (9) research, and (10) continuous improvement. Criteria have been updated to include criterion 8-10 by USGIF in the 2018 version of the Collegiate Geospatial Intelligence Accreditation Policies and Procedures guide whereas, previously only criteria 1-7 were required. This program self-study document based on the USGIF guidelines and requirements can be hundreds of pages in length including program specific or USGIF mandated appendices outlining detailed course syllabi, faculty qualifications, student GEOINT specific projects, etc. Additionally, programs seeking USGIF accreditation must complete an EBK crosswalk demonstrating how well the programs individual course objectives and outcomes align with the following competencies detailed in the EBK: Competency I: GIS & Analysis Tool, Competency II: Remote Sensing & Imagery Analysis, Competency III: Geospatial Data Management, and Competency IV: Data Visualization. Each competency listed above is further broken down into sub competencies and learning objectives that should be associated with those sub competencies to complete the EBK document. An abbreviated example of accreditation criteria associated with Competency II: Remote Sensing & Imagery Analysis from the 2019 EBK can be seen in Figure 1. A programs EBK crosswalk must effectively demonstrate 51% of its courses objectives and outcomes align with the competencies/sub competencies in the EBK to be considered for USGIF accreditation. USGIF’s current EBK also makes strides in identifying emerging competencies in the realms of data science, machine learning, virtual reality, automation, etc. (EBK 2019). The emerging competencies section in the EBK indicates USGIF is heavily involved in ensuring the modernization of program curricula based on growing industry needs.

2.3 CEAB

The Canadian Engineering Accreditation Board (CEAB) is part of Engineers Canada, and it serves as the accreditation body for all engineering programs in Canada. Each engineering program is primarily evaluated on content and graduate attributes amongst other criteria. In terms of content, a program is required to have a certain number of accreditation units in five categories: mathematics, natural sciences, engineering science, engineering design, and complementary studies. Each program course contributes a certain percentage for one or more of these content categories. Each program course also has a list of learning outcomes, where each learning outcome contributes to one of twelve graduate attributes at the introductory (I), developing (D), or applied (A) level. The twelve graduate attributes are: 1) knowledge base for engineering; 2) problem analysis; 3) investigation; 4) design; 5) use of engineering tools; 6) individual and team work; 7) communication skills; 8) professionalism; 9) impact of engineering on society and the environment; 10) ethics and equity; 11) economics and project management; and 12) life-long learning (Detchev et al., 2020). Overall, the learning outcomes from all program courses should have a comprehensive coverage of all the graduate attributes at the three levels.

T4. Positioning		
Prerequisites (P) ++	1. Units of measure and calculations	1. List System International (SI) units of measure used for mass, energy, force, illumination, brightness, wavelength, frequency, length, time, and power. 2. Define how to convert imperial units of measure to System International (SI) units of measure for mass, energy, force, illumination, brightness, wavelength, frequency, length, time, and power. 3. Identify the correct units of measure when solving equations by performing dimensional analysis.
	2. Fundamental biology	1. Describe the basics of the process of human vision. 2. Describe the hydrologic cycle. 3. Summarize the process of photosynthesis.
	3. Scientific processes	1. List the steps in the scientific method. 2. Formulate a hypothesis and null hypothesis. 3. Graph data using a histogram, scatterplot, and line graph.
	4. Physics	1. Summarize color theory. 2. Summarize the conservation of mass and energy. 3. Summarize the conservation of momentum.
	5. Mathematics	1. Solve equations requiring basic algebra (no polynomial terms). 2. Plot coordinates in a cartesian plane. 3. Substitute numeric values for constants to solve a polynomial.
Foundational (F) ++	1. Physics	1. Summarize the differences of light as a particle and light as a wave. 2. Outline Planck's law with respect to spectral density, temperature, and a black body. 3. Outline Stefan-Boltzmann's law with respect to radiant emittance and temperature.
	2. Terminology	1. Define the following terms and specify their appropriate units of measure: spectral reflectance, radiant emittance, energy flux, frequency, emissivity, phase, bandwidth, spectral resolution, illumination, reflectivity, absorption, absorbance, transmission, radiance, irradiance, radiometric resolution. 2. Define remote sensing and describe its purpose. 3. Summarize the major steps in remote sensing.
	3. Mathematics	1. Create a histogram. 2. Solve equations using polynomials. 3. Solve equations using exponents.
	4. Computer Science	1. Define bit, byte, and binary. 2. Summarize how a Red, Green, and Blue (RGB) pixel renders color. 3. Define screen resolution with respect to pixels.
Application (A) ++		1. Compare/contrast photogrammetry, radargram, and interferometry. 9. Differentiate the process, advantages, and disadvantages of mosaicking an image set with respect to positioning. 2. Characterize the process of using polarization to determine elevation. 3. Distinguish how fiduciary marks are used.
Mastery (M)		1. Create algorithms for positioning imagery with respect to custom coordinate systems, locations with extreme terrain relief, and fine scale needs. 2. Create automated systems for positioning imagery.
++ Indicates additional criteria not illustrated in the figure		

Figure 1. Abbreviated example of program criteria requirements to meet varying levels of program competency from the 2019 USGIF EBK.

2.4 EUR-ACE®

EUR-ACE® is a system of accreditation that identifies high-quality engineering degree programs (at Bachelor’s and Master’s degree levels) in Europe by providing a set of standards and requirements (EUR-ACE® 2023). It was established in 2004 by a consortium of 14 partners related to engineering education, including professional organizations, associations of engineering schools, and organizations responsible for the accreditation of engineering degrees. The system is currently coordinated by the European Network for the Accreditation of Engineering Training (ENAEE), a non-profit association that authorizes agencies to award the EUR-ACE® label (ENAEE 2023). The EUR-ACE® accreditation aims to achieve mutual recognition of accredited engineering degrees at the European level. The system is based on a bottom-up approach, requiring the active participation of national accreditation agencies. To get the EUR-ACE® accreditation, the study program must have established learning outcomes consistent with the program outcomes established in the EUR-ACE® Framework Standards for the Accreditation of Engineering Programs (EAFSG 2021) and be positively assessed in an external evaluation process or meet the quality requirements established in the aforementioned document. The EUR-ACE® system was introduced in European Countries where there were already nationally recognized engineering degree accreditation agencies and promoted in those countries where there were no degree accreditation agencies in engineering.

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Fifteen different agencies are already authorized to award the EUR-ACE® label for different Countries, such as the ASIIN – Accreditation Agency for Study Programs in Engineering Informatics, Natural Sciences and Mathematics (Germany); the CTI – Commission des Titres d'Ingénieur (France); the ANECA & IIE – National Agency for Quality Assessment and Accreditation (Spain), etc. (EUR-ACE® Agencies 2023)

For Italy, the only agency authorized to issue the EUR-ACE® label is the Agency for Certification of the Quality and EUR-ACE® Accreditation of Engineering Study Programs (QUACING), founded in 2010. More than 65 Italian study programs have been currently accredited by QUACING. Hereafter will be presented only the accreditation procedure defined by the QUACING agency regulations for Italian study programs.

The provided quality certification can be applied to: 1) BD (Bachelor's Degree courses), 2) MD (Master's Degree courses), 3) SMD (Single-cycle Master's Degree course, 5 years), 4) I and II level master's. The access to the accreditation process is subject to the presentation of an application by the study program in engineering with the following eligibility criterion: the first year of courses (third year for SMD) must be already completed for at least one year.
The overall accreditation process consists of different activities:

- Preceding the evaluation visit
  - Appointment of the evaluation group
  - Indication of the internal coordinator of the degree program
  - Date of the evaluation visit and visit agenda
- During the evaluation visit (2 days)
  - Verification of the quality requirements defined in the QUACING model
  - Promote the improvement of the quality requirements
- Following the evaluation visit
  - Evaluation report
  - Examination of the evaluation report
  - Approval of the evaluation report and formulation of the proposed certification/accreditation decision
  - Certification/accreditation decision (A – fully satisfactory; B – more than satisfactory; C – satisfactory; D – partially satisfactory; E – certification/accreditation not granted)
  - Information and appeals

The validity of the certification/accreditation depends on the obtained decision: from grade A to C the validity is of 6 years from the date of the evaluation visit with a mid-term control visit; for grade D is of 3 years from the date of the visit (QUACING 2020).

The EAFSG for the quality assurance are defined in terms of:

- Student workload requirements, described by using ECTS credits (European Credit Transfer and Accumulation System) and by setting minimum thresholds of ECTS:
  - minimum 180 ECTS credits for BD
  - minimum of 120 ECTS for MD
  - minimum of 300 ECTS for SMD
- Program outcomes framework, defines the minimum threshold suitable for the overall European engineering programs, by providing 8 learning areas (for both BD and MD) compliant with the (Dublin Descriptors 2004):
  - Knowledge and understanding;
  - Engineering Analysis;
  - Engineering Design;
  - Investigations;
  - Engineering Practice;
  - Making Judgements
  - Communication and Team-working
  - Lifelong Learning
- Program management of the study programs articulated in 5 key standards:
  - Programme Aims
  - Educational Process
  - Resources
  - Monitoring
  - Management System

For what concerns curriculum requirements, the provided standards report very broad indications about its design and activities, focusing on a student-centred teaching and learning approaches (QUACING 2020). The guidelines also refer to national standards for the design of degree programs, provided in Italy by ANVUR (Italian National Agency for the Evaluation of Universities and Research Institutes) and evaluated by CUN (National University Council). Educational activities are divided into fundamental and characterizing, where a range of ECTS related to the specific SSD have to be specified.

Currently, more than 4000 engineering degree programs have been accredited in Europe and abroad with the EUR-ACE® label. The EUR-ACE® database allows to search and filtering for labelled programs: 18 BD and 8 MD programs, explicitly related to Surveying, Geomatics, and Geospatial topics, are currently listed as labelled programs in 6 different Countries (EUR-ACE® Database 2023). In Italy, there are no specific degree programs devoted to Surveying, Geomatics, or Geospatial topics (Tucci et al., 2019). Single courses on the above-mentioned topics are usually held in Engineering degree programs related to Civil, Building, and Environmental Engineering, which can require their own EUR-ACE® label.

2.5 NCEES

The national council of examiners for engineering and surveying (NCEES) is an organization that was created in 1920 to regulate licensure for surveying in the United States, providing uniformity of licensure across all states (NCEES 2023). For the surveying profession NCEES administers two exams, the Fundamentals of Surveying (FS) and the Principles and Practice of Surveying (PS). The FS exam is the first step that students have to take in their path for surveying licensure after their graduation from an ABET accredited program. The FS exam is a computer-based exam with 110 questions. After passing the exam, surveyors can accrue experience in the field of surveying (usually four years) and take the PS exam to become licensed. The PS exam is a computer-based exam with 100 questions and is designed for surveyors who have gained at least four years of professional experience. NCEES periodically reviews the exam to ensure currency with industry and professional needs of surveyors. The existing FS exam was revised in July 2020 and the PS exam in January of 2019. Surveying / geomatics / geospatial programs monitor these changes and usually adapt their curriculum to the NCEES changes to ensure their graduates are well prepared for passing the NCEES exams.

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For each exam NCEES provides specifications with the subjects that examinees should be familiar with. For the NCEES FS exam we find the following relevant subjects (NCEES 2020):

- Surveying practices and methods:
    - Instrumentation (e.g., GNSS/GPS, levels, total stations, robotic total stations, scanners, UAS)
    - GNSS/GPS surveys (e.g., static, kinematic, OPUS, real-time networks)
- Mapping processes and methods:
    - GIS (e.g., feature collection, map projections, coordinate systems, metadata, database design and management, spatial data analysis, GIS applications)
    - Digital terrain model (e.g., machine control, triangulated irregular network [TIN], digital surface model, digital elevation model)
    - Photogrammetry and remote sensing (e.g., close range, conventional, softcopy, ground control, quality control, flight planning, project planning, UAS, drone, LiDAR, satellite, digital image analysis and processing)

In the NCEES PS exam we find the following relevant subjects (NCEES 2019):

- Professional survey practices:
    - GPS/GNSS including satellite constellations, static GPS, RTK, PPP, and virtual networks
    - GIS; GIS spatial databases and metadata; Datums and projections related to GIS

2.6 CBEPS

The Canadian Board of Examiners for Professional Surveyors (CBEPS) is the accreditation body for all Canadian jurisdictions except for Quebec. CBEPS has a much more detailed approach to accreditation than CEAB. The "old" CBEPS syllabus is grandfathered in till 2026 and includes twelve core and one out of five elective subjects (CBEPS, 2019):

- C1 Mathematics; C2 Least squares estimation and data analysis; C3 Advanced surveying; C4 Coordinate systems and map projections; C5 Geospatial information systems; C6 Geodetic positioning; C7 Remote sensing and photogrammetry; C8 Cadastral studies; C9 Survey law; C10 Land use planning and economics of land development; C11 Business practices and the profession; and C12 Hydrography
- E1 Spatial databases and land information systems; E2 Advanced hydrography; E3 Environmental management; E4 Advanced remote sensing; and E5 Advanced photogrammetry

The syllabus for each subject is broken down into topics (or chapter headings) and each chapter heading has a list of sub-topics. Typically, one or two university courses are necessary to cover the required topics for each of the CBEPS subjects. A person who fulfills the above listed twelve core and one elective subjects is issued the "CBEPS certificate of completion".

The "new" CBEPS syllabus is about to be released this year (CBEPS, 2023). The syllabus is broken down into eight bins or clusters: S1 Mathematics and science; S2 Modelling and analysis; S3 Geodesy; S4 Surveying; S5 Remote sensing; S6 Geospatial information systems; S7 Law, tenure, boundaries, cadastres, and planning; S8 Professional practice. Each of these bins contains a list of key principles (or subjects) and each key principle comes with associated syllabus items (or topics) and competencies/learning outcomes. This new syllabus will be phased in, while the old one will be phased out, in the next three years.

3. DISCUSSION

The previous paragraphs provide a brief overview of each accreditation and licensure body that is considered in this paper. These are major accreditation bodies followed by thousands of programs in Northern America and Europe. We should highlight and praise the exemplary service that these organizations provide to the students, employers, and in general to society. By providing standards that institutions can follow, the accreditation and licensure bodies ensure that students receive a high quality of education, and that they achieve / meet specific technical and non-technical outcomes and competencies that are essential for a continuously evolving global workforce. Due to rapid technological advancement in the fields of Photogrammetry, Remote Sensing, and Geospatial Sciences it is important that curricula are current, and they are frequently reviewed and updated. The discussion for the reviewed accreditation and licensure bodies is focused on the following main elements (1) detail curricula requirements, (2) currency in curricula requirements, (3) flexibility for changing curricula, and (4) a system / framework for updating the curricula.

With respect to the detail and currency of curricula requirements, we notice that most bodies provide very broad requirements. For instance, ABET provides a percentage range of the overall credits that should focus on technical content with some additional discipline specific curricula requirements being provided as a list of subject areas. Similarly, the NCEES provides a good list of topics and sub-topics that students should be familiar with. Other bodies such as the CEAB and EUR-ACE® do not provide specific curricula requirements. Because of the broad requirements it is difficult to answer whether their curricula requirements are current or not. This greatly depends on the individual program and the system that they have implemented in identifying needs for curricula changes. In the specific case of EUR-ACE the curricula requirements definition depends also on the National Agencies devoted to the accreditation of the EUR-ACE label. As an example, QUACING Agency refers to national standards for the topic list and their credits; the ASIIN Agency, responsible for German accreditations, defines a list of topics (geodesy, remote sensing, photogrammetry, etc.) necessary for a specific degree program (e.g., MD in "Geomatics"), and a sort of grade for the expected knowledge (sound, profound, basic knowledge) (ASIIN 2020). Compared to the other bodies, USGIF and CBEPS provide an unprecedented level of detail in the curricula requirements (e.g., see Figure 1). The USGIF and CBEPS approach, although burdensome, is advantageous because programs are given specific content that programs need to cover. Therefore, updating of the curricula mostly rests with USGIF and CBEPS, respectively. Through this review, we have found the USGIF and the new CBEPS curricula to be the most up to date. It should be noted that while the new CBEPS syllabus is now modernized, it is even more detailed than the old one. It would be good to see the key principles (or subjects) and/or their associated competencies / learning outcomes be categorized into mandatory (i.e., must-haves) and optional (i.e., nice-to-haves), where all mandatory and a certain portion of the optional must be met.

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The following questions also arise: What is the level of flexibility that accreditation bodies should allow in updating / changing their curricula? Also, how often should the curricula requirements be updated considering the rapid technological changes? Some subjects and skills can become obsolete, and new topics need to be introduced. For example, we need to consider the new paradigm for the future surveyor where skills of operating instruments and software (e.g., sharp-eyed, extracting linework manually) become obsolete because datasets are now collected with more automated assistance (e.g., automatic target aiming, automatic linework extraction) (Staiger 2023). Technical and mathematical knowledge, programming skills, business administration and project management, and other soft skills (e.g., communication and teamwork) start to become more important for the future surveyor. The broader approach followed by the other accreditation bodies generates greater flexibility and freedom for introducing and implementing curricula changes. However, for the same reasons we sometimes find programs that still have courses with obsolete descriptions and content, because faculty and programs are not "forced" to update their curricula by the accrediting body. Many times, this is often connected with having faculty teaching the same course for several years and finding it hard to understand, integrate, and adjust to technological changes. Some accreditation bodies, like ABET, place the burden of updating the curricula on an advisory board as well as the faculty teaching in the program. They need to meet periodically, and they are tasked with ensuring that the program curricula are up to date with respect to the current industry needs. Therefore, curricula changes can be identified fairly quickly. We should also point out that even in the case of a program identifying curricula changes, these can take several years to be implemented. Most institutions have multi-step revision processes for creating new courses and updating existing ones, which can lead to additional delays (e.g., 2 or more years) in updating curricula. Considering the rapid technological changes, internal institutional processes, and that accreditation cycles are about 5-6 years, we recommend reviewing and updating curricula every 5-6 years or sooner.

Accreditation licensing body	Detail curricula Requirements	Currency in curricula requirements	Flexibility for changing curricula	System for curricula updating
ABET	No	N/A	Yes	Yes
USGIF	Yes	Yes	Yes	No
CEAB	No	N/A	N/A	N/A
EUR-ACE® (QUACING)	No	N/A	N/A	N/A
NCEES	Yes	Yes	Yes	N/A
CBEPS	Yes	Yes	No	N/A

Table 2. High level comparison of reviewed accreditation and licensure bodies

We also identify a lack of guidance for developing curricula requirements. The International Society of Photogrammetry and Remote Sensing (ISPRS) being an international organization that pulls togethers geospatial sciences leaders from academia, government, and the private sector, should be a leader in defining and updating the curricula requirements for courses in photogrammetry, remote sensing, and geospatial sciences. This can be accomplished through the related Technical Commissions, and specifically through Technical Commission V: Education and Outreach. The working groups within the technical commission, and collaborating with other technical commissions, can create sample curricula and periodically review them and update them. These then can be adopted and adapted by programs that want to teach the above subjects.

4. CONCLUSIONS

The fields of Photogrammetry, Remote Sensing, and Geospatial Sciences are experiencing rapid technological changes. This means that academic programs need to monitor those changes and respond in a timely manner by updating their curricula. Another integral component of many programs is considering accreditation and licensure requirements. In this paper we have reviewed four accreditation bodies that are mostly followed in Northern America and Europe. We also reviewed the licensure bodies for surveyors/geomaticians in the USA and Canada. Our review shows that most accreditation bodies have broad curricula requirements with only USGIF and CBEPS having more detailed requirements. All bodies provide flexibility for updating the curricula; however, a system for assisting programs to identify curricula changes is somewhat lacking. It is worth mentioning ABET's approach where an advisory board consisted of alumni, professionals, employers, government, and instrument manufacturers, can provide periodic feedback to the program.

We also point out that ISPRS can assist in defining and updating curricula requirements for courses in photogrammetry, remote sensing, and geospatial sciences. In our future work, and in our capacity as the officers of Working Group I of Technical Commission V (Defining and updating the curricula requirements for courses in photogrammetry, remote sensing, and geospatial sciences), we will work on defining the basic competencies that students should obtain to support existing and future industry needs. Finally, we will document and disseminate sample curricula that other programs can adopt and adapt as needed.

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