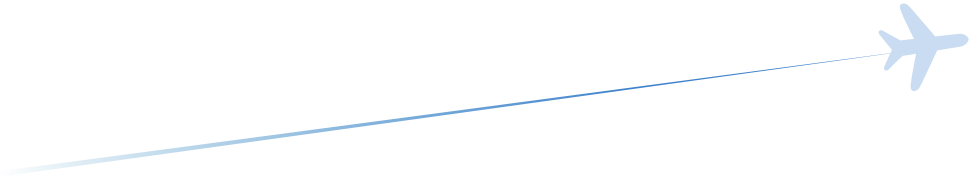

D3.9 The Engage wiki - an update on the KTN's knowledge hub functionality, research maps and repository

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Copyright Statement

Engage

THE SESAR KNOWLEDGE TRANSFER NETWORK

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Abstract

This report is a reference document for the Engage wiki. It summarises the key features developed, their status and the legacy planning for the wiki. *Inter alia*, the wiki hosts the first interactive research map of European ATM, an ATM concepts roadmap, the first consolidated listing of European university programmes and a new, one-stop (data) repository for the research community. Key outputs and results enabled through the wiki, such as mapping research gaps, are discussed in Engage D3.10, which focuses specifically on opportunities for innovative ATM research. These deliverables comprise a pair of legacy deliverables of particular use and importance for any KTN launched within the SESAR 3 Exploratory Research programme.

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1 Introduction

This report is a **reference document for the Engage wiki**. It summarises the key features developed, their status and the legacy planning for the wiki. This work has been conducted over several years, with increased activity in 2020 and 2021 to resolve underlying data provision issues. Table 1-1 summarises the key content features, their status, and the section of the deliverable (where appropriate) where the corresponding details are presented.

Key outputs and results enabled through the wiki are discussed in Engage D3.10 [7], the basic framework of which is structured around three **research pillars**: (i) a research gap analysis; (ii) the Engage thematic challenges [6]; and, (iii) 'horizon' flagships. We introduce (i) and (iii) in this deliverable. Whilst D3.10 focuses specifically on opportunities for innovative ATM research, D3.9 focuses on the development and implementation of the wiki *per se*. Together with D3.10, this deliverable comprises a **pair of legacy deliverables** that the consortium considers will be of particular use and importance for any KTN launched within the SESAR 3 Exploratory Research programme.

The Engage wiki was launched at the SESAR Innovation Days' closing session, on 10 December 2020. User registration was opened on the same day. Any researcher or user may apply for a (free) authorised account to become an active member of SESAR's Knowledge Transfer Network community.

The live link to wiki is: https://wikiengagektn.com/EngageWiki

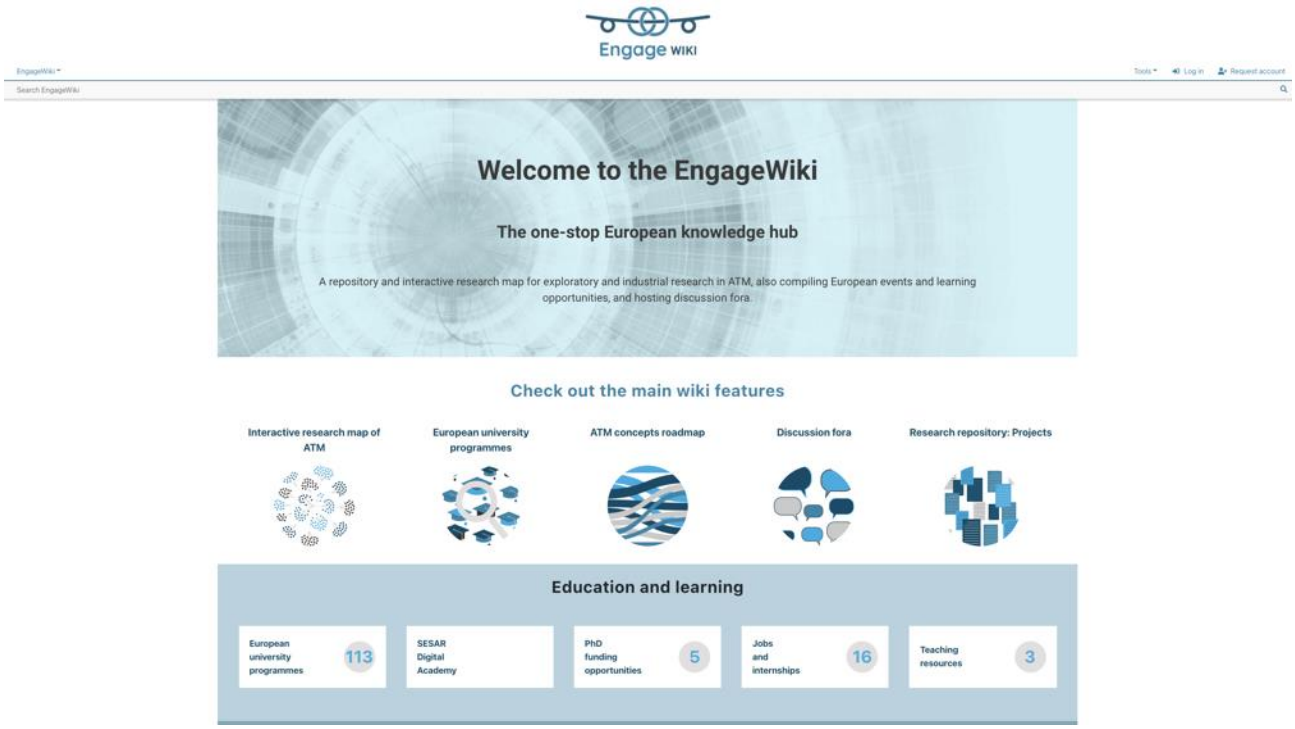


Figure 1-1 Wiki landing page

Table 1-1 Wiki features, status and links

Wiki activity / page name	Short description	Current status	Link
Interactive research map	Interactive research map visualisation where users can explore the results of a bottom-up clustering from unsupervised machine learning applied to SESAR 1 and SESAR 2020 projects and papers	**Active** in the wiki; detailed in this report in Section 3	https://wikiengagektn.com/EngageWiki:Interactive_research_map_of_ATM
ATM concepts roadmap	Interactive roadmap that shows how previous (SESAR) research connects with the flagship activities of the 2020 Strategic Research and Innovation Agenda, and identifies future challenges	**Active** in the wiki; detailed in this report in Section 4	https://wikiengagektn.com/EngageWiki:ATM_concepts_roadmap
Discussion fora	Discussion fora for common interest research communities. Open to all registered users	**Active** in the wiki; detailed in this report in Section 5	https://wikiengagektn.com/Special:WikiForum
European university programmes	Interactive database of undergraduate (UG) and postgraduate (PG) programmes offered in Europe; features UG courses related to air transport engineering and aviation management and PG courses that perform ATM-related research; user-updateable	**Active** in the wiki; detailed in this report in Section 6	https://wikiengagektn.com/EngageWiki:Programmes
Teaching resources	Three introductory courses that are available for use by any (academic) institution, free of charge, via a registration process hosted on the EngageWiki	**Active** in the wiki; detailed in this report in Section 7	https://wikiengagektn.com/Teaching_Resources
Research repository	One-stop, go-to source for information: a single European point of entry for ATM knowledge. With improved search functionality and accessible meta-source of research data	**Active** in the wiki; detailed in this report in Section 8	https://wikiengagektn.com/EngageWiki:Research_repository
PhD funding opportunities	Open PhD funding opportunities. Open to registered users to add new opportunities	**Active i**n the wiki	https://wikiengagektn.com/EngageWiki:PhD_funding_opportunities
Jobs and internships	Vacant job and internship positions. Open to registered users to add new vacancies	**Active i**n the wiki	https://wikiengagektn.com/EngageWiki:Jobs_and_internships

2 Data sources and background

2.1 Background

Data required by the interactive research map, ATM concepts roadmap and research repository consist primarily of SESAR project deliverables, Solution data packs and conference papers. The sourcing of this material started in May 2019 and has continued into November 2021, feeding the updated wiki functionality. In addition to sourcing material, metadata describing each project, deliverable and conference paper were also required – this proved to be a challenging task, with a large amount of manual processing carried out for older material.

As reported in D3.8 [8] material has been acquired from the SESAR 1 and SESAR 2020 programmes:

- SESAR 1 projects and activities 2008-2016 (see Figure 2-1);
- SESAR 2020 projects and activities 2015-2024 (see Figure 2-2).

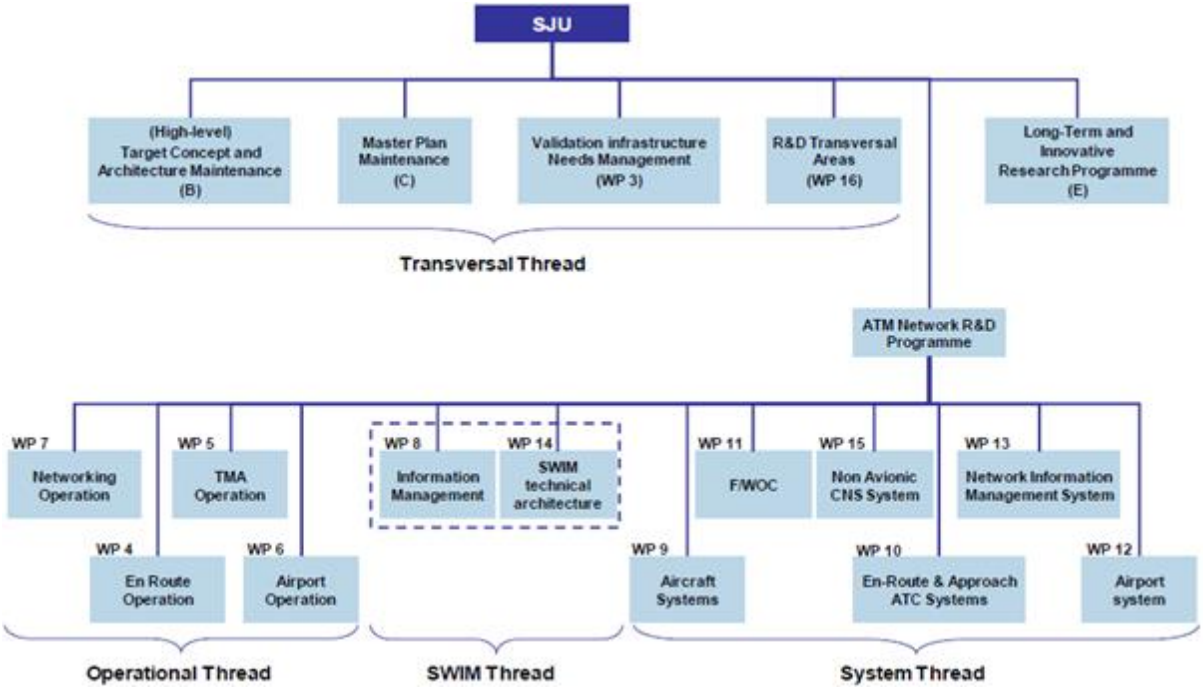


Figure 2-1 WP activities of the SESAR 1 Programme 2008-2016

Source: [12] (Figure 3)

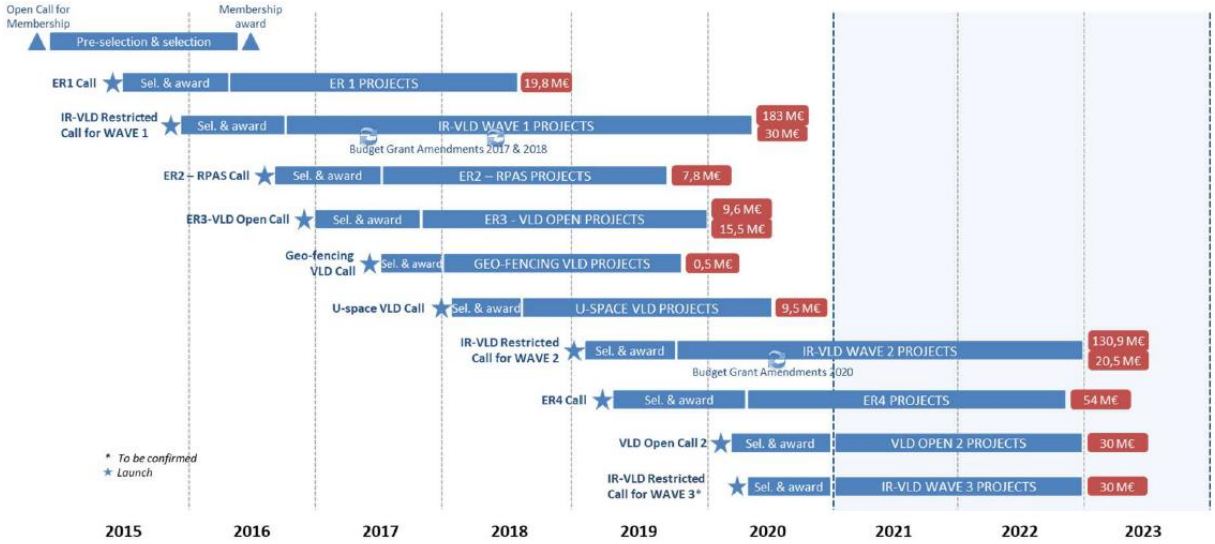


Figure 2-2 Call activities of the SESAR 2020 Programme 2015-2022, as of 2021

Source: [14] (Figure 10)

At the launch of the first public version of the wiki (December 2020), the interactive research map and ATM concepts roadmap had been developed using deliverables from 338 SESAR 1 and SESAR 2020 projects, along with papers from the annual SESAR Innovation Days conferences. However, there were gaps in the coverage of projects from SESAR 2020 Calls, missing SESAR 1 metadata and unfortunately no deliverables were GDPR-ready for publication in the repository.

2.2 Data sources

Since the launch of the wiki, further material has been sourced and corresponding metadata prepared by the Engage team. Of the 456 SESAR 1 and SESAR 2020 projects identified to date, material has been obtained for 426 (i.e. 88 projects added since the launch). Table 2-1 lists the SESAR Calls and projects from which material has been sourced (1873 deliverables).

Table 2-1 SESAR material

SESAR programme	Calls	Projects	Deliverables
SESAR1	IR	226	775
	IR-AIRE III	7	7
	IR-Demo	8	8
	IR-LSD	14	15
	IR-RPAS	9	9
	WP-E	43	157
SESAR 2020	IR Wave 1	24	224
	IR Wave 2	2	10
	ER1	28	242
	ER2	28	242
	ER3	16	172
	ER4	40	155
Total	12	426	1873

SESAR 1 deliverables were made available to Engage by the SJU from various SESAR libraries, covering industrial research Calls ('Best and Final Offer', RPAS, trials and demonstrations) and Workpackage E (Exploratory Research Calls). Whilst restricted material could be analysed for use by the interactive research map (Section 3) and ATM concepts roadmap (Section 4), only public material could be published in the research repository (see Section 8) after being anonymised. The Engage Team are grateful for the help given by the SJU with the task of anonymising these deliverables, to conform to GDPR requirements.

In contrast, published SESAR 2020 deliverables and Solution data packs were sourced from CORDIS [11], including industrial research waves 1 and 2, and four exploratory research Calls. Note that each Solution data pack could consist of multiple deliverables. All SESAR 2020 material could be analysed for the wiki tools, with the research repository linking back to the original material in CORDIS.

A total of 1873 deliverables have been sourced to date. Note that new material continues to be published by on-going SESAR 2020 projects.

In parallel to the sourcing of SESAR deliverables, conference papers presented at the SESAR Innovation Days (SIDs) and the USA/Europe ATM Research and Development Seminars (ATM Seminar) have been collated with the assistance of EUROCONTROL (See Table 2-2 and Table 2-3). A total of 310 SIDs papers (2011-2020) and 343 ATM Seminar papers (2011-2019) are now available in the wiki. Known associations with SESAR projects have been identified, e.g. of the 34 papers presented at the 2018 edition of the SIDs, 9 papers were associated with ER1 projects, and 1 each for ER2 and ER3 projects. Note that the anonymisation of published conference papers is neither required nor desirable.

Table 2-2 SIDs papers sourced and matched with SESAR projects

SIDs	Total Papers	Papers associated with projects*
2011	28	17 WP-E
2012	27	14 WP-E; 1 IR
2013	28	13 WP-E; 1 IR
2014	30	19 WP-E; 2 IR
2015	28	17 WP-E; 1 IR
2016	32	3 WP-E; 2 IR; 6 ER1
2017	35	20 ER1
2018	34	9 ER1; 1 ER2; 1 ER3
2019	38	1 ER1; 4 ER3; 6 IR Wave 1
2020	30	10 ER3

* SIDs papers determined to be associated with SESAR projects; SESAR projects in scope (i.e. papers from non-SESAR projects have also been identified, but are not in scope here); possible for more than one paper per project to be accepted at each SIDs.

Table 2-3 ATM Seminar papers sourced (associated projects to be determined)

ATM seminars	Total papers
2011	69
2013	67
2015	69
2017	72
2019	66

The following tables show the key metadata fields prepared for projects, deliverables and conference papers. Note that administrative fields are not shown, and some fields are incomplete due to the unavailability of data (e.g. project maturity). Metadata have been used in the analyses for the interactive research map and ATM concepts roadmap, as well as by the output and filter functions of both wiki tools and the research repository.

Table 2-4 SESAR project metadata

Field	Description	Example
PROJECT_NUMBER	unique identifier (WBS number for SESAR 1; GA number for SESAR 2020)	E.02.33
PROJECT_NAME	full project name	Strategic Allocation of Traffic Using Redistribution in the Network
PROJECT_ACRONYM	project acronym; blank if no acronym	SATURN
PROJECT_PARTNERS	project consortium; coordinator listed first	University of Trieste, University Libre de Bruxelles, University of Belgrade, University of Westminster
PROJECT_BUDGET	total budget (in euros, incl. co-funding)	594000
PROJECT_START	year project was contracted to start	2013
PROJECT_CLOSE	year project was contracted to close	2015
SESAR_PROGRAMME	SESAR 1 or SESAR 2020	SESAR 1
CALL	SESAR Call	WP-E
CALL_ID	SESAR Call identifier	12-120610
PROJECT_THEME	Call topic or theme	Enabling Change in ATM
PROJECT_URL	project website	http://www.saturn-sesar.eu/
V-Level_TRL	highest level of maturity associated with project	-

Table 2-5 SESAR deliverable metadata

Field	Description	Example
IDENTIFIER	document unique identifier	10485
FILENAME	original or assigned filename (SESAR 2020 deliverables downloaded from CORDIS have been renamed)	E.02.33-SATURN_D0.10 Final Project Report.pdf
PROJECT_NUMBER	WBS number for SESAR 1; GA number for SESAR 2020 (duplicates permitted)	E.02.33
UID_2	document ID (duplicates permitted)	E.02.33.D06
SJU_DEL_NUM	SJU/EC deliverable numbering	D06
PROJ_DEL_NUM	project deliverable numbering	D0.10
DEL_NAME	project deliverable name	Final Project Report
SJU_OR_MB	SJU Foreground or Member Foreground	SJU FG
FILE_URL	CORDIS link to public version of the document (SESAR 2020 deliverables only)	-

Table 2-6 Conference paper metadata

Field	Description	Example
ID	paper unique identifier	2014-28
FILENAME	original filename	SID 2014-28.pdf
YR	year of conference	2014
TITLE	paper title	Better pricing strategies for ATM?
TRACK	conference track	Economics
PROJECT	project acronym (incl. non-SESAR projects)	WP-E project SATURN
WBS_NUMBER	WBS number for SESAR 1; GA number for SESAR 2020 (duplicates permitted)	E.02.33
AUTHORS	named authors	Tatjana Bolić, Desirée Rigonat, Radosav Jovanović, Andrew Cook, Graham Tanner

Future updates to data provision are discussed in Section 10.

3 Interactive research map

3.1 Overview

To support the mapping of ATM research concepts, the Engage research mapping task focused on discovering themes and clusters of research. The main idea was to extract key information from previous SESAR projects, and to use this to create research themes (clusters). We here present a bottom-up approach to map and classify research projects. By gathering information in the form of keywords from project documentation, and by subsequently applying clustering algorithms, it was possible to define new clusters of homogeneous projects. The end goal of this task was to build interactive maps (on-line) that are easy to use and embrace both ER and IR activities. This contributes to the mapping of the landscape of research directions for SESAR 3.

All the information presented in this section can be found at the following EngageWiki page: https://wikiengagektn.com/EngageWiki:Interactive_research_map_of_ATM

3.2 Research mapping flow

The process of knowledge mapping based on SESAR ER and IR outputs described in Section 2.1 comprised several key steps:

1. pre-processing;
2. natural language processing (NLP);
3. keywords analysis and statistics;
4. machine learning.

In the following sections, the details of the steps are discussed. Examples and results are shown in each section.

3.2.1 Pre-processing SESAR outputs

Almost all SESAR project deliverables and research papers are published in PDF or Word format. The projects use the project report templates supplied by the SESAR JU. This means that these documents share similar structures and provide the potential of being processed by customised software. Before any computer algorithm can be applied to mining the text of these reports, it is important to convert them into plain text, so they can be processed by software tools.

There are several challenges associated with dealing with these PDF documents. First of all, there are fixed contents that can appear in all documents, such as header, footer and cover pages. These elements have to be removed, which often requires manual effort. Secondly, there are often different font formats included in these documents: the developed tools have to be able to remove the formatting information, and keep only the text. Lastly, even though most of the content is presented in text format, there could be potential text information in images. This may require additional pre-processing involving image recognition, which is currently out of scope.

3.2.2 Common information removal

For all project reports, pages containing general information on the project, such as authoring and approval information and document history, were removed through a manual process (although see later comment on automation). Then, the common elements of the documents were removed, which included the header and footer sections.

3.2.3 Text extraction

Next, the plain text needs to be extracted from the PDF documents generated by the previous step. Several different tools were evaluated for the extraction of text. For example, Adobe Acrobat, web-based PDF conversion tools, as well as stand-alone, open-source pdf-to-text tools. A customised tool was finally built based on the open-source package library in Python, *pdftotext*, to accomplish this task. Besides its benefit of being open-source, the choice of this Python library allows easy integration of PDF pre-processing into the mapping framework. The text extraction tool removes all the formatting elements contains in any PDF document and leaves only the text content.

3.2.4 Natural language processing

Natural language processing (NLP) is a powerful text-mining approach for analysing text content with modern computing power. One of the fundamental uses of NLP is to extract key information from a large amount of text (see Figure 3-1). A customised NLP tool was developed by Engage. It uses the plain text generated from each report as input. Then, it is designed to filter out information that is not relevant to research (e.g. common verbs, punctuation, common nouns, etc.). Only information that could potentially be related to research is retained. Finally, using statistical methods, the keywords of each report can be automatically generated.

Figure 3-1 Three key process of the NLP process for information extraction

(a) Tokenisation

In natural language processing, 'tokenisation' refers to the process of dividing the contents into pieces, which are called 'tokens'. They are often loosely referred to as 'words' or specific 'terms'. Several tokenisation techniques were tested, for example:

- **Treebank word tokeniser:** This is an efficient and fast method for tokenising natural languages. However, it has limited ability to handle combinations of words.

- **Multi-word expression tokeniser:** This method takes a string that has already been separated into tokens and re-tokenises it. It allows the merging of different words into a single token. This can be used as an extension to the previous method. However, it requires manual definition of the combination of these words, or requires training from the tokens.

- **Punkt sentence tokeniser:** On some occasions, it is also desired to first extract sentences before filtering out tags that are not an essential part of the content. The Punkt sentence tokeniser method can be used to accomplish such a task. However, it requires a machine learning model to be trained using a large quantity of text in the same language.

It is possible to observe that not all tokens are useful information for the knowledge mining process. For example, punctuations and common English words need to be filtered out in a further processing step.

(b) Cleaning

The cleaning process is designed to continue the previous step to filter out information that is not related to the purpose of knowledge mapping. The following steps are taken to produce a clean list of tokens:

- Removing punctuation (e.g. “.”, “,”, “:”, “(”, “)”, etc.)
- Removing tokens less than three characters in length (e.g. “of”, “on”, “a”, “an”, etc.)
- Removing common English words (e.g. “the”, “and”, “with”, etc.)
    - This module is designed based on the English language *stopwords* library from the NLTK
- Converting words in plural form to singular form (e.g. inputs -> inputs, technologies -> technology, controllers -> controller)
    - This model is designed based on the *WordNet* English language lexical database, which is part of NLTK
- Removing words that are not a noun (such as adjectives and adverbs)
    - This task is performed by employing the position tag identification using NLTK
- Removing common words that are common for SESAR research and publications (e.g. “ATM”, “figure”, “aircraft”, etc.)
    - This is based on a customised set of stop words constructed from common aviation knowledge
- Generating common bigrams tokens from the single word tokens (e.g. “trajectory” + “prediction” -> “trajectory_prediction”)
    - This task is accomplished by using the bigram generator using NLTK. Then the most common bigrams are used for the input of multi-word tokeniser to produce these combined tokens

After all the previous steps are taken, a cleaned list of tokens can be generated.

Most of the remaining tokens are related to research content. It is already possible to see that some tokens appear more often than others from one page of content in a SESAR research deliverable.

(c) Additional cleaning of personal content

After the common NLP process, names (from authors or references) can sometimes be identified as tokens. In rare cases, when a name appears multiple times, it can end up in the list of keywords (in the following step). In order to prevent sensitive information appearing in the research map, an additional cleaning step was introduced to remove any names in the results.

This process consists of both automatic and manual effort. Common names are identified by a standard NLP library: Stanford Named Entity Recogniser (*StanfordNER*). Uncommon names are spotted and removed manually.

Often, names are mistaken as keywords when lists of references are placed through the deliverable content, rather than the end of the document. It is recommended that in the future SESAR deliverable, the reference lists should be placed at the end of the documents.

(d) Statistical analysis

By combining tokens from all the pages, it is possible to construct a more accurate landscape of the research project. One of the most efficient ways to analyse these combined tokens is to use statistics. Frequency analysis is employed to extract the most important information.

In this way, it is also possible to visualise the results of the entire NLP approach. In Figure 3-2, the most common tokens and their frequency counts are shown. (The most common 80 tokens and their frequency counts are shown.) From this visualisation, one can instantly recognise the most common research elements indicated in the report.

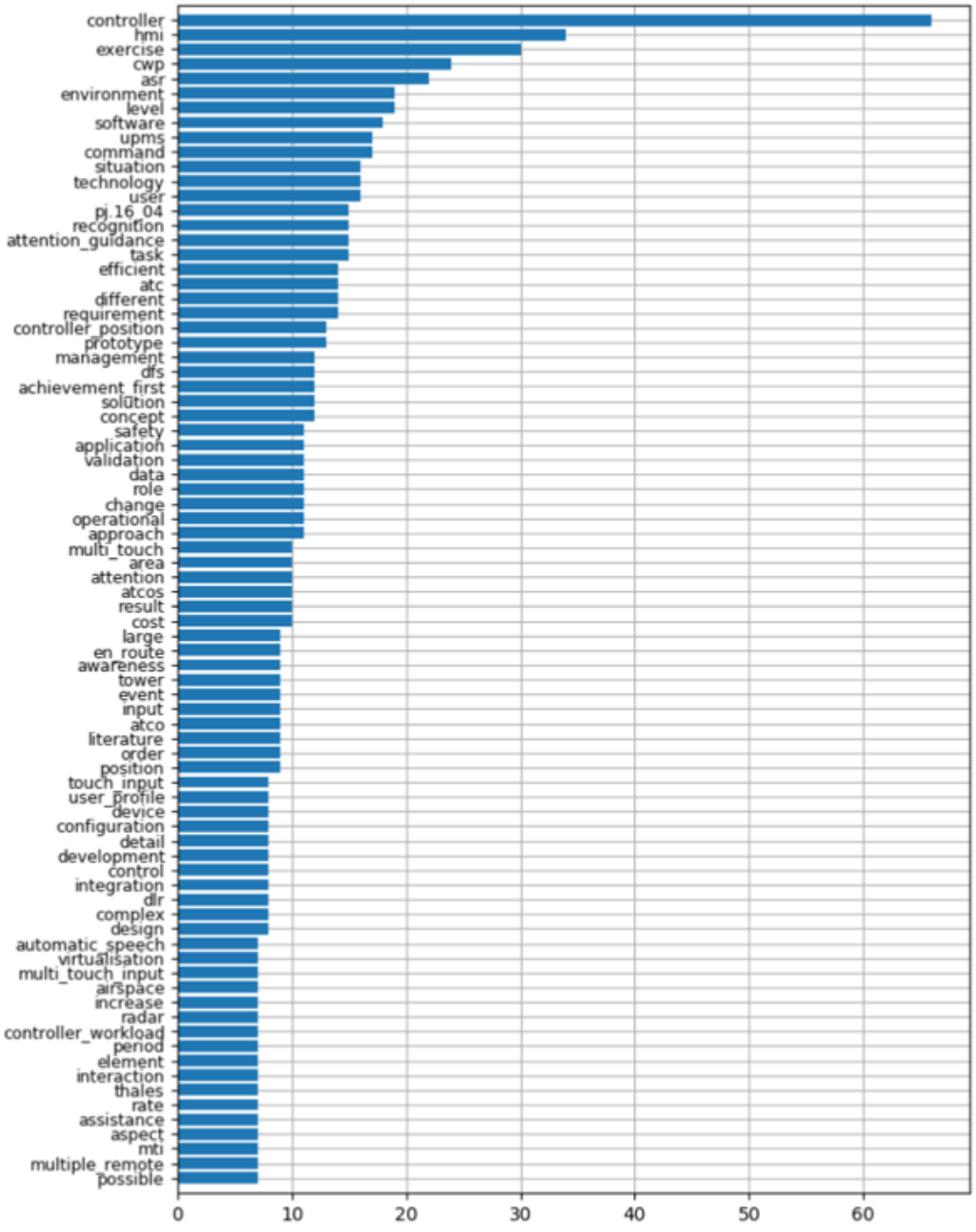


Figure 3-2 Final statistical analysis of the tokens in the example report

3.2.5 Keyword identification

Based on the previously generated statistics, the top most common tokens are extracted and used as the keywords of each output. In addition to the common tokens, normalised weights are calculated, according to the frequency of the term (i.e. all weights add up to 100).

controller:6.10	hmi:3.14	exercise:2.77	cwp:2.22
asr:2.03	environment:1.76	level:1.76	software:1.66
upms:1.57	command:1.57	situation:1.48	technology:1.48
user:1.48	pj.16_04:1.39	recognition:1.39	attention_guidance:1.39
task:1.39	efficient:1.29	atc:1.29	different:1.29
requirement:1.29	controller_position:1.20	prototype:1.20	management:1.11
dfs:1.11	achievement_first:1.11	solution:1.11	concept:1.11
safety:1.02	application:1.02	validation:1.02	data:1.02
role:1.02	change:1.02	operational:1.02	approach:1.02
multi_touch:0.92	area:0.92	attention:0.92	atcos:0.92
result:0.92	cost:0.92	large:0.83	en_route:0.83
awareness:0.83	tower:0.83	event:0.83	input:0.83
atco:0.83	literature:0.83	order:0.83	position:0.83
touch_input:0.74	user_profile:0.74	device:0.74	configuration:0.74
detail:0.74	development:0.74	control:0.74	integration:0.74
dlr:0.74	complex:0.74	design:0.74	automatic_speech:0.65
virtualisation:0.65	multi_touch_input:0.65	airspace:0.65	increase:0.65
radar:0.65	controller_workload:0.65	period:0.65	element:0.65
interaction:0.65	thales:0.65	rate:0.65	assistance:0.65
aspect:0.65	mti:0.65	multiple_remote:0.65	possible:0.65
assurance:0.65	description:0.56	multi:0.56	milan:0.56
label:0.56	tower_environment:0.56	intelligence:0.56	cwpv:0.56
interface:0.56	performance:0.56	virtual:0.56	dlh2a:0.56
traditional:0.56	demonstrate:0.56	usability:0.56	prague_approach:0.56
operational_concept:0.56	ontology:0.56	voice:0.56	part:0.56

Figure 3-3 Final keywords identified in the example report

3.3 Research clustering

The final step is to find and explore the connection between different research activities and outputs using the plain text extracted from all the outputs. A multi-dimensional map of all these outputs was generated using an unsupervised machine learning algorithm based on the combination of two key techniques:

- TF-IDF (term frequency–inverse document frequency) information retrieval;
- unsupervised K-means clustering.

Table 3-1 Clusters and associated keywords

Cluster №	Cluster keywords
1	aop, airport, platform, validation, exercise, monitoring, requirement, performance, status, information, apoc, solution, task, definition, test, service, stakeholder, analysis, maturity, decision
2	solution, package, validation, service, operator, airport, maturity, airspace, route, information, performance, benefit, system, concept, tma, improvement, separation, environment, step, safety
3	requirement, status, block, title, message, system, service, information, route, category, controller, function, clearance, ground, trajectory, runway, identify, prototype, position, test
4	controller, atco, system, tower, sequence, airport, function, automation, requirement, runway, task, operator, information, traffic, safety, solution, workload, aerodrome, situation, aman
5	sector, airspace, trajectory, route, complexity, network, traffic, conflict, information, system, actor, service, demand, planning, solution, capacity, dcb, requirement, measurement, controller
6	passenger, airline, delay, cost, modelling, airport, capacity, network, mechanism, transport, ansps, value, price, sector, trajectory, indicator, number, scenario, travel, airspace
7	swim, service, supervision, prototype, validation, step, enablers, specification, information, system, interoperability, standardisation, requirement, standard, exchange, description, definition, infrastructure, technology, maturity

Cluster Nº	Cluster keywords
8	assessment, material, security, modelling, solution, risk, application, stakeholder, guidance, recommendation, task, mfa, change, technique, validation, system, coordinator, package, information, deployment
9	gnss, navigation, surveillance, system, satellite, ground, gbas, gps, receiver, spectrum, frequency, signal, performance, solution, aeromacs, technology, cat, requirement, service, test
10	procedure, approach, rnp, pilot, operator, controller, demonstration, runway, airport, separation, validation, exercise, speed, system, navigation, concept, segment, fuel, scenario, noise
11	drone, service, operator, system, airspace, mission, information, risk, area, pilot, uas, scenario, capability, technology, navigation, security, traffic, rule, aviation, zone
12	uncertainty, modelling, trajectory, system, predictability, approach, information, sector, weather, controller, scenario, simulator, value, network, conflict, traffic, parameter, method, analysis, forecast
13	rpas, pilot, rpa, exercise, controller, procedure, demonstration, atco, simulator, traffic, mission, operator, loss, contingency, airspace, atc, safety, airport, emergency, intruder
14	trial, demonstration, exercise, fuel, route, airline, efficiency, traffic, procedure, reduction, benefit, delay, regulation, sector, arrival, pilot, impact, capacity, tta, period

3.4 Visualisation

We built a customised web-based application to visualise and explore the clusters and all the projects. Figure 3-4 shows the overview of the 14 clusters based on all available projects funded by SESAR.

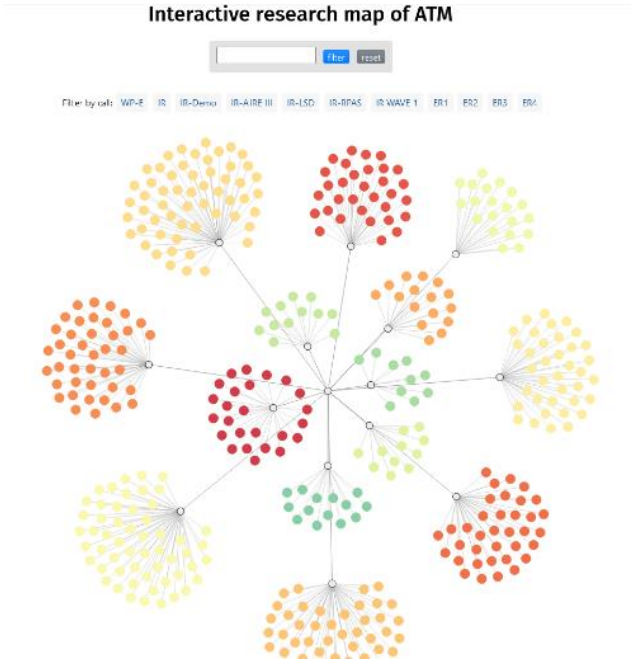


Figure 3-4 Research mapping clusters

The search bar allows projects with relevant metadata, including project titles, keyword, partners, etc, to be quickly identified.

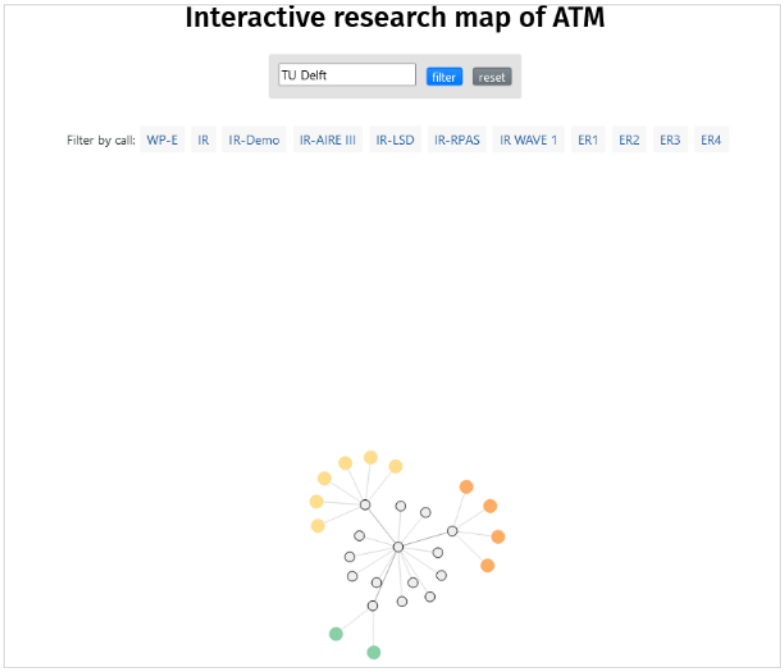


Figure 3-5 Search by partner (e.g. TU Delft)

The projects can also be filtered by different SESAR calls. Figure 3-6 shows the example of all available ER3 projects, as well as the cluster they belong to.

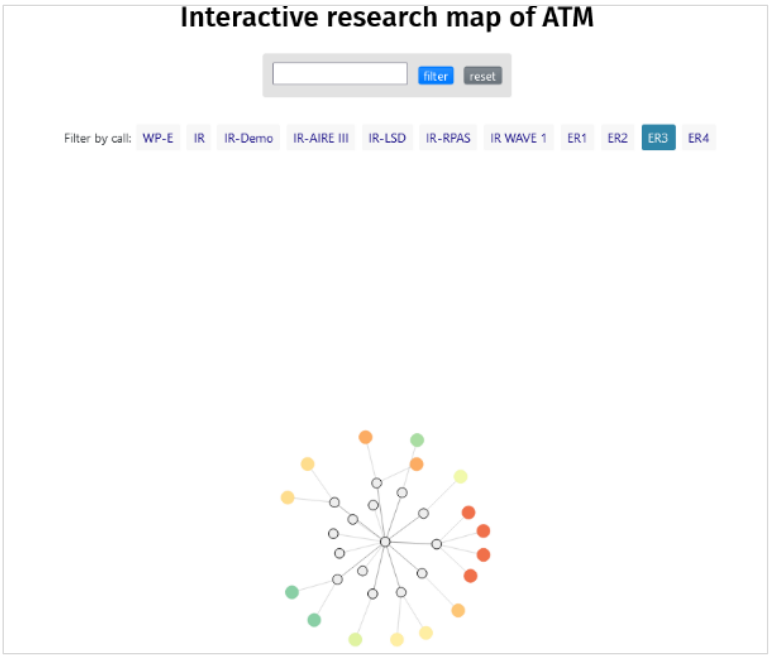


Figure 3-6 Filter by call (e.g. ER3)

When a specific project is selected, detailed information is shown. Figure 3-7 shows an example project. The displayed information includes: Call information, partners, research theme, budget, duration, keywords, and public deliverables. The public deliverables are directly linked to public documents in EngageWiki's research repository (see Section 8) or documents in the European Commission's CORDIS portal.

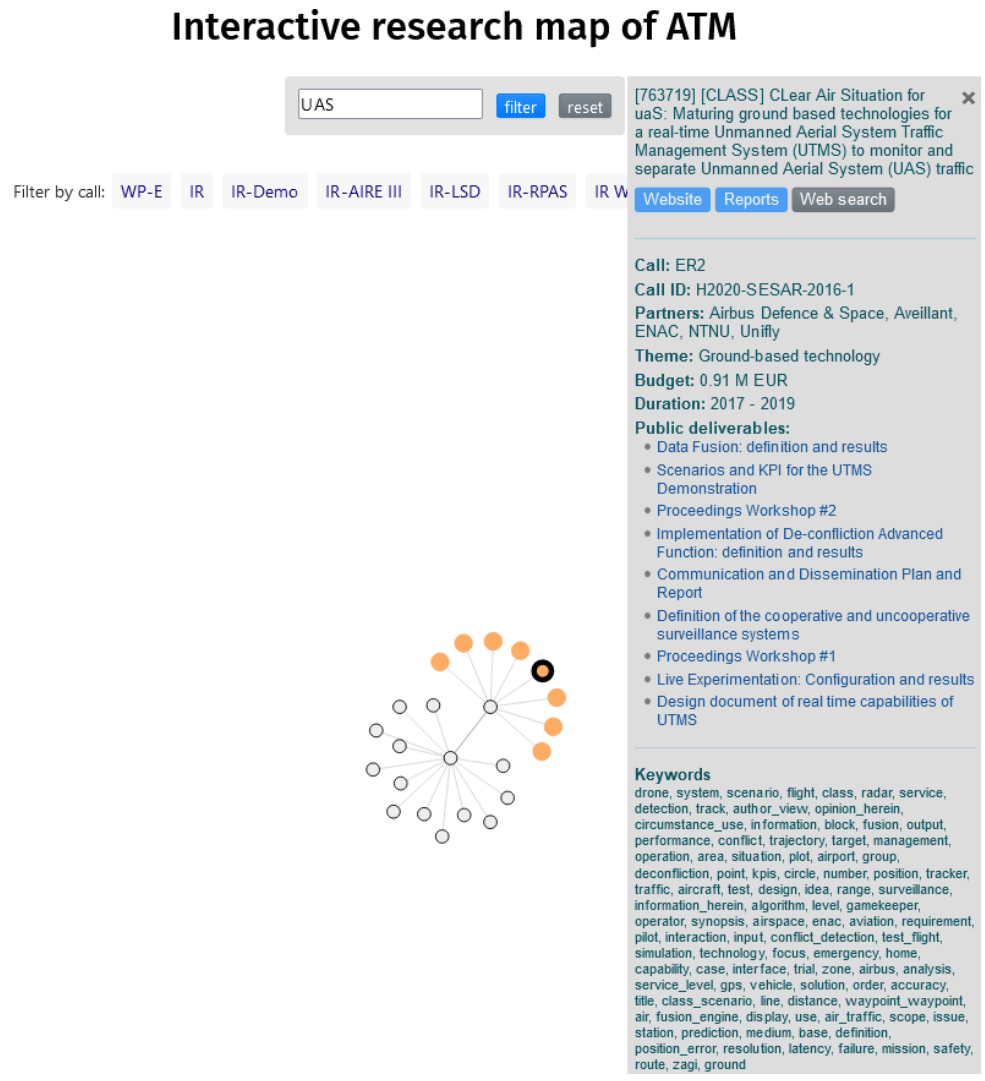


Figure 3-7 Detailed project information

4 ATM concepts roadmap

4.1 Overview

The aim of developing the ATM concepts roadmap was to provide an **interactive mapping tool** of research activities, both from past to present, and near future to further ahead. The roadmap builds on the data gathered from previous research projects and the work carried out developing the interactive research map of Section 2. From the work previously carried out and reported in Engage D3.8 [8], progress has been made especially in:

1. Engaging the wiki community, through **active promotion** in the Engage summer school 2021 and TC1, TC2 and TC3 workshops, collecting useful feedback on the functionalities and information present in the wiki from the users' perspective;

2. Exploring research activities and possible key areas to identify **future research needs** that require specific attention for ATM.

In addition to the interactivity of the map, this latter point, identifying future research directions, has been deployed through two working methodologies, which we have called **'forward' clustering** and **'reverse' clustering** analysis, the results of which are integral components of Engage D3.10 (Research and innovation insights) [7]. These are detailed below.

4.2 The SRIA flagship activities at the core of the map

Mapping the ATM research landscape is a dynamic process. During the development of the concepts roadmap in Engage, the Strategic Research and Innovation Agenda, Digital European Sky [15] (henceforth simply 'the' SRIA) was published, presenting the agenda for the future Integrated ATM partnership, i.e. the SESAR 3 JU. The goal of the SRIA is to support the delivery of the Digital European Sky, describing the scope of research and other actions aimed at further modernisation of Europe's ATM capabilities and U-space. Strategic research and innovation roadmaps for the years 2021 to 2027 are presented, as actions needed to deliver the implementation of the "European ATM Master Plan 2020 edition, strategic phases C (defragmentation of European Sky through virtualisation) and D (Digital European Sky) up to 2040+" [15]. The SRIA will be the starting point of the SESAR 3 work programme. It identifies nine flagship activities/roadmaps in the 2021-2027 period, listed in Table 4-1 below. Many interdependencies can be found between the flagships, and there are three horizontal topics that should cover the entire programme ('Aviation Green Deal', 'Artificial intelligence for aviation' and 'Civil-military interoperability and coordination'). The R&I in the flagships covers the three funding instruments that will be used in the new SESAR 3 partnership – Exploratory Research, Industrial Research and Digital Sky demonstrators.

The Engage consortium decided to use the SRIA as a keystone for its ATM concepts roadmap, particularly with regard to the 'forward' cluster and 'reverse' cluster analysis, as we will describe below. The nine SRIA flagship activities (see Table 4-1) form a core reference point of the roadmap.

Table 4-1 The nine SRIA flagship activities (horizontal activities in bold font)

№	SRIA flagship initiative
1	Connected and automated ATM
2	Air-ground integration and autonomy
3	Capacity-on-demand and dynamic airspace
4	U-space and urban air mobility
5	Virtualisation and cyber-secure data sharing
6	Multimodality and passenger experience
7	**Aviation Green Deal**
8	**Artificial intelligence (AI) for aviation**
9	**Civil/military interoperability and coordination**

4.3 'Forward' clustering and research gap analysis

The term 'forward' clustering has been used to encompass a data-driven methodology to identify **potential gaps or shortcomings in the currently planned research** (in the SRIA), by reflecting on the existing work corpus (i.e. the (project) materials as described in Section 2). This identifies future research directions to be explored. This work is divided into a similar sequence as for the interactive research map: text processing, research clustering, semantic similarity analysis and identifying research gaps. Here, however, the final step is a more deliberated and extensive work activity, which is pursued in detail in Engage D3.10 [7], as we outline below.

(i) Text processing

Extensive initial work was undertaken to process the SESAR ER and IR textual data (deliverables) of the various projects, provided to be used in the following data-driven analysis. Firstly, a stage of pre-processing of the 'pdfs' was carried out in order to not only extract the textual information but also to carry out a first cleaning by eliminating texts such as authoring and approval information, document history and header and footer sections. After the text extraction, **natural language processing (NLP)** was performed to extract key information from the large amount of text. The key steps performed in this NLP approach were: tokenisation, cleaning, statistical analysis and keywords generation. For a more detailed explanation of this process, see Sections 2 and 3.

(ii) Research clustering

The research clustering had the aim of providing a connection between different research activities and outputs using the plain text extracted. Using an **unsupervised machine learning algorithm**, 14 clusters were identified, based on the similarities in project keywords. A multi-dimensional map of these outputs was generated and can also be visualised in the 'interactive research map' section of the wiki. For a more detailed explanation of this process, see Section 2. The dynamic functionality of the map is described in Section 4.5, below.

(iii) Semantic similarity analysis

In order to be able to link past and future research concepts, the objective was to find for each project in our current database (as summarised in Section 2.1), to which of the flagship initiatives it most related. It was decided to use an unsupervised NLP technique called **semantic similarity analysis,** which scores the similarity of two texts based on how similar their words are, even if they are not exact matches. The objective of the selected algorithm was to rank the similarity of the projects with the SRIA flagship initiatives. To achieve this, the algorithm should be able to compare the text extracted from each of the projects with the descriptive text of the SRIA flagship activities, obtaining a measure of their similarity. The descriptive texts of the SRIA [15] flagship initiatives ("Problem statement"; "Description of high-level R&I needs/challenges" and "Expected high-level outcomes and performance objectives") were extracted manually and then pre-processed in a similar way to the texts extracted from the projects. A language model was constructed using **word embedding,** which allows words with similar meanings to have a similar representations in a multi-dimensional space. Due to the complexity and specificities of the language related to air transport and the aviation industry in general, it was decided not to use pre-trained word embedding models and to instead create a specific word embedding model using the text of the projects, that of the SRIA flagship activities, and the other extracted projects (in total, more than 1 million sentences). As an end result, a semantic similarity index was obtained for each of the projects in our database with respect to the descriptions of the nine SRIA flagship activities. The projects were then tagged with the SRIA flagship activities with the highest similarity index. For a more detailed explanation of this process, see document D3.8 [8]. As can be seen in Figure 4-1 (NB. 2022 clusters shown), the result of this process results in the mapping that can be seen in the left-hand half of the ATM concepts roadmap (from 'SESAR Calls' to 'SRIA flagship activities'). (The dynamic functionality of the map is described in Section 4.5, below.) The research clustering work has allowed us to create and visualise the temporal evolution of how the different projects from the various SESAR Calls are grouped into the 14 identified research clusters. Then the semantic analysis allowed us to see how all this research previously performed fits with the proposed nine activities for 2030. This provides a single view of previous research and how it links to future research concepts, both in the SRIA, and even beyond (see Section 4.4): thus mapping new research directions for SESAR 3.

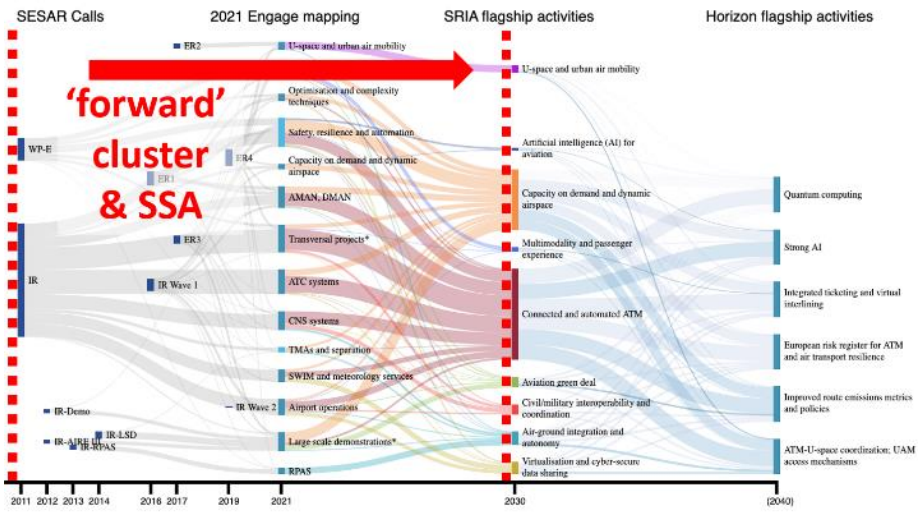


Figure 4-1 'Forward' cluster analysis

(iv) Research gap analysis

The process to identify potential research gaps deployed a hybrid combination of quantitative and qualitative analysis. Through the use of NLP techniques, similar to those previously described, key statistical information (e.g. keyword analysis, semantic similarity indices, outlier detection) was extracted from the texts corpus in order to identify areas that are potentially poorly covered in the SRIA and yet with remaining potential interest to the research community. Subsequently, these results were interpreted by ATM experts in the Engage consortium. The results are discussed in Engage D3.10, which focuses specifically on opportunities for innovative ATM research, whereas this deliverable (D3.9) focuses on the development and implementation of the wiki *per se*.

4.4 'Horizon' flagship activities and 'reverse' clustering

Engage set out to advance the definition of future research concepts and directions beyond what is already published in the SRIA. The nomenclature 'horizon' flagship activities is used. 'Horizon' reflects the familiar concept of horizon scanning in research, identifying future concepts. 'Flagship activities' is used as a complementary term to the SRIA 'flagship activities'. These ideas were conceived and developed by the consortium. The concepts had to be futuristic in the sense that they had not already been (fully) researched in the ATM domain, either through omission and/or because the underpinning principles (e.g. for quantum computing) are still at a very low TRL (level 0 or 1). These concepts did, however, at least have to map to some extent onto existing ATM activities in the SRIA: if they connected to *none of these at all*, it is difficult to justify their relevance to ATM, considering the relatively broad scope and maturity of the SRIA. The timeline indicated, "(2040)", is somewhat illustrative, in that some could be partially developed at higher TRLs sooner, others later. The horizon flagship activities, new research directions, are:

- Quantum computing;
- Strong AI;
- Integrated ticketing and virtual interlining;
- European risk register for ATM and air transport resilience;
- Improved route emissions metrics and policies;
- ATM-U-space coordination; UAM access mechanisms.

As with the forward cluster analysis, these are mapped onto the SRIA flagship activities to show the strength of the relationships between the two flagship activity types. The current mapping is shown in Figure 4-2 (i.e. 2022 clusters shown). Work related to the horizon flagship activity identification is reported in the parallel deliverable, Engage D3.10 (Research and innovation insights) [7]. Based on these texts, for each flagship activity, the reverse cluster comparative analysis illustrates the stronger and weaker links between the flagship types. This is represented in the ATM concepts roadmap by variations in the colour intensity of the link, thus providing a visualisation of the level of connection and co-coverage of the SRIA flagship activities and the future concepts identified by Engage. (The link intensities may be somewhat better visualised by hovering over the horizon flagship activity nodes, for example.)

These activities may be updated and further populated through continued research, drawing on outputs from Engage, more widely in SESAR, and even beyond ATM, through wiki user inputs, and including interdisciplinary concepts, during SESAR 3.

(The reader may care to note that previous to using the SRIA, and in earlier Engage reporting, the Engage team were sourcing the 2020 edition of the European ATM Master Plan [16], SESAR's 'airspace architecture study' [13], Flightpath 2050 [10] and the ACARE Clean Aviation SRIA [2] as benchmarks for future research comparisons. However, these are all variously covered in SESAR's integrated Strategic Research and Innovation Agenda, Digital European Sky [15], thus forming our new comparative keystone, as discussed.)

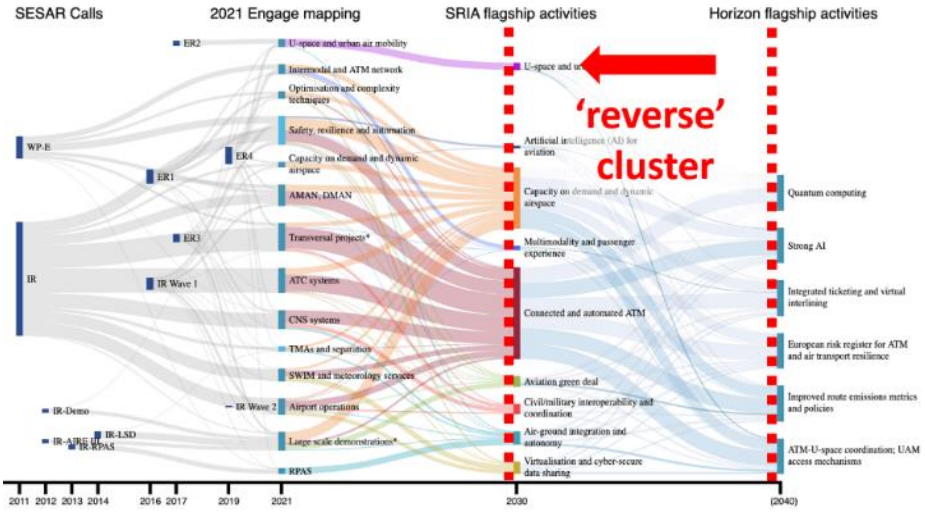


Figure 4-2 'Reverse' cluster analysis

4.5 ATM concepts roadmap – live in the wiki

All the information presented in this section can be found at the following EngageWiki page: https://wikiengagektn.com/EngageWiki:ATM_concepts_roadmap

Figure 4-3 shows the view of the wiki page corresponding to the ATM concepts roadmap (NB. 2022 clusters shown). The roadmap was built as **Sankey diagram** visualisation, in which the width of the links is shown proportionally to the flow of a specific quantity, in this case 'research activity' (measured by proxy as the number of projects). The visualisation provides an aggregated view of research direction evolution and connections over time. The visualisation is fully interactive. The user is able to move the different nodes for better visualisation as well as hover over the various links and nodes. Hovering will make the link or the whole node highlighted, as can be seen in Figure 4-4 and Figure 4-5, for better identification, and will cause a pop-up text to appear with extra information on the number of projects related to that node or link.

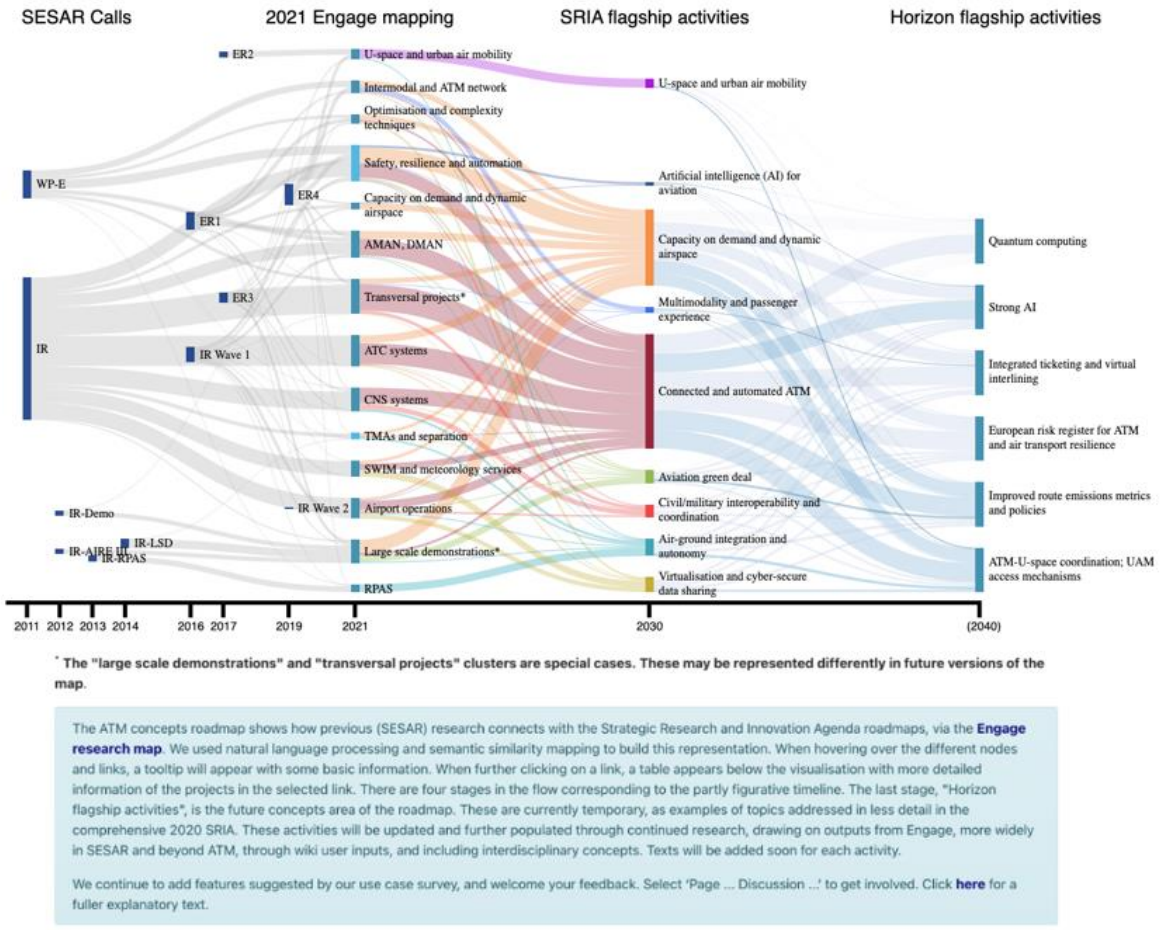


Figure 4-3 ATM concepts roadmap main view

In addition, at the bottom of the main page, the user can find explanatory information about the visualisation. This includes information related to the special nature of some of the displayed clusters ("large scale demonstrations" and "transversal projects"). It also includes a summary of how the visualisation works and what information is being displayed. There is a link to a dedicated wiki page where a more detailed explanation of the process of creating the visualisation, in particular the creation of the different links, is given. Finally, if the user clicks on a node or a link, a dynamic reference table with information about the projects related to that link or node will appear below the Sankey diagram. The name of the project, the SESAR Call to which it belongs, as well as the research cluster to which it belongs and the SRIA flagship activity with which it is most similar semantically is displayed. Furthermore, a last column displays a link where the user can access the 'Research repository' in the wiki to see the documentation available for specific projects, for those which we were able to publish (see Section 2).

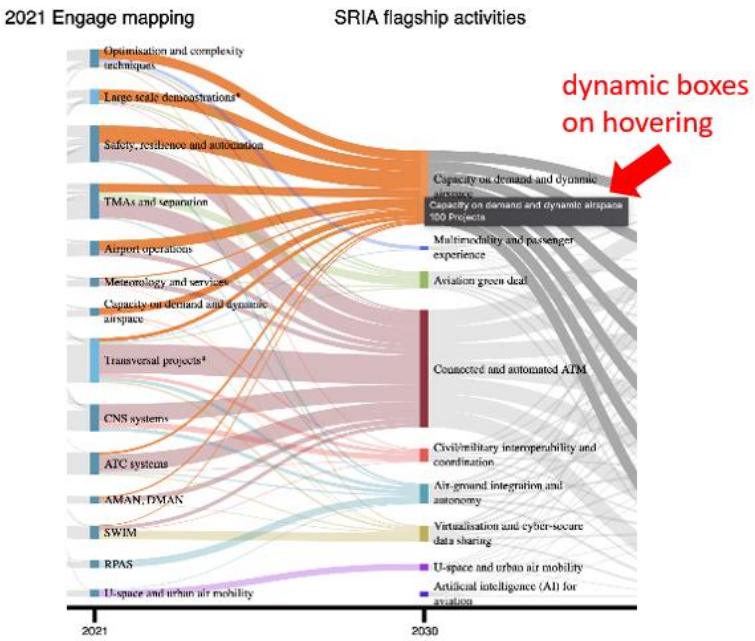
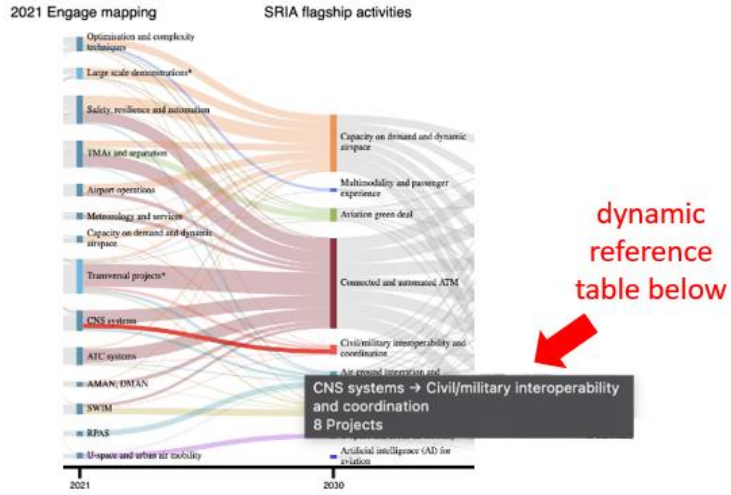


Figure 4-4 Hovering interactivity of the roadmap



Link: CNS systems → Civil/military interoperability and coordination

Number of projects: 8

Project Name	SESAR Call	Engage mapping	SRIA flagship activities	Research repository
[09.24] ADS-B In/Out for military aircraft	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.01.07] CNS System of System definition and roadmap	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.00] Global Co-ordination & Management	IR	CNS systems	Civil/military interoperability and coordination	Link
[09.20] Military Data Link Accommodation	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.02] Non Avionic CNS System	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.04] Surveillance Infrastructure Rationalisation	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.04.01] Surveillance Infrastructure Rationalisation	IR	CNS systems	Civil/military interoperability and coordination	Link
[15.04.05.b] Surveillance ground system enhancements for ADS-B (Prototype development)	IR	CNS systems	Civil/military interoperability and coordination	Link

Figure 4-5 Project table displaying interactivity

5 Wiki discussion fora

5.1 Objective

The creation of discussion fora in the wiki arose in response to the objectives initially set out in Sub-Task 4.2.3 of Engage. The aim was to: create a forum that allowed researchers to comment on the content and relationships of the 'interactive research map' and the 'ATM concepts roadmap'; on the documentation in the repositories; and to serve as a platform to ask questions about the research performed and enabling constructive comments and useful debate. The forum was inspired by those that have had significant impact in other fields, such as Quora or Stack Overflow. Similar to these, but with the focus on ATM, the fora were built to inform, deliver clarity and answer specific questions posed by the users and at the same time provide the users a curiosity-driven exploration of different research topics. In both cases, the aim was also of fostering new partnerships and developing a more interconnected and collaborative ATM community.

5.2 Wiki discussion fora – live in the wiki

All the information presented in this section can be found at the following EngageWiki page: https://wikiengagektn.com/Special:WikiForum

A dedicated wiki page was created for the wiki discussion fora. This page can be accessed directly from the wiki homepage. Figure 5-1 shows the layout of the page. The various fora are divided into two main categories: general discussion and wiki related. The 'wiki related' content contains fora related to the functionalities and workings of the wiki. They allow users to comment on problems with wiki functionalities, provide feedback on content, or simply keep up to date with the latest add-ons. The 'general discussion' content contains themed fora for open discussion where users can create or join ongoing conversations. No user other than administrators can create fora at this level. It was decided internally that the initial set of fora should include one for each thematic challenge identified in Engage[1], *viz.*:

1. Vulnerabilities and global security of the CNS/ATM system;
2. Data-driven trajectory prediction;
3. Efficient provision and use of meteorological information in ATM;
4. Economic incentives for future ATM implementation;

[1] See Engage D2.7 (Annual combined thematic workshops progress report (series 3)) [6] for further details. This deliverable reports on the organisation and results obtained from the third and fourth editions of the Engage thematic challenge (TC) workshops held in 2021. Due to the Covid-19 pandemic, the third editions of the TC2 and TC3 workshops, initially scheduled to be held in 2020, were delayed to the beginning of 2021. The TC1 and TC4 workshops reached their third edition in 2021, while TC2 and TC3 closed with the fourth edition. The main lessons learned relate to data availability, collaboration opportunities, machine learning and artificial intelligence methodologies and approaches, and incentives for future ATM implementations.

as well as more general ones to foster community dialogue. To this end, fora were set up for users to comment on other research topics not covered by the thematic challenges, for example, but not limited to, the horizon flagship activities discussed in Section 4.4, and with a questions section where researchers can ask open questions to other researchers.

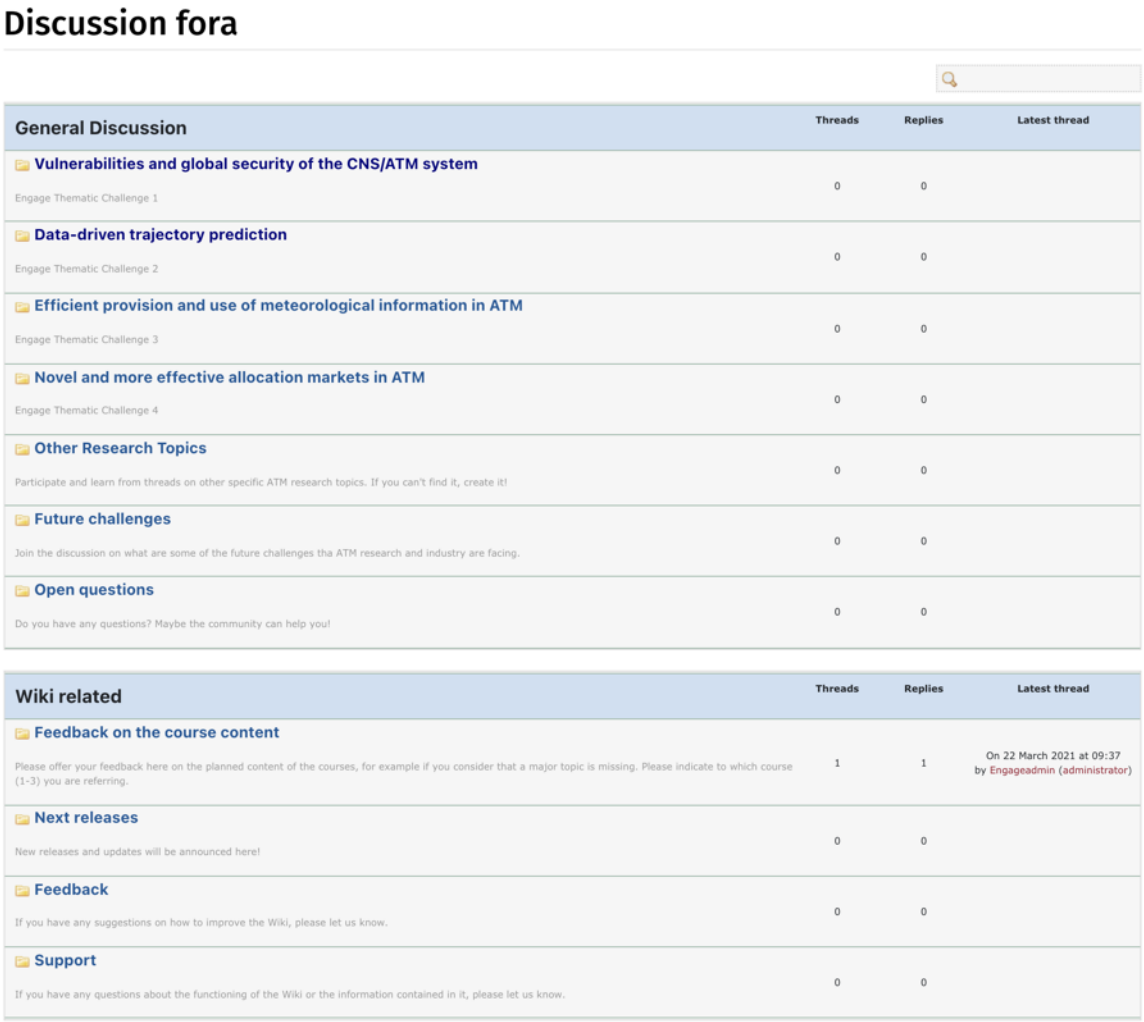


Figure 5-1 Wiki discussion main page

The discussion fora is an open section of the wiki where all users, registered or not, can access and see all the posted content. If a user wants to contribute to the fora, he/she must have a wiki user account and be logged in. A wiki user does not need additional special permissions to participate in a forum. Once logged in, the user can select the forum where he/she wants to contribute. In the top right hand corner of the forum the user will find the option to “New topic”, see Figure 5-2. Clicking on this option will open a form, Figure 5-3, where the user can write the title of the topic to be created as well as a text block where the first comment of the topic can be written.

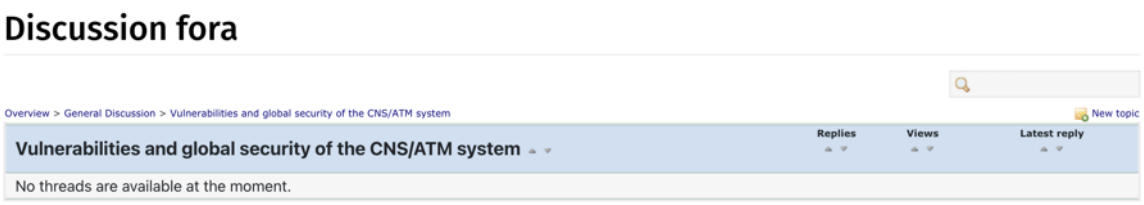


Figure 5-2 Example forum view

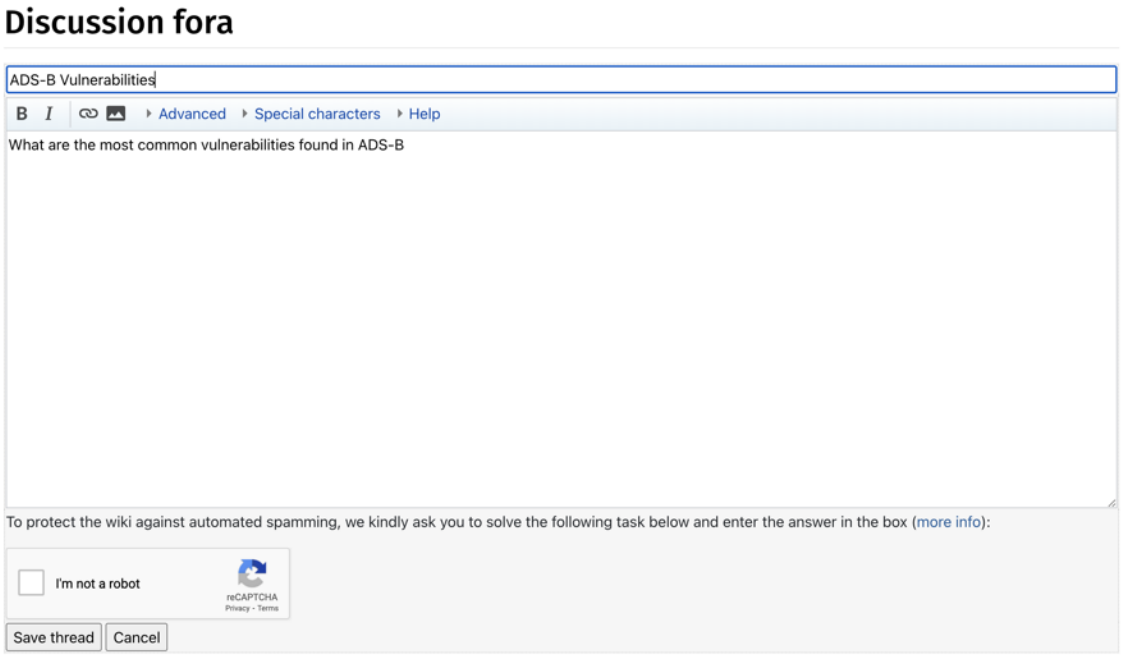


Figure 5-3 Example adding new topic to a forum

Once the topic has been created it will appear in the forum section,

Figure 5-4, with additional information on the number of views, number of replies and date of the last reply. The topic would now be available for other users to participate in.

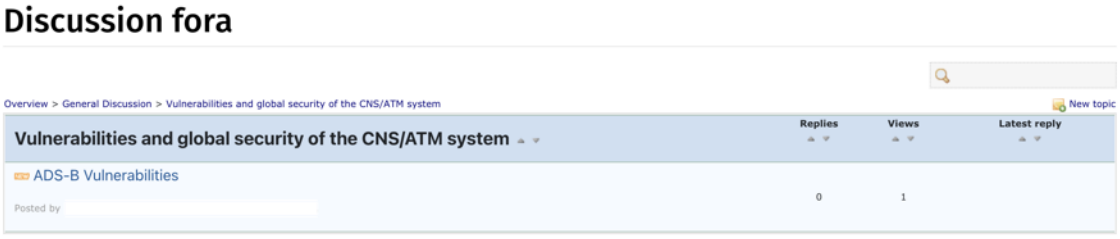


Figure 5-4 Example forum view with one topic

To participate in an existing topic it is as easy as selecting it and writing the desired comment, Figure 5-5 and Figure 5-6. The forum allows the user to manage their comments by being able to edit them once they are posted, delete or quote other comments to facilitate communication in the forum.

Finally, users are able to follow specific fora or topics, such that they will receive updates when there are new comments, or additions, and thus keep up to date with all the fora activity.

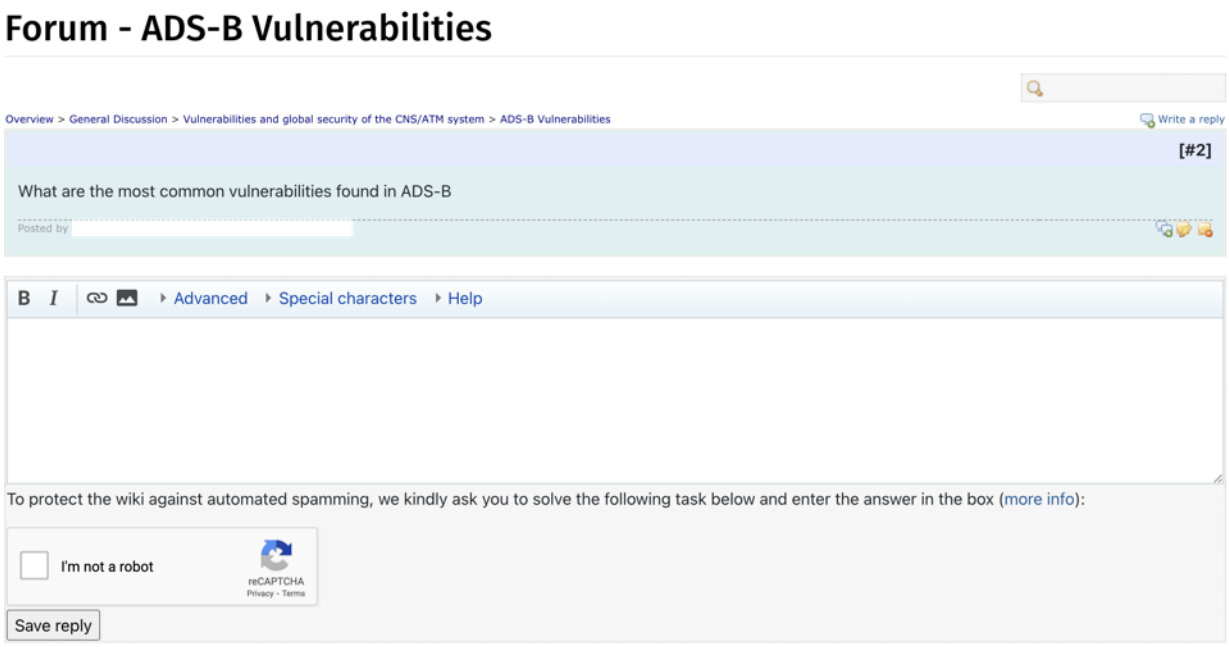


Figure 5-5 Example adding a comment to a topic

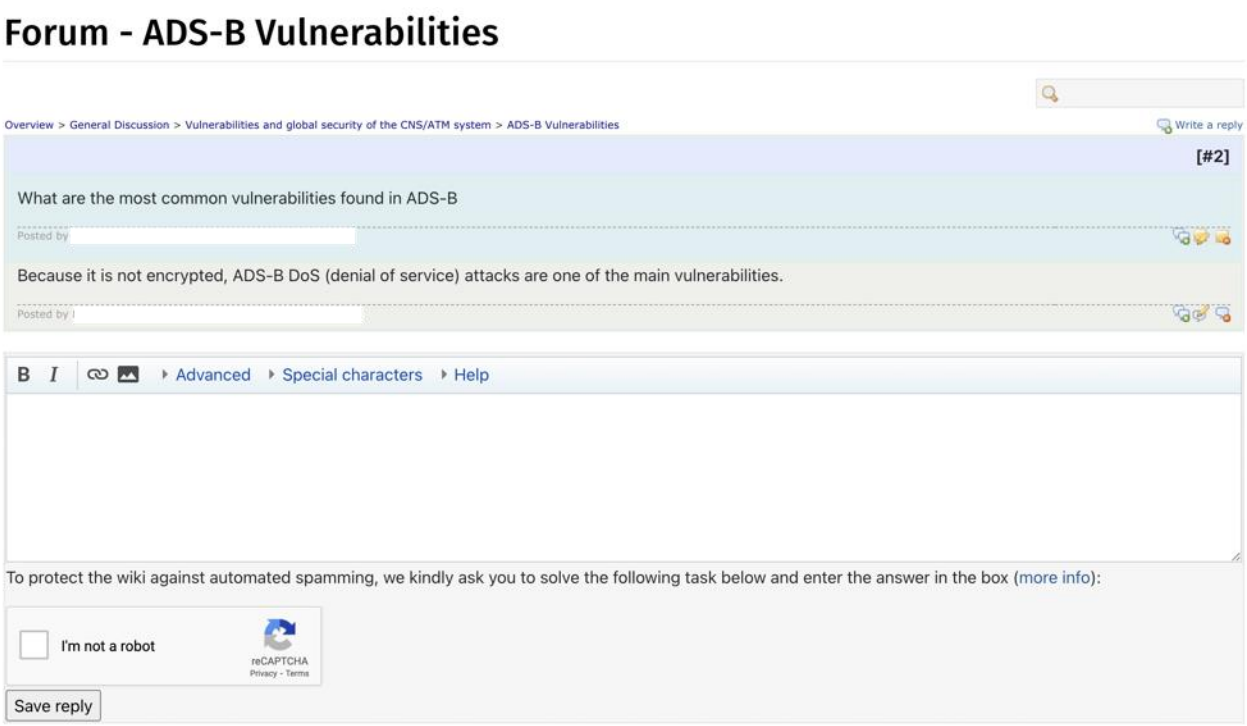


Figure 5-6 Example topic view

5.3 Fora uptake and outlook

Notwithstanding the ambition of fostering new partnerships and developing a more interconnected and collaborative ATM community, the discussion fora have not gathered the hoped-for momentum. It is to be hoped, however, that through further activities and promotion such as those mentioned in Section 10, that these fora may gather sufficient impetus to become hubs for various communications and discussions in SESAR 3.

However, attracting audiences to voluntarily contribute to wikis often does not work very well (e.g. based on the experiences of ComplexWorld and during Engage). This requires significant (at least weekly, preferably daily) effort to stimulate contributions, after populating with attractive topics. Specific topics are more successful than open/general discussions, especially when these relate to particular events (e.g. conferences, summer schools, workshops) and/or where a specific topic has been tackled: often these two motivations (of event and topic) may coincide. A further example may be hosting discussions around specific technical sessions of the SESAR Innovation Days or to encourage inter-project researcher collaboration across a SESAR 3 research topic (e.g. multimodality), even integrating across ER-IR on specific issues. It is not known whether any future KTN would allocate such high levels of effort to such fora activities, but with support from the SJU comms team, if corresponding returns were deemed sufficient (e.g. enabling inter-project collaboration; delivering improved learning outcomes for students), such collaboration might serve to overcome limitations of available effort. This could be framed around more specific use-cases, such as new entrant researchers and those engaging with the SESAR Digital Academy and, for example, wishing to connect with the wider ATM community or collaborate on teaching activities.

A further initiative driving higher traffic to such fora, would be to publish information in the wiki (such as FAQ responses to Calls published by a SESAR 3 KTN and corresponding links to previous research in the wiki repository to help write corresponding proposals), which may then serve to turn such visitors into potentially contributing users. As a final observation, the wiki was launched relatively late during the lifecycle of the SESAR 2020 KTN, whereas its availability from the launch of any SESAR 3 KTN may well serve to drive up user numbers, with promotional activities to increase visibility from the start and time being invested in developing topic content rather than the platform itself.

6 University programmes database and MSc courses

6.1 Methodology

The objective behind the creation of the university programme database as well as embedding it in the wiki was to provide a first building block for the establishment of a comprehensive European programme aimed at **educating and training future ATM professionals**. The list of programmes was created as a fusion of the work previously carried out in Engage.

This section provides an update to the **university programme database** constructed under Task 5.1.1 of Engage. D5.1 [3] provides a more detailed description of the methodology applied to the initial design of the database and its tables, aimed at collecting and displaying information on postgraduate degrees. The initial list produced, comprised a sample of PhD programmes and Master's programmes and covered the institutions and opportunities in the ECAC area. The relevant information obtained included: postgraduate university programmes that offer ATM-related postgraduate research opportunities, descriptions of courses offered, tuition fees, keywords, typical numbers of postgraduate students, numbers of faculty and other authorised research supervisors. Over the course of the project, the approach to the postgraduate programmes database changed, due to two reasons. First, the EU's General Data Protection Regulation (GDPR) came into force on 25 May 2018, replacing the Data Protection Directive 95/46/EC, which impacted the handling and publication of information. Second, through interaction with academic stakeholders, it became clear that whilst structured programmes exist at the Master's level, the doctoral theses in ATM were not necessarily linked with ATM-related programmes but might be awarded in other fields with application for ATM. Due to these two reasons it was decided to concentrate Engage efforts on the undergraduate and Master's programmes.

The initial list of **undergraduate** programmes was constructed under Task 5.3.1 of Engage. The aim of this task was not to generate the list itself, but rather to provide a review of undergraduate training materials. The study was conducted during 2019 and covered 44 ECAC countries, gathering information such as institution, degree(s) offered, duration and language. 162 aviation-related programmes were initially compiled, and after considering their curricula, 45 programmes (at 42 universities) were identified as offering courses on airports, airlines or ATM and were selected for further analysis. These universities were contacted directly to gather more information on their course syllabuses, along with additional information such as the date a programme was introduced and graduate numbers.

The Engage team proposed to merge the two lists into a single database of programmes that could be uploaded to the wiki. Since the lists were not compiled for the same purpose, however, there was a disparity in the amount and type of information they contained. It was decided to merge the two lists, focusing on content common to both whilst avoiding the presence of fields where a large part of the programmes had missing information. Prior to this merge, a final update of the lists was carried out, mainly to validate that the programmes still existed, either by confirmation from the institution or by information found on their websites. The final database uploaded to the wiki consists of nine fields, as shown in Table 6-1.

Table 6-1 European university programmes database fields

Nº	Field	Short description
1	Institution	University name
2	Faculty	University faculty (if applicable)
3	Country	Country of the institution
4	Programme Type	Postgraduate or undergraduate
5	Degree	PhD, Master's, BSc, ...
6	Programme Name	Air Transport Management, Aviation, Aeronautical Engineering, ...
7	Language	English, Spanish, German, ...
8	Duration	In years and part-time status (if applicable)
9	Web page	Institution web url (if available)

The final database uploaded to the wiki contained undergraduate programmes that offered introductory courses related to ATM, airport or airlines and postgraduate programmes that offered ATM-related courses or postgraduate research opportunities. The list of programmes available in the wiki as of September 2021 include **62 Master's programmes** and **51 undergraduate programmes**, which satisfy the previously mentioned conditions.

Two types of wiki pages were created for the database: a more traditional spreadsheet format with a simple filter/search bar and a second page which had a more advanced number of filtering options with the data presented in a 'pageblock' type format. Once both pages were created, internal feedback from Engage partners was collected. The feedback was then distilled into specific changes and the pages were modified accordingly. The final decision was to make the pageblock type format page the main UG/PG programmes accessible in the wiki. It is envisaged that future maintenance (adding or modifying programmes) will not be carried out solely by the Engage team, but that the community itself will keep the wiki updated. Universities were notified of this in the first quarter of 2021 as part of a survey, inviting colleagues to request user accounts to maintain their course content (see Section 6.3).

6.2 European university programmes - live in the wiki

All the information presented in this section can be visualised at the following EngageWiki page: https://wikiengagektn.com/EngageWiki:Programmes

The merged undergraduate and postgraduate database was uploaded to the wiki and visualised with dynamic filtering functionalities as a main objective. The different programmes in the database are displayed, instead of in a more traditional table format, as individual 'capsules' containing the main relevant information. Although this format is less useful for providing an overview of all the programmes in the database, it is preferable when using search filters and was therefore selected.

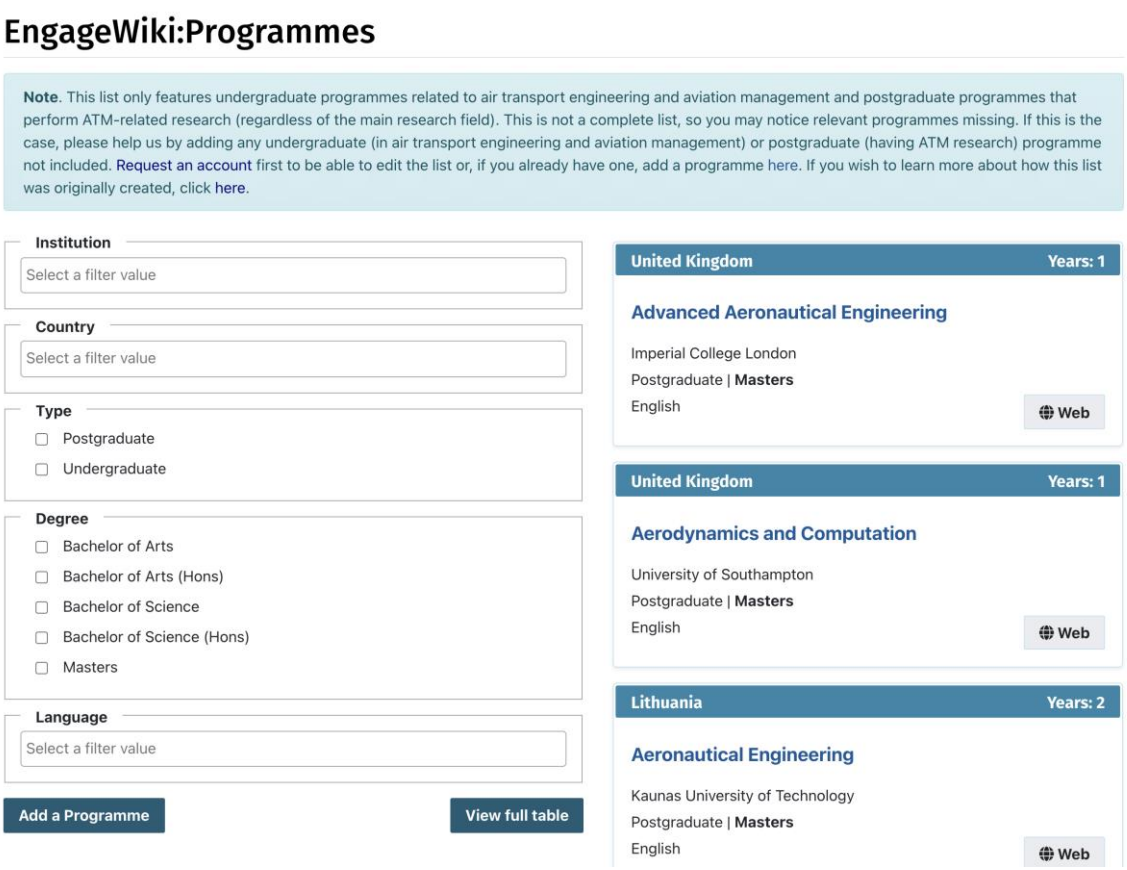


Figure 6-1 European university programmes main page

As can be seen in Figure 6-1, at the top of the page there is a short summary, which briefly explains the characteristics of the programmes present in the database as well as encouraging the participation of users to extend and keep the database up to date. There is also a link to another dedicated page which explains in more detail how the programme information was collected and how the programmes were chosen.

In the left column we see the main filter panel. This panel allows users to perform a specific search of programmes through the use of different fields. There are two main types of filters, the first whereby the user directly selects the desired options from a list of checkbox options and the second whereby, with the help of free text, the user can search then select the desired option as can be seen in Figure 6-2. Note that all filters can be used in conjunction with each other as shown in Figure 6-3.

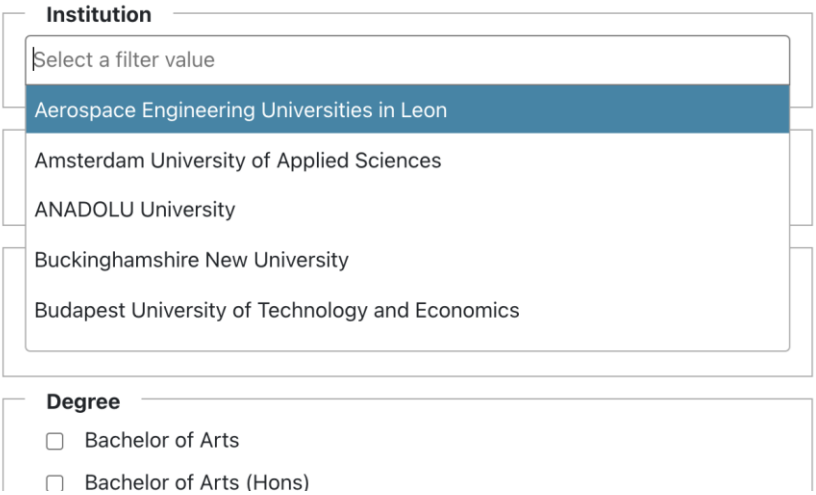


Figure 6-2 Text search and select filter

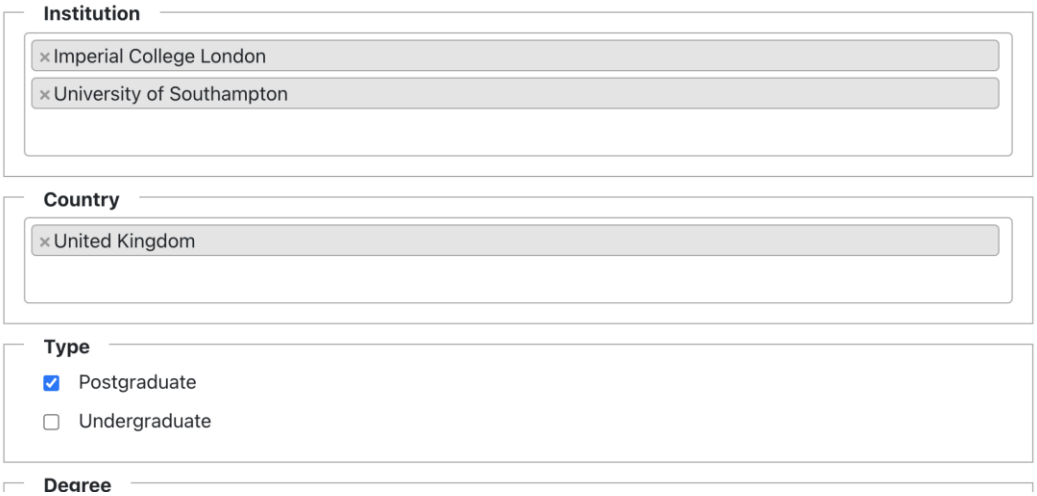


Figure 6-3 Example of multiple filters applied

On the right column we can see the different programmes present in the database in the form of capsules as mentioned above. For a manual search the user is able to scroll down the page to view the different programmes. When a filter is applied, the column is automatically updated to show only programmes matching the selected conditions. From the information presented for each programme the user is able to be redirected to the institution's programme page through the 'Web' button (or clicking the programme name redirects the user to specific page with extra information) – see Figure 6-4.

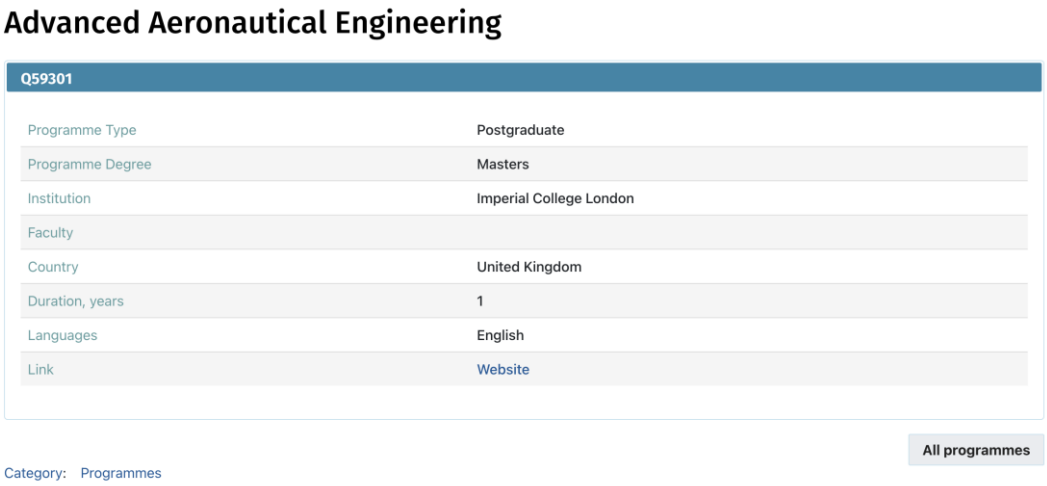
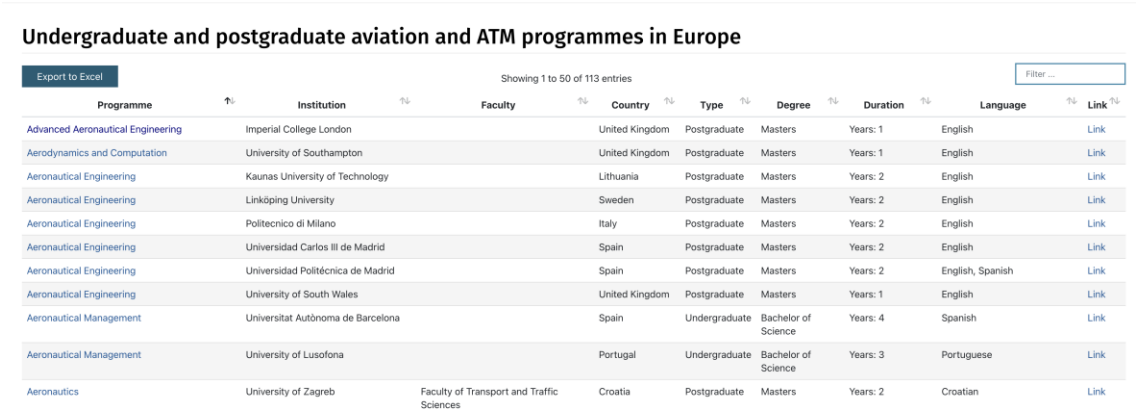


Figure 6-4 Example of programme dedicated page

Returning to the 'European university programmes' main page (see Figure 6-1), below the filter panel there are two buttons that the user can use. Starting with the one on the right, 'View full table', if clicked the user is redirected to a new page where the database of programmes is presented in a spreadsheet format (see Figure 6-5). On this page, the user can also access the links of the different programmes as well as extra information about the programme by clicking on the programme name. The page also has a filter on the top right-hand side, although it is more limited than the filters explained above. On this page the user is also able to download the entire database in '.xlsx' format by clicking on the 'Export to Excel' button in the top-left corner.



Programme	Institution	Faculty	Country	Type	Degree	Duration	Language	Link
Advanced Aeronautical Engineering	Imperial College London		United Kingdom	Postgraduate	Masters	Years: 1	English	Link
Aerodynamics and Computation	University of Southampton		United Kingdom	Postgraduate	Masters	Years: 1	English	Link
Aeronautical Engineering	Kaunas University of Technology		Lithuania	Postgraduate	Masters	Years: 2	English	Link
Aeronautical Engineering	Linköping University		Sweden	Postgraduate	Masters	Years: 2	English	Link
Aeronautical Engineering	Politecnico di Milano		Italy	Postgraduate	Masters	Years: 2	English	Link
Aeronautical Engineering	Universidad Carlos III de Madrid		Spain	Postgraduate	Masters	Years: 2	English	Link
Aeronautical Engineering	Universidad Politécnica de Madrid		Spain	Postgraduate	Masters	Years: 2	English, Spanish	Link
Aeronautical Engineering	University of South Wales		United Kingdom	Postgraduate	Masters	Years: 1	English	Link
Aeronautical Management	Universitat Autònoma de Barcelona		Spain	Undergraduate	Bachelor of Science	Years: 4	Spanish	Link
Aeronautical Management	University of Lusofona		Portugal	Undergraduate	Bachelor of Science	Years: 3	Portuguese	Link
Aeronautics	University of Zagreb	Faculty of Transport and Traffic Sciences	Croatia	Postgraduate	Masters	Years: 2	Croatian	Link

Figure 6-5 European university programmes spreadsheet format

Finally, by clicking on the 'Add a programme' button on the main page, below the filter panel, the user can add or modify a programme in the database. To do this, the user must first be registered for the wiki and then request editing permissions from the wiki team using the 'contact us' form. Once the request has been processed by the wiki team and approved, the user is able to use a predefined form, see Figure 6-6, to add a programme to the database, or to modify the information of an existing one. Changes to the database are updated immediately in the wiki.

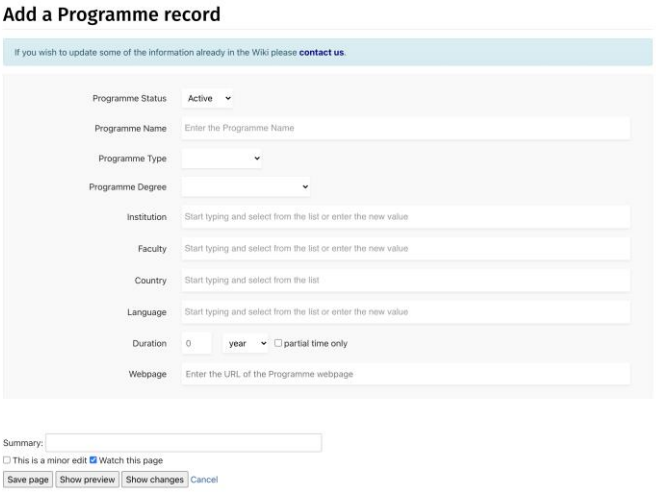


Figure 6-6 Add a Programme record form

6.3 Survey of universities in Q1 2021

As noted in D3.8 [8], a survey was distributed to universities in March 2021 with the dual purpose of **publicising the university programme database** and seeking **feedback on the content of the teaching resources material** under development. The opportunity was taken to also **promote the SESAR Digital Academy**.

65 institutions were contacted, however few responses were received, which were predominantly in relation to the programme database. Feedback included suggestions of new university programme entries and the reporting of difficulties editing programme content. The difficulties encountered by some users editing content was particularly important feedback, and the technical issue with wiki user accounts has been resolved.

6.4 Postgraduate research and events database

The initial version of the methodology and database tables for the postgraduate research and events in general, was reported in deliverable D5.3 [4]. Over the course of the project, the idea of a postgraduate research database transformed into two lists published in the wiki (see Figure 6-7 below):

1. PhD funding opportunities;

2. Jobs and internships.

Figure 6-7 Access to PhD funding opportunities and jobs and internships in the Engage Wiki

'PhD funding opportunities' and 'Jobs and internships' content are listed in a form – Figure 6-8 shows an example of PhD opportunities. Registered wiki users can add content themselves by editing the form. However, anyone can request new entries via the 'contact us' link seen at the top of the figure.

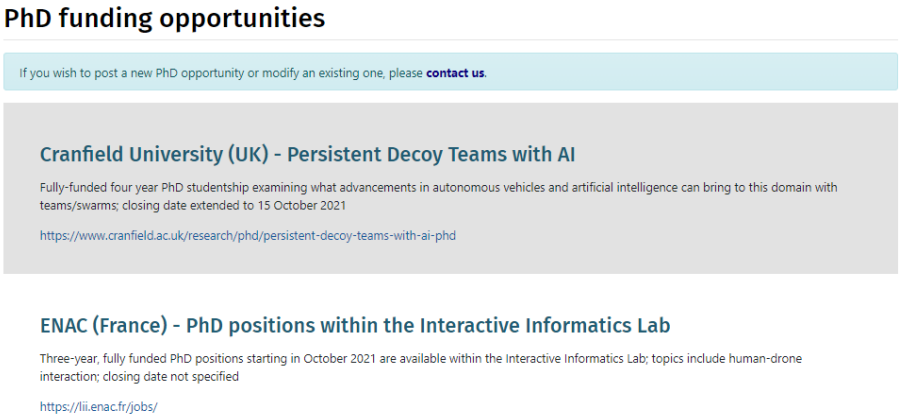


Figure 6-8 Example of PhD opportunities, with the link to 'contact us' form

The events database has also been transformed since its plans were described in D5.3. The level of detail of the original plans proved to be overly ambitious and were additionally impacted by the introduction of GDPR. Instead, events are maintained by the Engage team on a dedicated page on the Engage website (engagektn.com/events), grouped by the following categories:

- **SESAR Innovation Days:** information about the SIDs conference, Call for contributions and registration link (content adjusted post-conference);
- **Engage thematic workshops:** information about workshops organised by Engage;
- **Other workshops and webinars:** listing publicising forthcoming and recent (non-Engage) workshops;
- **SESAR Digital Academy:** listing publicising the registrations or recordings of SDA webinars;
- **Conferences:** listing of conferences;
- **Summer schools:** Engage summer school listing (details available on dedicated web pages);
- **Competitions and awards:** information about the SESAR Young Scientist Award and other relevant awards.

For each event listing, the date, location and link are provided – to date, over 260 events have been publicised. A separate web page publicises relevant Calls for contributions and proposals (engagektn.com/call-opportunities). Future migration to the wiki, in SESAR 3, would be possible.

7 Teaching resources

7.1 Course content

The course content of the teaching resources available in the wiki were developed by members of the Engage consortium, specifically by members of the University of Belgrade, Faculty of Transport and Traffic Engineering, with support from the University of Westminster. A more detailed breakdown of the authors of the content, as well as how it was produced, can be found in deliverable D5.15 [9]. The reason for the inclusion of this content in the wiki is to support Engage's objective of promoting and developing new talent with knowledge of future ATM scientific research needs, to sustain a supply of skilled researchers and to stimulate the next generation of ATM operational and engineering staff. As such, it provides **foundational material for the SESAR Digital Academy**. The teaching resources comprises three courses:

1. Introduction to air traffic management
2. Airline planning and operations
3. Airport planning and operations

The final design of the course content was not only based on the consortium's experience, but also took into account Engage's review of university undergraduate degrees in aviation during 2019, as reported in D5.4+ [5]. In addition, it should be noted that two internal content reviews were carried out, together with feedback obtained during the first Engage summer school, held in Belgrade in 2019. Each course consists of a PowerPoint slide deck for approximately ten lectures, together with complementary briefing notes for each course, e.g. listing additional sources of information.

7.2 Teaching resources - live in the wiki

All the information presented in this section can be found at the following EngageWiki page: https://wikiengagektn.com/Teaching_Resources

A dedicated wiki page was created for the teaching resources. This page can be accessed directly from the wiki homepage as shown in Figure 7-1 in the bottom-right corner. As can be seen in Figure 7-2, the "Teaching Resources" page provides a landing page where users can see not only the different courses available, but also an overview of what each course covers. Also, at the top of the page the user can find a brief summary explaining the purpose of these teaching resources as well as the material included per course. On the top right hand side of this page the user can find a button by which to request access to course content.

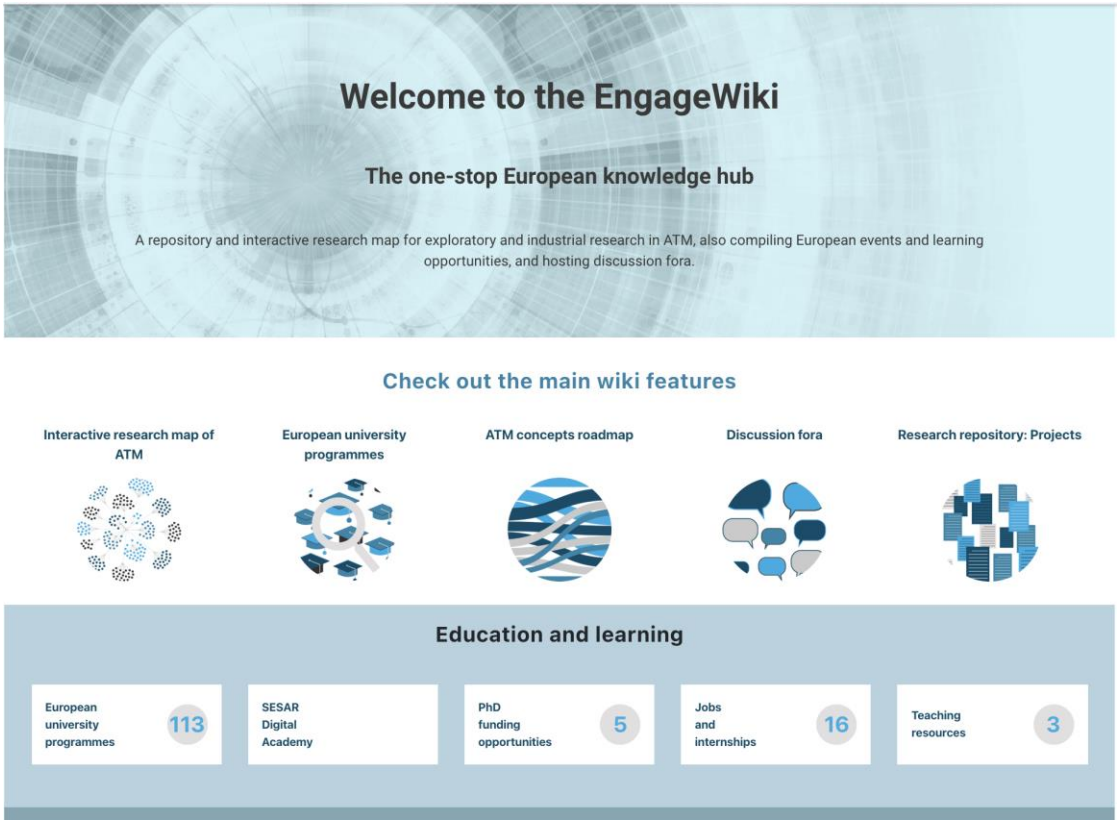


Figure 7-1 Wiki homepage

Teaching Resources

The Engage KTN supports European air traffic management education and training in the air transport community to develop new talent with knowledge of future ATM scientific research needs, to sustain a supply of skilled researchers and to stimulate the next generation of ATM operational and engineering staff. To support this objective, three introductory courses have been prepared, which will be made available to any research institution wishing to use them, free of charge. These include:

(**1**) Introduction to air traffic management;

(**2**) Airline planning and operations;

(**3**) Airport planning and operations.

Apply to access the courses

A wiki account is necessary to be able to apply, please log in or sign up here

Apply

Courses (2) and (3) provide essential contextual knowledge on air transport and thus a better understanding of course (1). Each course comprises:

(**a**) a package of PowerPoint slides for approximately 10 lectures;

(**b**) a set of supplementary briefing notes for each course that list additional sources of information.

Content of the three courses:

(1) Introduction to ATM

1. **Air Traffic Control as part of Air Transport System**
   a) Air Traffic System
   b) Air Navigation Services
   c) SESAR programme
2. **Airspace Management (ASM)**
   a) Airspace division in the horizontal and vertical plane
   b) Airspace classes, aircraft vertical position, aircraft separation, flight conditions and rules
   c) Airspace sectorisation problem
3. **Air Traffic Service (ATS)**
   a) Types of Air Traffic Control System (procedural and radar systems)
   b) Air Traffic Controller (ATCo) decision making processes
   c) Data necessary for ATCo work – flight plan, meteo data, messages
   d) ATCo activities
   e) Air Traffic Control – ATC, Flight Information Service – FIS, Alerting Service – AS
   f) Air Traffic Control Units – airport, approach, en-route
   g) ANS charges
4. **Air Traffic Flow Management (ATFM)**
   a) Introduction to flight planning and messaging
   b) ATC Capacity and Traffic Demand
   c) Strategic, pre-tactical and tactical planning
   d) Network Management
   e) Air Traffic Flow and Capacity Management (ATFCM) phases
   f) Measures for capacity and demand regulations
5. **ATM Performance Measurement**
6. **Essential Data Sources in Aviation and ATM**
7. **Future concepts in ATM**

Figure 7-2 Teaching resources wiki page

In order to request access to course content the user needs to have a wiki account and be logged into it. Once the user is logged into their account, when pressing the 'Apply' button, an on-line form will open, which needs to be submitted. An example of the form can be seen in Figure 7-3. To complete the form, the user must fill in all the required information (username, email address, contact person, etc.) as well as confirm that the course content will be used for not-for-profit educational use only, that it will not be adapted or changed, and that the Engage KTN will be acknowledged as the source. Once the form is submitted, the wiki team will review the request and if not otherwise considered, will grant the necessary permissions for the **downloading of the course content free of charge**. When a user is authorised to download course content when accessing the 'Teaching Resources' page, the 'Apply' button will have changed and in its place will be a button with the text 'Access', as shown in Figure 7-4. By clicking on this button, the user will be taken to a previously restricted page, Figure 7-5, where through three different links he/she can download the contents of the different courses in a compressed 'zip' file.

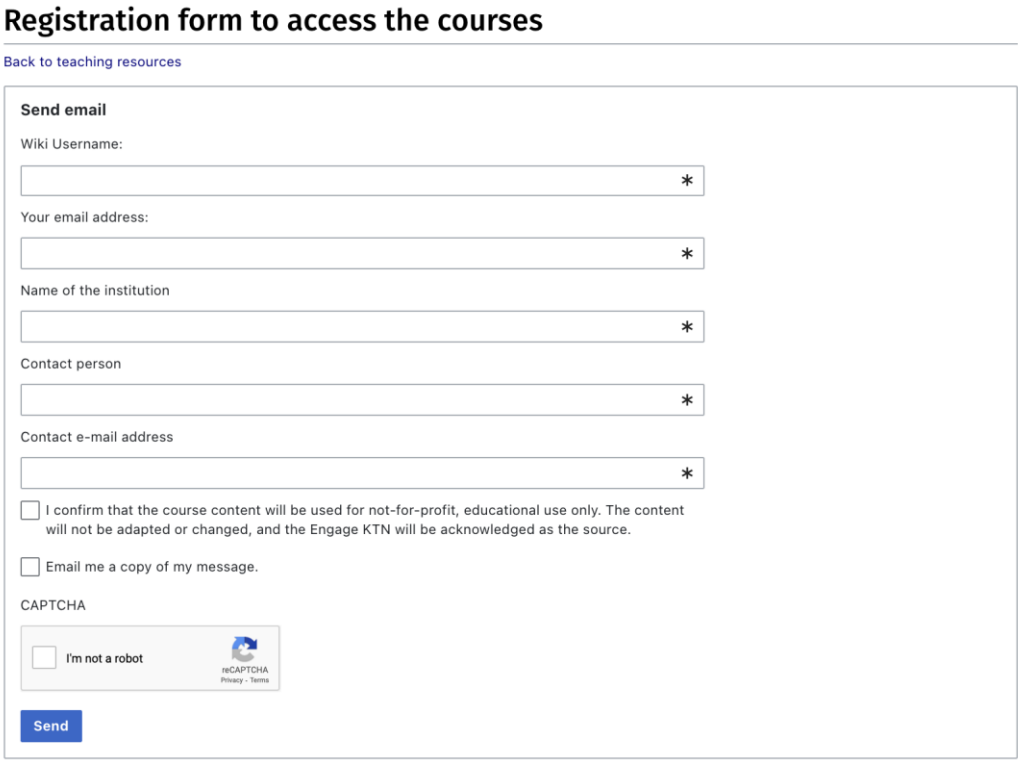


Figure 7-3 Teaching Resources registration form

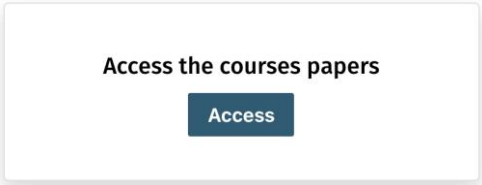


Figure 7-4 Course content 'Access' button

Figure 7-5 Course content download page

7.3 Courses content storage

The storage system for the course contents follows the same structure as all the attached files of the wiki. The storage takes place in an Amazon Web Services (AWS) server, which is external and independent to the wiki. Further information about wiki storage, and how the external files are organised, can be found in Section 9.3.2. All the files can easily be accessed by clicking the download link, even if the link is external to the wiki URL.

8 Research repository

8.1 Methodology

The sourcing of SESAR deliverables and conference papers hosted in the research repository is described in Section 2.2. Deliverable and conference paper metadata (see Table 2-4, Table 2-5 and Table 2-6) are used by the research repository's search and filter functionality. The project identifier field, containing either the SESAR 1 WBS number or SESAR 2020 grant agreement number, is used to link deliverable and conference paper metadata with project metadata.

In order to make the documents accessible in the wiki, they had to be stored publicly. The storage system for the deliverables and conference papers follows the same structure as all the attached files of the wiki. The storage takes place in an Amazon Web Services (AWS) server, which is external and independent to the wiki. Further information about wiki storage, and how the external files are organised, can be found in Section 9.3.2. Once the files were uploaded to AWS, a mapping had to be created between the public download links and the metadata. This was necessary in order to be able to upload them to the wiki and have them correctly labelled. This resulted in the creation of a new set of metadata, which was used for the creation of the research repository in the wiki. The metadata related to project information was filtered to contain only complete and necessary information to identify a project, i.e.:

1. Project identifier (WBS number or SESAR 2020 grant agreement number)
2. Project name
3. Project acronym
4. SESAR programme (SESAR 1 and SESAR 2020)
5. Call (e.g. ER1, ER2, IR, WP-E)
6. Start year
7. End year

The metadata related to the deliverables and reports of the projects contain the following information (note that the download links to documents in CORDIS were maintained in the metadata):

- Project identifier (to link with the project information)
- Name of the deliverable/report (to be used in the wiki)
- URL for download (both AWS and CORDIS)

Finally, the conference papers required only one metadata file, as it was not necessary to map several documents to unique projects. It contains:

- Conference paper ID
- Year of the conference

- Paper title
- Theme (e.g. Advanced Air Traffic Services, Airports, Airspace Management)
- Conference name
- URL for download

The end result of this process is that the research repository has **362 projects,** with a total of **1440 deliverables/reports (including CORDIS links)**, and **653 conference papers**.

8.2 Research repository - live in the wiki

All the information presented in this section can be visualised at the following EngageWiki page: https://wikiengagektn.com/EngageWiki:Research_repository

The final research repository database was uploaded to the wiki following a similar style to the one used in the European university programmes and was visualised with dynamic filtering functionalities as the main objective. The different projects and papers in the database are displayed, instead of in a more traditional table format, as individual 'capsules' containing relevant information. As mentioned in previous sections, although this format is less useful for providing an overview of all the projects and papers in the database, it is preferable when using search filters, and was thus selected.

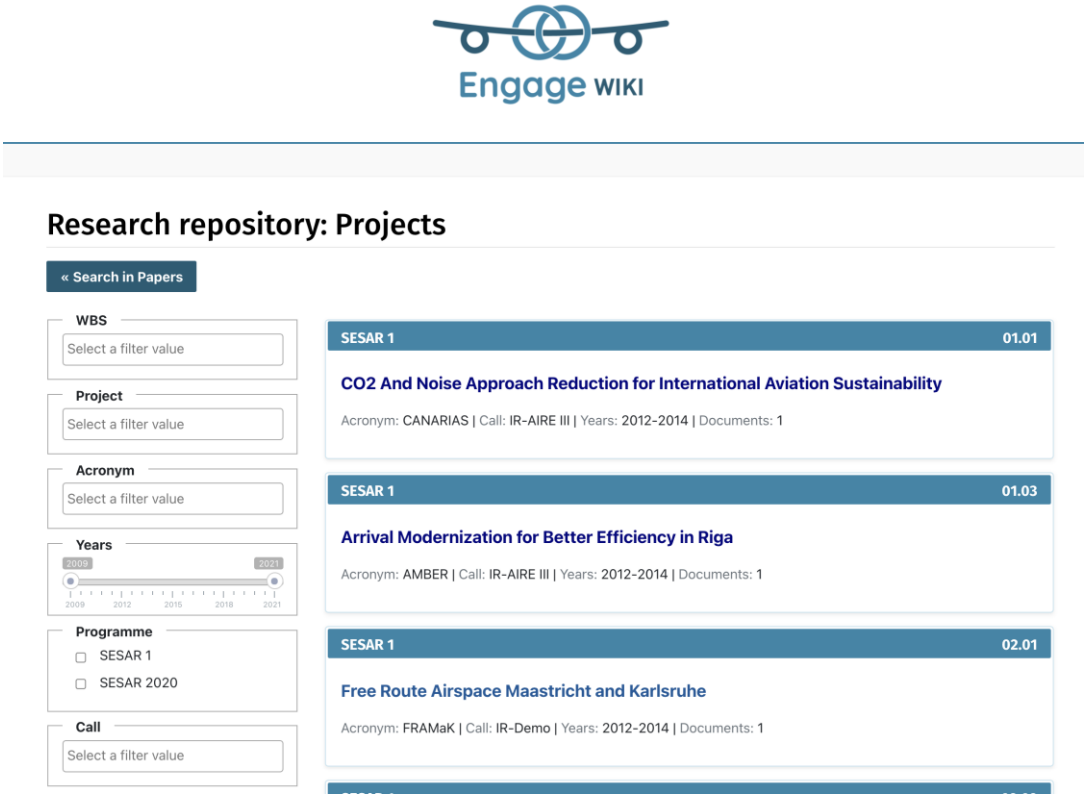


Figure 8-1 Research repository (Projects) main page

By default, when a user accesses the research repository, they access the projects database. If they want to perform a search for papers there is a button at the top-left, as shown in Figure 8-1, to change the view to the papers database.

Figure 8-2 Research repository (Papers) main page

The layout and functionality is analogous in both the projects and papers areas of the repository.

In the left column, we see the main filter panel. This panel allows users to perform a specific search of projects/papers through the use of different fields. There are three main types of filters: the first, whereby the user directly selects the desired options from a list of checkbox options; the second, whereby with the help of free text the user can search then select the desired option; the third, whereby a slider filter enables a temporal range specification. These can be seen in Figure 8-1 and Figure 8-2. Note that all filters can be used in conjunction with each other as shown in Figure 8-3 and Figure 8-4.

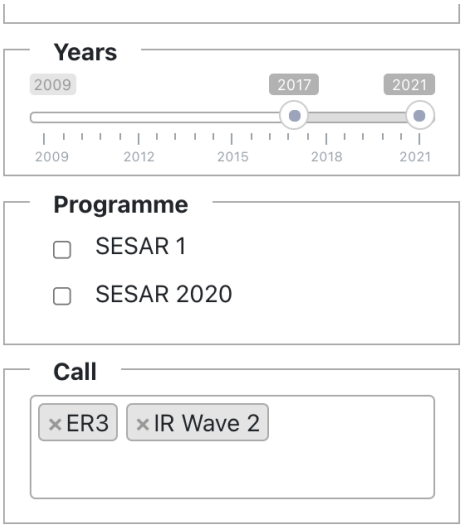


Figure 8-3 Example of multiple filters applied (Projects)

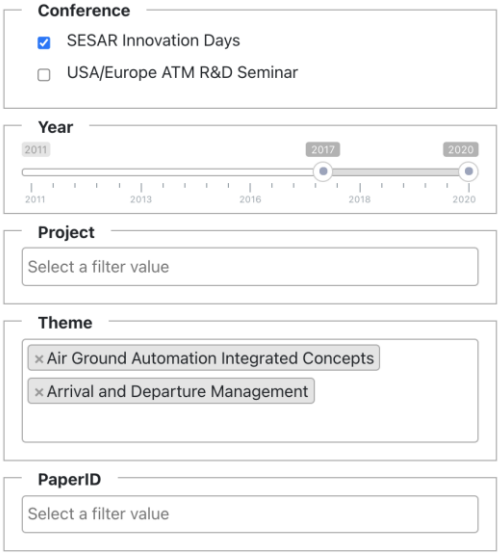


Figure 8-4 Example of multiple filters applied (Papers)

In the right column we can see the different projects/papers present in the database in the form of capsules, as mentioned above. For a manual search, the user is able to scroll down the page. When a filter is applied, the column is automatically updated to show only projects/papers matching the selected conditions.

In the case of projects, by clicking on a project capsule the user will be redirected to a project-specific page in the wiki where they will find information related to the specific project (WBS, acronym, SESAR programme, Call, start year and end year) as well as a list of all available project documents, see Figure 8-5. These include documents available exclusively in the EngageWiki database, as well as some available in the CORDIS database. Clicking on any of these documents will redirect the user to the relevant page, where the document will be downloaded automatically. In the case of papers, there is

no dedicated wiki page. If the user clicks on the title of the paper in the capsule, instead of being redirected to a specific page, the user is redirected directly to the download link.

Figure 8-5 Example of project-dedicated page

9 Lessons learned

This section summarises a range of lessons learned regarding the data acquisition (primarily SESAR project deliverables) and (pre-)processing during the set up and running of the Engage wiki. It also presents lessons relating to user registration and participation, plus protection from external (bot) attack and the secure, remote storage of files on Amazon Web Services.

9.1 Data and document format issues

Extended periods of time were needed to complete the task of sourcing and preparing materials, to resolve underlying data provision issues (e.g. resolving initial legal constraints on accessing SESAR 1 deliverables). The preparation of corresponding metadata was largely a manual task (see Sections 2, 3 and 4); and GDPR affected how information from the wiki tools could be displayed (e.g. ensuring the removal of personal names from keywords) as well as the publication of deliverables in the wiki's repository. This took up a huge amount of effort and resources for the Engage consortium in particular, and for SJU colleagues in support.

In Section 3, we also discussed a number of issues relating to processing the (SESAR) PDF documents. These variously related to header, footer, cover pages, font formats, text information in images, proper names being mistaken as keywords by automated tools, and lists of references placed through the deliverable content, rather than at the end of deliverables. Future work, in SESAR 3, could define an improved reporting format, including systematic key word indexing, to achieve a compromise between convenience of reporting and automated analyses, with a shift more towards the latter, thus better enabling future analyses, similar to those presented here, and taken forward in Engage D3.10 [7], where the recency of data used in the research gap analysis is also discussed.

9.2 User registration and user participation

Soon after the wiki was created, it was multiply attacked, creating thousands of new pages with inappropriate content. The wiki was down for a few days, since the hosting provider noticed the attack and took it down so the issue could be fixed. The user registration was blocked temporarily, the users and pages were deleted and the wiki was restored. After this happened, tests on user registration were made and the user registration was filtered through a form included in the wiki. Each user request is now sent by e-mail to an e-mail address managed by the consortium. Every user has to complete an information form, so the wiki managers can double check that they are not a bot 'user' and that they have an appropriate profile (e.g. ATM-, aviation-, research-related, etc). Once this information is checked, it is individually approved or denied. After this system was implemented, the user registrations related to bots were fewer than 10. This system, although not automatic, has proven useful and secure.

The main lesson learned on user registration and rights, has been that the easiest and most productive way of managing the wiki in terms of user rights, is to create a new user group dedicated to each feature as needed. This means that each user can be added to as many groups as needed, and can thus use the wiki in different ways. The main groups assigned are currently:

- **Bot:** 'users' added to this group are automatically marked as spam and blocked from editing;
- **Administrator:** this is only used by the Innaxis team as they are the ones who have full control of the wiki;
- **Program editor:** the users under this group are allowed to edit the university programmes under: https://wikiengagektn.com/EngageWiki:Programmes;
- **Editor:** only used by the Engage team as it provides editing privileges to certain pages, which regular users don't need to have;
- **Approved for the courses:** this group was created in order to control the users that registered for the Engage courses on Engage's 2021 summer school, under https://wikiengagektn.com/Teaching_Resources. By creating this group, each user requesting access to the courses content was individually accepted by the Engage consortium, so we could control the download of the courses content available in AWS (see Section 9.3.2);
- **Forum administrator:** can add new topics to the discussion fora: https://wikiengagektn.com/Special:WikiForum.

None of the new users are given these rights when registering, but they can be added to any of the groups by the admin users. Every user who registers has the permissions to edit the PhD funding opportunities page, the jobs and internships page and the discussion fora (by editing threads but not adding new topics, which can only be done by admin users).

Many user groups were created in order to achieve a balance between user permissions and user active bases. The wiki was created with the idea of it being used and edited by any user on the desired features, but also there are many pages and features that cannot have editing permissions in order for them to work (such as the interactive research map or the ATM concepts roadmap).

From the beginning, the wiki was created with the aim of having an active user base. The idea was not only to have a set of tools and a repository, but also to host an active community. This has been one of the most difficult tasks the Engage team has encountered. Getting an active on-line community up and running is very difficult and, in the case of widespread fora such as Quora or StackExchange, can take years. This 'cold start' is often a problem in these types of on-line communities and even more so in niche communities such as ATM. To try to solve this problem, special efforts were made to advertise the wiki in different events (e.g. SIDs, workshops, and summer schools). In addition, the consortium published a number of introductory/promotional videos on the wiki landing page, in 2022.

Although thanks to these efforts it was possible to increase the number of users of the wiki, the active participation of users is still low and should be considered as one of the important objectives in any future development. The number of external *registered* users is 70. It is currently not possible to measure the number of page *accesses* in MediaWiki. We installed a plug-in that shows users info. This, unfortunately, only shows information for the editing of basic/main pages but not a count for the child pages, that would be more useful. Further modifications would be needed for this.

Further fora engagement and promotion was discussed in Section 5.3, and is picked up again in Section 10.

9.3 Technical lessons

9.3.1 Wiki hosting

The wiki and its domain are hosted together within Siteground. They are hosted in an independent hosting account. The hosting has sufficient space to host the wiki on a basic plan, and all the external documents to it are hosted in Amazon Web Services (AWS, see Section 9.3.2). Having an independent account for the wiki hosting also eases any handover of the wiki and its management by anyone who is provided with credentials (e.g. a future KTN, under SESAR 3). SiteGround provides hosting tools that are also common to any website and these are easy to use.

9.3.2 External resources storage

The server where the wiki is hosted has extra space available, but it is recommended that all the resources of this server are used towards the proper functioning of the wiki, as this would take up extra resources when some of the heaviest features are in use (such as the European university programmes, the interactive research map of ATM or the ATM concepts roadmap).

Amazon Simple Storage Service (Amazon S3) is an unmanaged object storage service that supports different workloads and data types, such as unstructured and structured data. This service offers the setting of custom file-based service levels for cost efficiency as well as other useful features such as: file versioning out of the box, file event notifications and server access logging, which is really useful for monitoring and managing the platform.

Amazon supports having different data storage partitions in Amazon S3 using so-called ‘buckets’. There is a dedicated namespace per bucket to provide a custom data structure per bucket. Some features are enabled or disabled at the bucket level: file versioning, file encryption, public access and server access logging. Innaxis owns an Amazon Web Services account with S3 buckets and has set up a bucket that contains a dedicated Engage public folder, where Innaxis public documents related to the Engage project are stored. A specific folder for the wiki was created within the Engage folder and this is where the courses have been stored. The reason for choosing AWS over other services was mainly the security it offers, added to the fact that it is easy to use and manage, with unlimited storage data.

Input data is stored in separate buckets per data provider. In particular, all the files in the wiki are stored under the same bucket, separated from other data sources hosted in an Innaxis AWS account. This way, we can offer custom features for data providers and provide a dedicated storage interface that they are comfortable to manage. Those partitions have file versioning disabled, although we manage data releases in folders, but this isn’t the case for the Engage wiki bucket as there is a unique version of the files. We prefer this approach to simplify duplicate file management. Also, files are not encrypted in the platform and files are compressed in order to minimise download times and save costs. Modification permissions are managed through AWS IAM. Finally, server access logging is enabled for all data partitions, ensuring both expected and unexpected access is properly logged and handled through the monitoring service. For security purposes, Innaxis is the owner of this storage bucket, and is the only entity with access to it. Licensing handover and future KTN provisions are discussed in Section 10.

10 Next steps and SESAR 3

10.1 Existing support for the wiki in 2022 – our commitment

As previously set out in Engage deliverable D3.8 [8], the following summarises the activities that will, and will not, be supported by the current KTN **after closure of the project** in 2022.

1. **Wiki maintenance**: the content will be accessible to the whole community, including the wiki pages and all the material that is associated with it / uploaded thereto. However, no additional updates will be made, except those mentioned in (2) and (3). The material available up to the project closure date will be frozen, maintaining it as it was at that date. This maintenance level will require some continued resources to cover the hosting costs, but limited work effort. The Engage partners have agreed to cover the expenses associated with the wiki maintenance in read-only mode for five years after the contract closure. Access and navigation through all wiki pages will be available, including interactive maps and filtering.

2. **Existing users**: users previously registered as wiki contributors (registered authors) will still be able to update the wiki content. These updates will not be monitored by the Engage partners. Most users have rights to edit the discussion fora, the PhD funding opportunities and the jobs and internships page. The users that have rights to edit the European university programmes will continue to be able to do so. Users that have access to the teaching resources page will be able to access the courses content.

3. **New users:** the Engage consortium will continue to review and accept new user requests until the end of the KTN, after which, no user requests will be reviewed. The registration link will be hidden just before the end of the project.

4. **'Contact us' forms:** contact forms or contact e-mails will be removed from the wiki before the end of the project (since responses would not be managed under the current contract), or replaced with a SESAR 3 SJU contact point, as preferred. If the latter is adopted, provision would need to be arranged for how responses/requests would be managed in practice.

Alternative provision for (2) - (4), in 2022, for example designed for the period before any KTN is launched within SESAR 3, is discussed in Section 10.2. Provision beyond this, i.e. for any KTN launched within SESAR 3, is discussed in Section 10.3.

In order to promote the use of the wiki, some short videos about the wiki and its features were created and posted on the landing page of the wiki, in 2022.

Furthermore, on approval by the SJU, the two Engage 'legacy' deliverables:

- D3.9: The Engage wiki - an update on the KTN's knowledge hub functionality, research maps and repository)
- D3.10: Research and innovation insights

will be e-mailed *directly* to all the Engage industry partners (https://engagektn.com/about/), who may not be party to some other lines of communication), in addition to being published on the Engage website and wiki, with direct promotion also requested of the SJU via the SESAR *e-news*. Feedback will be invited on these reports, and such feedback will be shared with the coordinator of any (new) KTN launched as part of the SESAR 3 ER programme.

10.2 Extended support for the wiki in 2022 – bridging the gap to SESAR 3

This section describes additional support for the wiki, which could be provided by some members of the current consortium, **subject to a new contract** (irrespective of the funder), for example designed for the period **before any KTN is launched within SESAR 3**, to maintain the wiki in a more active mode than the more passive mode described above.

Firstly, constraints (2) - (4), above, would be relaxed, and supported as per the *current* KTN wiki support.

Furthermore, the following activities could be additionally supported:

- adding one batch of new, pre-anonymised (by the providing party; supplied with appropriate input metadata) materials to the EngageWiki **repository**, as one action (i.e. not dispersed over several months);
- carrying out one new research clustering and update of the **interactive research map**;
- carrying out one **new forward cluster, or gap analysis**, as per Section 4.3, providing (uninterpreted) raw output for further research purposes by interested parties;
- adding **new horizon flagships to the ATM concepts roadmap** and mapping them to the SRIA (this comprises integrating *new* PDFs provided by a third party, and is in *addition* to the posting of those developed as per Engage deliverable D3.10);
- supplying and executing (as appropriate) **communications** on the above tasks in a manner preferred by the SESAR 3 JU communications team;
- **managing and liaising** on the above tasks, with support to the contracting client.

Regarding the first bullet-point, the new data could be added to extend IR/ER coverage. Such material could be sourced as a priority from recently completed and on-going SESAR 2020 projects and conferences (e.g. SIDs, ATM Seminar and potentially ICRAT). Table 10-1 shows the status of relevant material in the wiki from projects funded through recent SESAR 2020 Calls.

Table 10-1 Wiki coverage of recent SESAR 2020 Calls

Call	Project start-end dates	Status of project material in the wiki
VLD Geofencing	2018-2019	not considered yet
U-space	2018-2020	not considered yet
ER4	2020-2022	partial coverage
VLD Open 2	2020-2022	no material available at the time of sourcing
IR Wave 3	2020-2022	no material available at the time of sourcing

10.3 The wiki in SESAR 3

Regarding the potential handover of the wiki to any KTN launched within SESAR 3, if required, the current consortium *gives notice that*:

- the EngageWiki hosting and domain are both secured with sufficient longevity to hand over all licensing and access control to any future KTN in SESAR 3, should this be required. Full and sufficient details would be disclosed to the SESAR 3 JU, by the current KTN coordinator, on request and without delay, to effect a smooth transition to any such successor KTN;

- a full review of the lessons learned, as described in Section 9, is recommended to be carried out by any KTN launched within SESAR 3, in consultation with the SESAR 3 JU, and, in particular, that the current KTN coordinator would put itself at the disposal, *gratis*, of parties engaged in such a review, for corresponding matters of clarification.

Regarding potential activities associated with the wiki's development in SESAR 3, the current consortium *recommends that*:

- further data be added to the repository and incorporated into the interactive research map and ATM concepts roadmap on an annual basis (including projects flagged in Table 10-1, those funded through SESAR 3 Calls, and material from other non-SESAR industrial research programmes), in conjunction with a full review of the lessons learned, as described in Section 9;

- through promotional activities such as those mentioned in Section 10.1, the wiki discussion fora be further deployed to gather sufficient momentum to become hubs for various communications and discussions in SESAR 3; several examples were given in Section 5.3;

- the horizon flagship activities of Section 4.4 may be updated and further populated through continued research, drawing on outputs from Engage, more widely in SESAR and beyond ATM, through wiki user inputs, including interdisciplinary concepts, and formally integrated into the ATM concepts roadmap;

- the future research proposed by the research community through the Engage workshops and catalyst fund activities, *inter alia*, and as put forward by the Engage consortium, including the recommendations for the implementation of this research, as set out in Engage deliverable D3.10 (Research and innovation insights) [7], be reviewed and duly considered for further action, in particular through any KTN launched within SESAR 3;

- as per Section 10.1, the two Engage legacy deliverables (D3.9 and D3.10), having been e-mailed directly to all the Engage industry partners, in addition to being published on the Engage website and wiki, with other direct, wider promotion requested of the SJU, the feedback invited and received on these reports should be shared with the coordinator of any KTN launched within SESAR 3.

11 References

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12 Acronyms

AI	artificial intelligence
ATM	air traffic management
AWS	Amazon Web Services
AWS IAM	Amazon Web Services Identity and Access Management
BAFO	best and final offer
CORDIS	Community Research and Development Information Service
EC	European Commission
ECAC	European Civil Aviation Conference
ER	exploratory research
GA	Grant Agreement
GDPR	General Data Protection Regulation
H2020	Horizon 2020 research programme
ICRAT	International Conference for Research in Air Transportation
IR	industrial research
KTN	knowledge transfer network
LSD	large scale demonstration
MFF	multi-annual financial framework
NLP	natural language processing
NLTK	natural language toolkit
PG	postgraduate
R&D	research and development
R&I	research and innovation
S3	Simple Storage Service (Amazon)
SDA	SESAR Digital Academy
SESAR	Single European Sky ATM research
SIDs	SESAR Innovation Days

SJU	SESAR Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
TC	thematic challenge
TF-IDF	term frequency-inverse document frequency
UG	undergraduate
URL	uniform resource locator
WBS	work breakdown structure
WP-E	SESAR Workpackage E (long-term and innovative research)

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