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Developing a Stackable Programme Based on the Advanced Air Mobility Systems MSc Course

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Abstract: This study proposes the development of content and materials for a stackable programme that aligns with the existing Cranfield University Advanced Air Mobility Systems (AAMS) MSc Course and integrates with ongoing Future Flight Challenge (FFC) projects, emerging research and development (R&D) capacities, and the growing demand for skilled professionals in the sector. The programme is structured into four phases: enhancement of taught modules through technology-enhanced teaching (TET), enrichment of project-based learning, bolstering of student experience and career development, and a stackable approach adaptable to various educational levels. This approach was evaluated using courses from the 2022/23 and 2023/24 academic years.

Keywords: Advanced Air Mobility, Future Flight, Cranfield University, Stackable Programme, Education Degrees.

1. INTRODUCTION

Advanced Air Mobility (AAM) represents an integrated framework designed to embed urban, regional, and low-altitude uncrewed aircraft systems (UAS) seamlessly into daily life, enhancing urban and regional connectivity. This system underscores a system-of-systems approach which prioritizes safety through real-time monitoring, collaborative airspace management, automated vehicle operations, and the development of vertiport infrastructure. AAM can be categorized into Urban Air Mobility (UAM) utilizing eVTOL aircraft within cities, Low-Altitude Uncrewed Aircraft for targeted deliveries, and Regional Air Mobility (RAM) leveraging existing airports for longer-distance travel (FAA NextGen office, 2023). Enabled by technological advancements in electrification and automation, AAM expands aviation's role in passenger transport, cargo delivery, emergency response, and infrastructure management, integrating aviation more profoundly into daily activities.

In the UK, the government and industry proposed the Future Flight Challenge (FFC) to establish a roadmap for the development of a new aviation system by 2030 (UK Research and Innovation, 2021). The roadmap sets the vision for the future aviation system and will demonstrate the safe integration and operation of drones, AAM and regional aircraft, with advancements in electrification and autonomy. The shortage of research and industrial personnel required to support the transition of AAM into future airspace was classed as essential by the UK Aerospace Strategy and EU studies (UK Research and Innovation, 2022). To maintain the status, personnel training is necessary for AAM delivery. Conventional aviation currently supports approximately 536,000 UK jobs, a figure projected to escalate to one million by 2030 due to emerging AAM roles. Aligning with the future flight vision, the UK has developed a clear plan and strategy for the emerging future flight workforce market (UK Department for Transport, 2024). An example of this is the £67 million investment in Cranfield University's Digital Aviation Research and Technology Centre (DARTeC), which aims to spearhead the UK's research into digital aviation.

As a prominent academic entity in FFC programs, Cranfield University has accumulated significant expertise, experience, and research and development (R&D) infrastructures in the realm of future flight, as depicted in Fig. 1 (Conrad et al., 2023; Turco et al., 2024; Wen et al., 2024; Zhao et al., 2023a, 2023b). In response to the continuous evolution in future flight, Cranfield is committed to initiatives that encompass the digitalization of Air Traffic Management (ATM), expansion of UAS applications, and their integration into manned aviation airspace. These advancements are generating substantial demand for skilled graduates who can contribute significantly to the advancement of AAM applications.

In 2022, Cranfield established the Advanced Air Mobility Systems (AAMS) MSc course, a Master's level (QAA FHEQ level 7) program offered by the Center for Autonomous and Cyber-Physical Systems. The course is aligned with the Future Flight Roadmap and Vision, aimed at delivering a robust understanding of the future flight ecosystem, its key players, roles and interdependencies, as well as key enablers in terms of products, systems, services and technologies. Particular attention to the course is given to real-world applications with strong industrial links. The concerns of engineering, regulations, safety and ethics in the context of the future flight ecosystem are also incorporated. This course targets both fresh STEM graduates and engineers currently engaged in the aviation, aerospace, and autonomous sectors,

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equipping them with the knowledge to innovate in intelligent and connected air traffic systems, thus enhancing their career prospects and providing substantial benefits to their employers.

We are acutely aware of the need to enhance our course to equip participants with the skills necessary to transform the aviation industry and to apply their knowledge in deploying emerging automated and autonomous solutions in the market. Additionally, there is a recognized need for a flexible, self-paced, and modular learning structure, hence the proposal for an online/offline stackable course.

This study thereby introduces a stackable training program on AAM designed to educate engineers on the comprehensive system-of-systems architecture of the integrated ATM and Uncrewed Traffic Management (UTM) ecosystems, along with their enabling technologies and infrastructures, including Communications, Navigation, and Surveillance (CNS), and associated intelligent solutions such as Artificial Intelligence (AI) and cyber-physical systems. This stackable programme will be based on a suite of continuing professional development (CPD) courses with attendees gaining credits from each one of them. That enables them to "stack" modular credentials to build to the level of education which suits them at their pace. And could lead to Postgraduate Certificate (PgCert), Postgraduate Diploma (PgDip), and Master of Science (MSc). Throughout this journey, the attendees will be recognized for their successful completion of a programme module.

This program has been funded by the UKRI Future flight: closing the skills gaps competition. The main contributions of this program are as follows:

- Update existing CPD course content and material where needed, such as those relevant to standards and regulations which are fast-growing and heavily targeted across the future flight sector.
- Complete the knowledge graph embedded in the course for more comprehensive coverage of the key capability and skills gaps identified by the future flight team, e.g., novel vehicle types and hydrogen fuel management under the broader Net Zero Strategy.
- Bring direct hands-on skills to attendees by means of exposing them to real-world R&D practices within Cranfield's various FFC projects.
- Tighten links with industrial partners to allow attendees to directly seek guidance and advice, leveraging the Industrial Advisory Board (IAB) of the course and Cranfield's DARTeC.

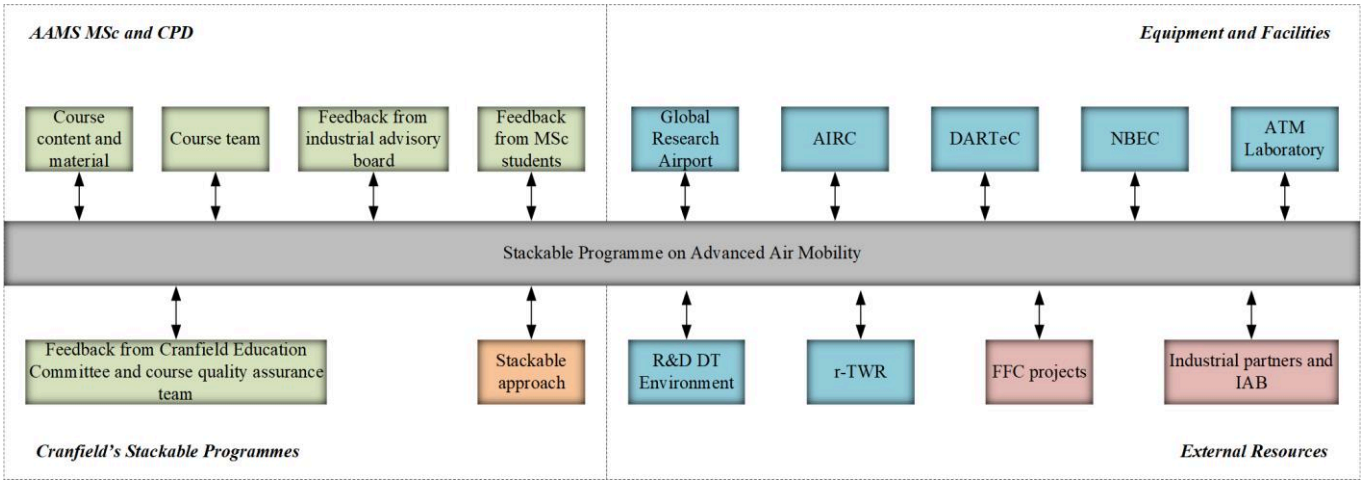


Figure 1. Cranfield University's experience, expertise, and R&D infrastructures in the future flight.

2. METHODOLOGY

This project capitalizes on our recent advancements from the future flight initiatives, leveraging our new research capabilities, academic resources, and industry collaborations to systematically enhance and expand the curriculum for our stackable program. As illustrated in Fig. 2, the methodology integrates several key activities designed to refine the existing course materials and further develop the program's modular structure.

2.1 Enhanced Course Materials and Contents

This project has introduced several innovations to enhance the course materials for the stackable program:

- The taught modules utilize a combination of standard teaching and assessment methods alongside technology-enhanced teaching (TET) techniques. Technologies such as software and videos are integral, facilitated by platforms like Canvas and the Virtual Learning Environment (VLE), which support both onsite and remote access.
- We have systematically reviewed and updated existing course materials to align with the Future Flight Roadmap and Vision. This includes enhancements to lecture notes through the creation, addition, or revision of content.

- We continue to implement problem-based learning, now enriched by our new capabilities such as the R&D Digital Twin (DT) Environment, digitalized ATM system, UTM systems from industrial partners like Thales' TopSky, and HILDA High-performance computing (HPC).

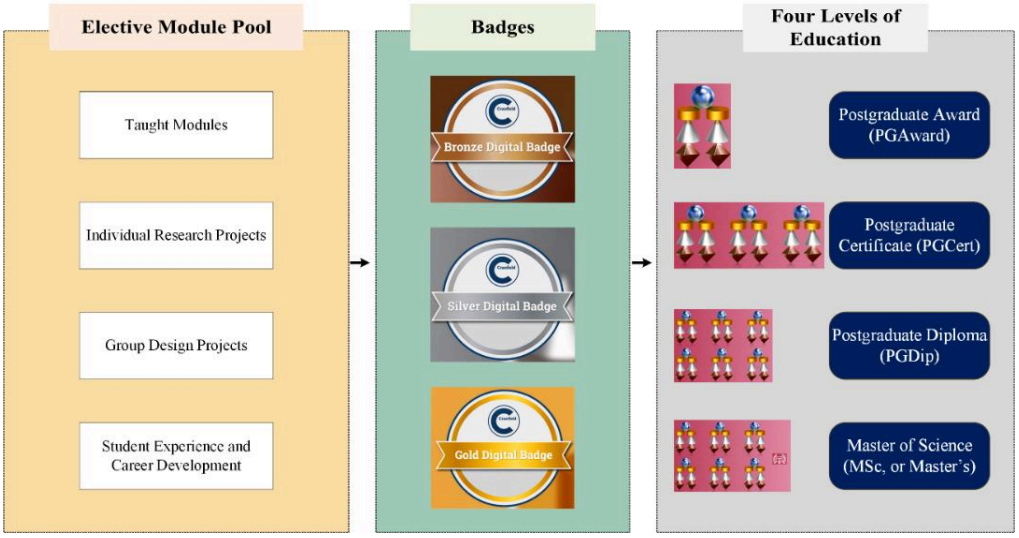


Figure 2. The proposed SPAAM approach.

Taught Modules. Fig. 3 illustrates the taught modules based on the AAMS MSc course. The nine taught modules are structured into four key components: AAM system of systems, Enabling Technologies, Intelligent Solutions, and Training.

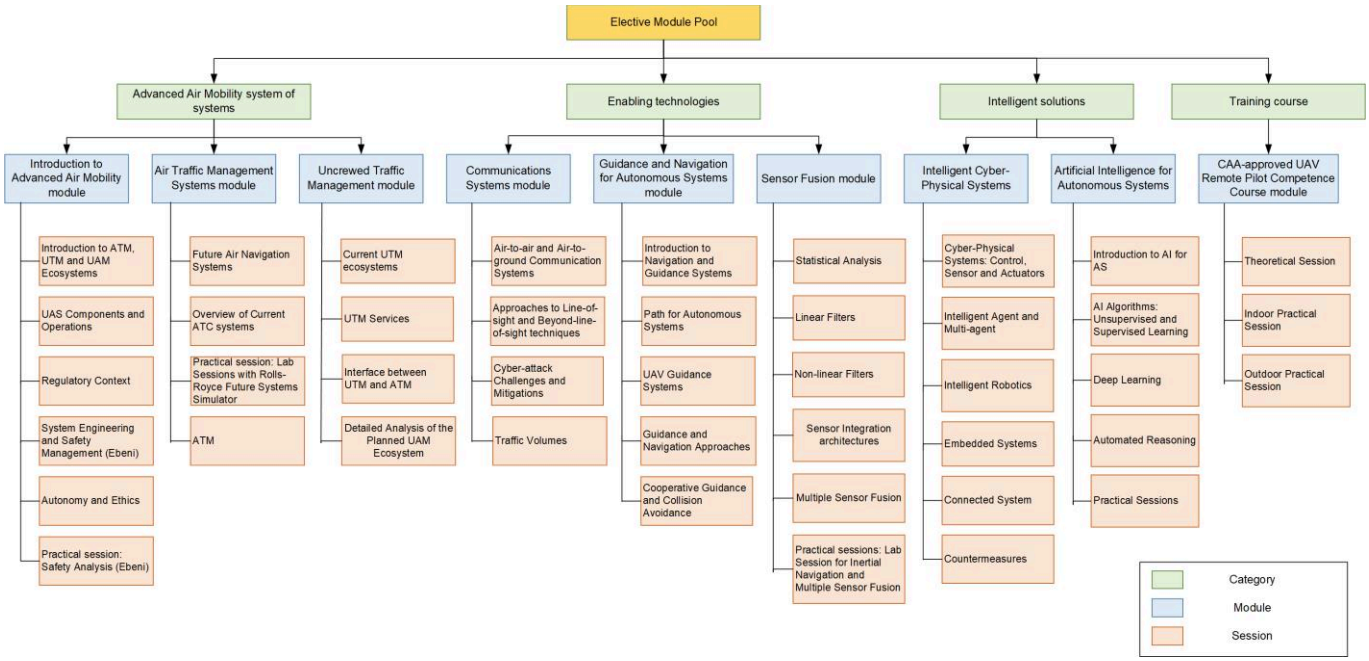


Figure 3. The AAMS MSc course structure.

Modifications have been made based on suggestions from the IAB and alignment with strategic visions. In details,

- Enhancing the Introduction to AAM Module: Updates include the Future Flight Roadmap and Vision, Standards and Regulations, and Advances in Net Zero strategies, including hydrogen fuel applications.
- Enhancing the ATM Systems Module: Enhancements cover ATM Digitalization, Automation Decision Support Tools, and Safety Management practices.
- Enhancing the UTM Module: Includes practical sessions utilizing newly deployed UTM systems, such as ANRA's SmartSkies and Thales' TopSky.

- Development of a New Statistical Learning Methods Module.
- Development of a New Data Analytics and Visualization Module.
- Development of a New Intelligent Airspace Management Solutions Module.

Adding New Sessions to the Civil Aviation Authority (CAA)-Approved UAV Remote Pilot Competence Course

Group Design Project (GDP). The GDP has been enhanced based on the classic Systems Engineering 'V' model and NASA's system design process to facilitate system design. The proposed approach encompasses the required activities to capture requirements, design solutions, and define all Test and Evaluation (T&E) activities. DT technologies and the ATM/UTM Research and Development DT Environment (AURD) are integrated into the GDP.

IRP. Topics for the IRP are sourced from industrial partners or are extensions of real-world research projects, making use of problem-based learning methods to provide practical experience. The IRP topics form a dynamic pool, continually updated to reflect the latest challenges and innovations in the field.

AURD. The AURD is an AWS cloud-based DT system that enables the safe, scalable, and sustainable development, verification, and validation of AAM systems, subsystems, and components. It is particularly promising for the course owing to its ability to integrate theoretical and practical learning, its alignment with AAMS's trends on autonomy and digitalization, and its scalability and adaptability. As a cloud-based Digital Twin for AURD system that enables the simulating/interfacing with AAM systems/subsystems/components, the AURD can support the students to upskill on all aspects of AAM operations.

2.2 The Stackable Approach

This program is based on a suite of CPD courses in AAM, with participants earning credits from each course. These credits can be "stacked," allowing attendees to progressively build their qualifications at their own pace. This flexible system can lead to PgCert, PgDip, or MSc. Unlike traditional MSc courses, participants in this stackable program are not required to register at the start of the academic year. Instead, they may register for specific CPDs at any point during the program, enhancing flexibility.

The stackable program allows students to accumulate credits by successfully completing each module. The curriculum includes three primary components: Taught Modules: Each of the eight modules is worth 10 credits; GDP: Valued at 40 credits; IRP: Valued at 80 credits.

Additionally, two optional modules, "Intelligent Airspace Management Solutions" and the "UAV Remote Pilot Competence Course," are offered but do not contribute credits towards the qualifications.

As illustrated in Fig. 4, upon the successful completion of program components, participants are eligible for the following qualifications: PgCert: Requires at least 60 credits, including compulsory completion of Modules 1, 2, and 6; PgDip: Participants must accumulate at least 120 credits, including Modules 1-8 along with the GDP; MSc: In addition to the PgDip requirements, participants must successfully complete the IRP thesis. An MSc is awarded upon achieving a total of 200 credits.

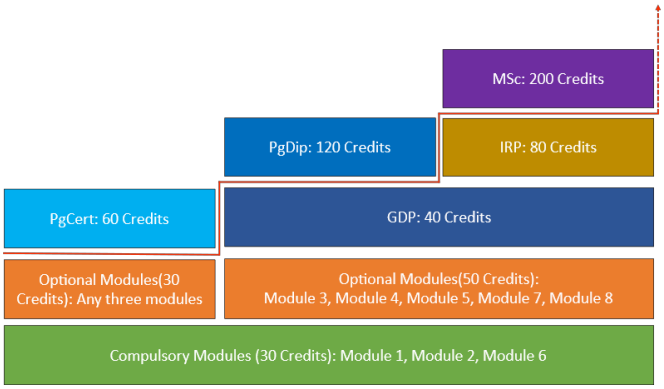


Figure 4. Details of the stackable approach.

3. EVALUATION AND RESULTS

This section presents a comprehensive evaluation approach, utilizing various methods to assess the educational effectiveness of the course. These methods include a taught experience questionnaire for students, project-based learning evaluations involving IAB, and reflective reviews with the University's Education Committee.

3.1 MSc Students Feedback

A questionnaire was designed for student feedback, drawing upon the Postgraduate Taught Experience Survey (PTES) provided by AdvanceHE. The survey was conducted among MSc students, collecting feedback through both ratings and comments across eleven sections of the course. Ratings for each question ranged from 1 to 5, where 1 indicates "very poor," 2 stands for "poor," 3 signifies "neither poor nor good," 4 represents "good," and 5 denotes "very good." Percentages were calculated based on the number of responses that received a rating of either 4 or 5. The questionnaire comprised a total of 40 questions. The results are summarized in Table 1.

3.2 IAB Feedback

IAB offer an objective and independent assessment of the course's evaluation processes, ensuring alignment with both industry standards and academic benchmarks. This external perspective is crucial for validating the credibility and reliability of the course assessments.

Feedback from industry experts on GDP and IRP is instrumental. It ensures that students engage with challenges and topics that are relevant and applicable in the professional domain. Such input helps bridge the gap between academic theories and practical industry expectations, enhancing the course's applicability.

Table 1. Summary of students' feedback on course experience

Section	Average Rating	Average percentage (%)
Teaching and Learning	3.83	76.6
Engagement	4.10	82.0
Assessment and Feedback	3.65	73.0
Dissertation/Major Project	3.83	76.6
Organization and Management	3.53	70.6
Resources and Services	4.39	87.8
Support	3.71	74.2
Skills Development	4.06	81.2
Community	3.89	77.8
Overall Experience of Course	**3.67**	**73.4**

For example, based on recommendations from the IAB, the GDP is continuously refined using a project-based learning approach. The following enhancements, informed by the feedback, will be implemented to improve the GDP:

- NATS and Skyports will play active roles in the GDP, providing industry-specific requirements and support.
- The GDP methodology will be upgraded to include the classic Systems Engineering 'V' model and NASA's system design process. This enhancement will incorporate proper project and engineering management practices into the GDP.
- NATS and Skyports will propose use cases that reflect the latest advancements in AAM, effectively connecting academic learning with evolving industry trends.

3.2 Education Committee Feedback

Feedback from the University Education Committee is pivotal in aligning the course with the overarching educational goals and strategic priorities of the institution. This input is crucial for ensuring the course contributes effectively to the university's mission, vision, and commitment to academic excellence. It also facilitates navigation through regulatory requirements, accreditation standards, and institutional policies, maintaining the course's role as a cornerstone of the university's commitment to providing high-quality, forward-looking education.

Active responses have been made to recommendations received from the Course Validation Panel (CVP), with details outlined in Table 2.

Through feedback from the University Education Committee, the adaptations and innovations made by the course team are documented. Changes made in response to student feedback or external examiners' critiques are also incorporated. These feedback loops create a dynamic and responsive educational environment, fostering a course that not only meets but often exceeds the expectations of students, aligns with industry demands, maintains academic integrity, and strategically contributes to the overarching goals of our esteemed institution. This collaborative and iterative process is a journey of perpetual refinement, where each cycle of feedback propels our course toward educational excellence and prepares our students for the challenges and opportunities of the future.

4. CONCLUSIONS

This paper presents a stackable programme designed to upgrade the AAMS MSc Course, aligning it with both industry needs and the future flight vision. Evaluations were conducted with feedback from AAMS MSc students, IAB, and the University Education Committee. The conclusions drawn from this study include:

- Enhanced Course Materials and Content: The project successfully improved the course materials and content for the AAMS MSc courses. Leveraging new academic and research capacities has made the course more relevant and comprehensive.
- Development of a Stackable Approach: The project established a tiered elective module pool, enabling participants to customize their education to different levels, which in turn benefits their experience and career development.
- Comprehensive Assessment and Feedback Integration: An assessment report was created that incorporates feedback from various stakeholders, including attendees, IAB, and the Cranfield Education Committee. This feedback was instrumental in refining the course to meet the high standards expected by all involved parties.

As for future work, the following steps are recommended to advance the programme further:

- Continuously enhance and update the AAMS MSc course materials to align with the latest industry trends and technological advancements.
- Broaden links with industrial partners to provide students with direct guidance and advice.
- Continue to enhance and refine the stackable programme to cater to varying experience levels and career aspirations.
- Regularly incorporate feedback from stakeholders, including attendees, external examiners, and industrial advisory panels in the future.

Table 2. The University Education Committee feedback

Recommendation		Response by Course Team
R1	Review the potential of IET accreditation and apprenticeship opportunities being taken forward.	Review of potential accreditation and apprenticeship bodies has been performed, such as BCS, IET and RAeS, as well as their requirements in general. The course team have identified RAeS as potentially the best option for the AAMS course specifically. Comments have been also exchanged with School Deputy Director of Education.
R2	Review the teaching strategy to ensure a variety of educational approaches.	Various educational approaches have been implemented, such as designing specific practical sessions for the students to realize what they learn from the lecture sessions, systematically restructuring the sessions within some modules, engaging a number of external lecturers to provide students with insights from industry directly.
R3	Reflect on the balance of lecture hours to practical hours in each module and ensure document consistency.	For each taught module that involves both lecture and practical parts, we have ensured that the documented hours are well followed.
R4	Think more broadly about the assessment strategy (for example introducing a variety of assessment types, both formative and summative).	A variety of assessment types have been implemented including both formative and summative to ensure a broad way for the assessment.
R5	Review the summative assessment details in the module descriptor of the 'Guidance and Navigation for Autonomous Systems' module to ensure there is clarity on what a student is expected to do and how they will receive feedback.	Assessment details have been communicated with the AAMS students to ensure clarity of the summative assessment.
R6	Leverage and engage resources across the University.	Numerous supports have been received across the University, including the SAS team, student experience team (specifically for supporting the creation of the VLE course pages), Library, Registrar, etc. From the course delivery perspective, some of our taught modules are currently shared by other MSc courses, which is of great support.

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