# THE „LUV“ PROJECT FOR THE CONCEPTION OF U-SPACE IN GERMANY

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## Abstract

With the adoption of the U-space regulation, the EU has created the legal basis for the establishment of U-spaces. This regulation leaves the member states some freedom of design with regard to the definition of processes, actors and responsibilities. To utilize this leeway, recommendations must be developed for the national implementation. The „LUV“ project develops an operational concept for the realization of an U-space airspace with a single common information service provider (SCISP) and several U-space service providers (USSP) including economic and simulative analyses, taking into account technical, legal and organizational requirements. These results will be used to develop recommendations for action for the national implementation. This paper presents initial results of this ongoing work.

## 1. INTRODUCTION AND PROBLEM DEFINITION

The EU created the legal basis for the establishment of U-spaces with the adoption of the U-space regulation in April 2021 [1]. Many details are left to national regulations of the EU member states. No technical details of implementation were defined, so the regulation left a lot of detailed work for analysis, interpretation, and development of solutions. One of the results of the "U-Space Reallabor Hamburg" [2] is that, for reasons of safety, complexity, and the need for unambiguous reliable information regarding traffic situation, position of the aircraft, and geographical data stock, a U-space model involving a SCISP should be pursued. In the “U-Space Reallabor Hamburg” project as well as UDVeo [3] practical concepts and solutions for the integration of UAS into the urban airspace were developed and essential processes of registration, flight permission and release as well as strategic and tactical conflict management were implemented. Additionally, initial elaborations on flowcharts of the mandatory and optional U-space services, dynamic changes in U-space airspace and coordination of manned and unmanned aviation have been created. LUV builds upon these results to realize the U-space operational concept and to develop recommendations for the national implementation of the U-space regulation (see [4]). The preliminary considerations from these two projects are further specified and systematized within LUV.

Based on the developed U-space operational concept, process models for the technical and operational foundation for the implementation of U-space airspaces are created, in which the individual actors, their responsibilities as well as information flows and involved systems in the respective process steps are presented. The group of actors considered and their interactions are expanded to include not only UAS operators, USSPs, SCISP, and ANSP, but also use cases involving General Aviation as well as Safety & Security Authorities (SSA) / HEMS, relevant supra-regional agencies, local agencies, and other data service providers (DSS). LUV also describes a possible process of dynamic reconfiguration of airspaces, which is of particular importance for the coordination of manned and unmanned aviation.

To identify regulatory tools for competitive and safe U-space operations, theoretical traffic scenarios and fundamentals of a practical drone operation are developed with respect to the described U-space operational concept. This includes scientific consideration of business and pricing models including appropriate models for USSPs and cost reimbursement mechanisms for the SCISP as well. Furthermore, a procedural proposal according to Art. 18f in [1]) is created, which enables the administrative participation of other, especially local authorities and agencies in the designation and design process of a U-space airspace, and promotes acceptance in the urban airspace through participation procedures. This paper focuses on a detailed technical view of the systems to be set up by the involved actors, the identification of required functionalities, and the communication structures with respect to scalability, configurability, confidentiality, and reliability.

## 2. BASIC PRINCIPLES OF THE OPERATING CONCEPT

A U-space provides a framework for UAS operators to conduct safe and efficient UAS missions in urban areas or areas with increased traffic volumes. Some use cases that can be facilitated through U-space structures are the inspection of long-distance infrastructure (e.g. railway tracks, power lines), real estate inspection, inter-hospital deliveries, or the use of UAS in agriculture. It also determines a set of rules and requirements that UAS operators need to abide by in order to be allowed to operate within a U-space. One of these requirements is to use mandatory U-space services from a USSP, which are specified in the U-space regulation [1]. These include network identification service (NIS), geo-awareness service

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doi: 10.25967/570074

(GAS), UAS flight authorization service (U-FAS) and traffic information service (TIS). Further services, such as the conformance monitoring service (CMS) and the weather information service (WIS) can be mandated by a member state based on the airspace risk assessment of a specific U-space. Additional voluntary services can also be procured. To obtain all or some of these services, UAS operators provide the USSP with data about their mission, vehicle, and flight plan, and in return they receive a dynamically updated traffic situation picture as well as warnings and clearances. Besides regular private or commercial UAS operators, there are also public agency operators that are not obliged to utilize U-space services from USSPs in Germany.

Since multiple USSPs will be able to operate in the same U-space, the operations across these USSPs need to be coordinated. To do so, information and data about planned and ongoing missions will be consolidated and distributed via a data hub – the Common Information Service Provider (CISP). In Germany, the CISP is expected to be implemented as a national single CISP, a SCISP. In terms of safety and data conformity, a nationwide SCISP creates a single source of truth regarding traffic and geodata and reduces interfaces between the individual USSPs. This reduces the risk of ambiguity in the data and thus the risk of safety critical incidents.

According to [1] the U-space ecosystem will require a number of data flow processes between the SCISP, and the U-space service provisions to UAS operators by USSPs. There will be a number of input providers to the SCISP and the USSPs, and another number of service consumer systems behind the USSP. Connected to the SCISP through data streams are actors that hold and provide necessary information for the operation of a U-space, such as the ANSP, geodata providers, control centers of public agencies, as well as further data providers. The main task of the ANSP within the U-space context is to provide traffic data of manned aviation and to initiate dynamic airspace reconfigurations (DAR) in case of manned aircraft operations in U-space airspaces. In return, according to the LUV proposal, the involved units of the ANSP receive information about unmanned aircraft operations in controlled airspace.

In Germany, the regulatory framework of the U-space ecosystem is defined by a range of institutions and agencies. The initial designation of a U-space airspace is the task of the Federal Ministry for Digital and Transport (BMDV). One possible way to facilitate this task is to appoint a U-space coordinator for each U-space. This coordinator would be in charge of conducting the risk assessment for the designation of the U-space airspace~~.~~ To ensure safe and structured operations, all essential actors tasked with infrastructure provision will be certified. This certification could prospectively be part of the responsibility of the Federal Supervisory Authority for Air Navigation Services (BAF). They would then establish and oversee the certification processes of the SCISP and the USSPs. UAS operators do not need to be certified but are required to be registered with the Federal Aviation Authority (LBA). Together with the State Aviation Authorities (LLBs), the LBA is also responsible for managing operational authorizations. Finally, police authorities are in charge of law enforcement, e.g. when UAS operators do not comply with the regulations.

## 3. SYSTEMS INVOLVED AND THEIR TECHNICAL INTERACTION

The most fundamental data services delivering into the SCISP system will be geodata sources and GIS systems on the one hand, and ATM traffic data on the other. A subset of the geodata is the U-space information as specified in [1], like U-space coordinates, names, relevant metadata, and geozones with qualifications and metadata for UAS. For geodata sources the contribution of aeronautical databases, of geodata sources providing the information on UAS-relevant objects and areas, and background map tile sources with geodata feature tiles, terrain feature tiles, or satellite imagery tiles need to be considered. The responsible authority to maintain the aeronautical map database in Germany is the Deutsche Flugsicherung (DFS). The geodata maintenance department is in charge of maintaining and updating the AERO-DB, which is the primary source for piloting charts, the AIP publication, and the map data in all ATM systems. Since the end of 2021, DFS also maintains the geodatabase for „DIPUL“, the “digital platform for unmanned aviation” in Germany (for details see [5]). DIPUL provides geozones (mostly no-fly zones resp. zones with preconditions for UAS flights) for UAS pilots nationwide. The DIPUL geodatabase contains not only the relevant data from the AERO-DB, but also all UAS geozones and no-fly-zones (NFZs) according to §21 of the LuftVO, plus the aforementioned background map tiles. These data components are collected with the Federal Agency for Cartography and Geodesy (BKG), plus from a variety of authority sources for specific subjects like nature reserves, or power distribution infrastructure. It turned into a significantly large dataset of more than 500 GB that reflects the current nationwide status of relevant UAS zones. This combined geodata base of the DIPUL therefore may act as a suitable starting point for the geodatabase of a nationwide SCISP. There will be more data and more contributions needed, as we will see at a later stage of our discussion. The geozones and their cyclic updates shall be provided to the USSPs, as well as event-based geodata extensions that are provided by third-party authorities. USSPs will use these data inputs for creating situational awareness displays and for the automated detection of conflicts.

ATM traffic data will be provided by the ANSP. Since ATM systems today are designed yet for specific locations like towers at major airports, or area control centers servicing a certain flight information region (FIR), it is not wise to retrieve the aircraft position data from there, but to use the ATM sensor data distribution in the RADNET, a packet-switched, protected, private, wide area network created and maintained by DFS. RADNET contains all measured/ sensed 4D aircraft position data that are visible in controlled airspace. These raw position data are tracked and fused by a central tracking unit, a multisensor data fusion (MSDF) tracker. In Germany, such a central MSDF tracking unit exists with the PHOENIX tracker in the DFS SCISP/UTM cloud (see [6] for details). This system has also been extended to read the position data of UAS and manned aircraft in VLL, and to track and fuse them as well. The evolution of the tracker for processing also UAS flights is described in [7]. If we understand U-space traffic information as the full set of manned and unmanned aircraft identification and position data, and kinematics (speed, course, RoCD, acceleration), this system is the potential source to provide these data to all U-spaces nationwide.

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The system is an extension of the ATM systems operating in ATC towers and area control centers. These ATC units also use the PHOENIX tracker core to process the ATM sensor data and to create an air situation picture for controllers, however, limited to the ATC sensors covering the related control zone only. Nevertheless, the ATM systems will be needed as well for the SCISPs full-service provision to the USSPs, namely for issuing DARs.

The U-space regulation's concept for the coordination of manned and unmanned aviation is based on three principles: (a) segregation into different airspaces (b) UAS have to give way to manned aviation, (c) within controlled airspace, DAR of a given U-space has to be performed when a manned aircraft enters it. A DAR can be implemented as a coordination message that is transferred from an air traffic controller`s action in an ATM system to the USSPs servicing the affected U-space via the SCISP system. The SCISP system, which is designed to operate fully automatically, uses the inherent geoinformation in the message to dispatch to the USSP(s) in the affected U-space. The USSPs forward the DAR information to the their UAS operators, which react accordingly and navigate their UAS out of the potential conflict. Additional details, like confirmation readback, treatment of contingency and emergency cases etc. are necessary, but omitted here for brevity.

Accordingly, the SCISP system fulfills several functions: provision of U-space information and geodata to the USSPs (incl. cyclic and temp. event-based updates), usage of ATM plots for MSDF tracking, and track provision (= traffic information) to the USSPs, dispatching of DAR coordination messages from ATM to USSPs, and back. The scope of the SCISP is nationwide, so its platform must be scalable to match the increasing needs. The potential number of connected USSPs may grow, and the connections will grow nationwide. The data communication will be both time and safety critical, which implies the necessity for encrypted communication, and 24x7 operation. Consequently, the SCISP system must be a firewalled, DMZ-protected, staged HA-cloud, which shall be automatically supervised by monitoring systems, scripted switch-over and fallback mechanisms, and serviced by scalable virtual hardware resources, residing on a physical server farm. Its service connections need high configurability to adapt to the individual link needs. At the same time, communication needs to be protected against spying and spoofing, e.g. protected by HTTPS. The DIPUL cloud is a suitable prototype for such a SCISP farm.

UAS traffic management (UTM) services and systems will be provided and operated by the USSPs. UTM systems will compute and provide their services to the operators based on the continuous data streams and tracking services of the SCISP and further information sources. UTM systems will provide comprehensive air situation displays to operators – desktop and mobile, or forward data to operators' command and control centers or ground control stations, using either direct browser-based web client displays, APIs, or data feeds. It is likely that the UTM systems will also be cloud-based.

UAS and local VFR aircraft in the VLL airspace are not detected by standard ATM sensors like radar, multilateration, or IFR aircraft ADS-B. Therefore, USSPs may install additional means of sensing and positioning this kind of traffic. Such local sensors may use LTE/5G transmissions of telemetry, FLARM, and local ADS-B transmitters and receivers to capture that traffic. When processing that data, USSPs might observe that there are missing aircraft position data, outliers, doubled data, and all kinds of positional and time-based error effects. Instead of trying to establish their own tracking infrastructure (which usually is going to be expensive), there is the possibility to use the MSDF in the SCISP system instead. USSPs could forward their local sensor data to the SCISP and in return receive fused tracks. The time delay of that communication is minimal, indeed very well observed in the SCISP monitoring systems, and the IMM-Kalman filter-based track computation compensates travel time effects (see [6] for details). Still it needs to be assured that USSPs can differentiate their services on the market, and no free-loading effects occur in case USSPs install additional sensors at their own cost and benefit. Thus, the economic viability of such a solution needs further evaluation.

Flight plan data of drone missions needs to be kept as private as possible to avoid harming the business interest of UAS operators. Nevertheless, as per U-space regulation, it is necessary to share details within a U-space, to facilitate identifying strategic conflicts of overlapping operations. While UAS operations that stay local in one U-space may be kept in the local systems of this U-space, this operator, and this USSP, the situation with operations exceeding one U-space hence will be different, the trans-local parts of the operation will eventually need to be coordinated with other USSPs. A similar situation will be found, when several USSPs operate in one U-space. It is also envisaged that non-local flights of SSA drone operations or military (MIL) operations will be shared with the affected U-spaces. A sufficiently detailed data model needs to be elaborated then for what part may be publicly shared and what needs to remain private.

Warnings and alerts in U-space comprise collision warnings among UAS, collision warnings among UAS and manned aircraft, NFZ area intrusion alerts for UAS, and conformance monitoring of an UAS to its published and coordinated flight plan. Responsible for the detection of potential conformance conflicts and the issuing of warnings are the USSPs. Local conflicts may be kept local, but conflicts that potentially exceed the local nature very probably need to be reported to a wider audience, which could be neighboring USSPs, or ANSP units. There is again some synergy to be found in using services that may already be computed at the SCISP level, e.g., conflicts of the area intrusion type, or conflicts between UAS and manned aircraft.

Weather data for UAS operations will soon be available in the DIPUL, and could also be available via the SCISP services to any USSP. Building on the existing collaboration between DWD and DFS, detailed weather data for UAS operations could be provided. Nevertheless, USSPs can choose to provide other weather services to UAS operators, e.g. coastal information or local city-related micro weather. In general, USSPs can take into consideration using any further local data service systems (DSS) that provide additional data for service enhancements. In port environments, for example, this could be the inclusion of ship traffic from the AIS system into the traffic information service. There is no need to distribute such data via the SCISP infrastructure.

NOTAM data by the GroupEAD are received permanently at the DFS cloud. These data components will also become part of the DIPUL in its next versions, and they can be distributed to the affected USSPs by the SCISP system, using the geospatial reference data in the NOTAM messages.

A challenge in the operation of U-spaces is the handling of temporary NFZs. These NFZs may be needed by communities to block the airspace above ground events, e.g. fairs or a weekly markets. Temporary NFZs will also be needed by police or SAR forces, e.g., in case of an accident. Due to the variety of actors, the collection of these data will need to be organized in a decentralized manner. Hence a geodata editing functionality into the SCISP database should be provided to the relevant actors for a given U-space, who will be able to create NFZ based on their individual responsibility (limiting geographical scope of their individual editing capabilities). This way, a nationwide collaboration of authorized contributors may be established that enables the consistent maintenance of temporary NFZs for U-spaces.

Our considerations so far can be summed up in the „Bowtie model“ of the U-space system landscape in Germany as depicted in figure 1.

The planned components in the SCISP system are depicted in figure 2. It displays just one segment of the necessary staged cloud. Components in the grey box are part of the central cloud system, designed in a HA architecture. The setup is a staged cloud with a private segment for testing, and a public segment for operations and public access. The white boxes outside the grey area symbolize the web-/browser-based clients, mainly those for NFZ editors. Reference displays, service and administration monitor are used by system operators, while the box on the left hand side represents access for the public to read the CIS web information pages (similar to what exists today in the DIPUL). Inside the grey box we find a series of servers, double-boxed to indicate the HA arrangement, and connected to a common data bus:

- a data distribution server filtering and distributing the subscribed data sets to the subscribing USSPs
- a publish&subscribe service in connection with a user management and related service configuration (both servicing human and machine interactors)
- a geoserver to provide the geodata to other servers and to the external clients including the links to the USSP systems
- and the geodatabase behind the geoserver
- a PHOENIX MSDF track server
- a mission resp. flight plan server for UAS, VFR aircraft and HEMS aircraft
- a conflict server, computing the conflicts between UAS and manned aircraft, and UAS and restricting geozones
- a NOTAM server to receive data from GroupEAD, filter it, and forward it to distribution
- a METEO server to receive data from DWD, transform it to needed parameters, and forward it to distribution
- an altitude conversion server to ensure permanently most accurate conversions between geometric and barometric altitudes for internal services (and optionally also for external customers)

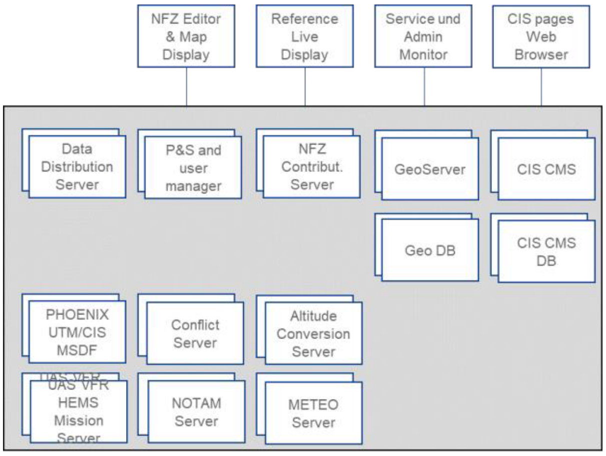

Figure 2: SCISP system components

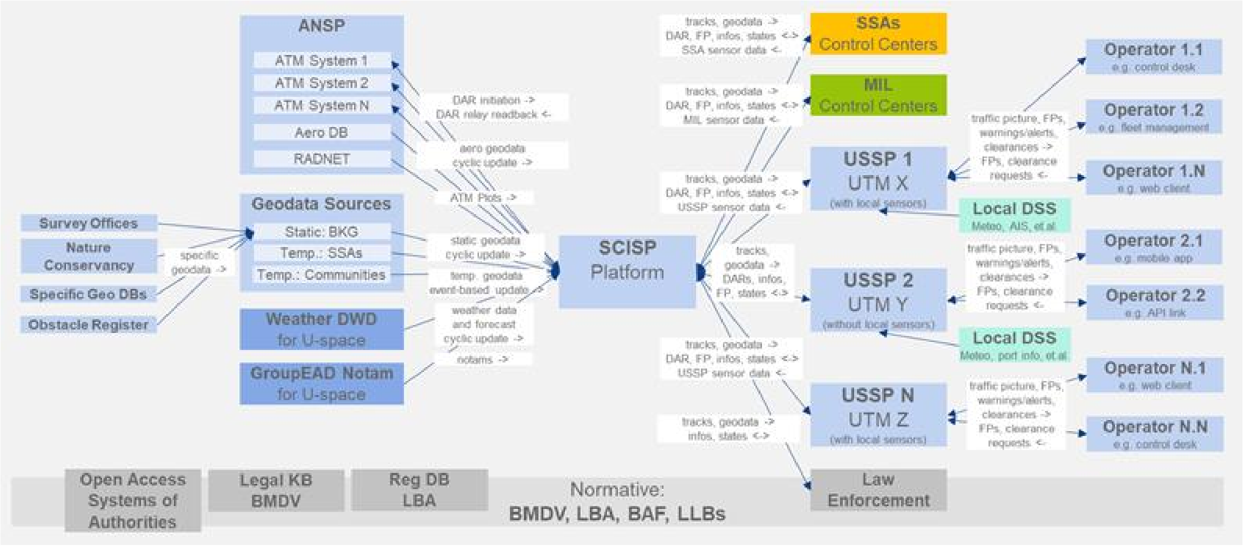

Figure 1: Bowtie model of the U-space system landscape

- a CIS content management system (CMS) to provide accessible website information on the SCISP services for both human and machine access
- and its content database

Figure 3 depicts a generic UTM architecture as the main system at the USSPs. We assume that it also needs scalability, stagedness, web-based clients, and HA. The SCISP and USSP platforms will permanently interact with each other.

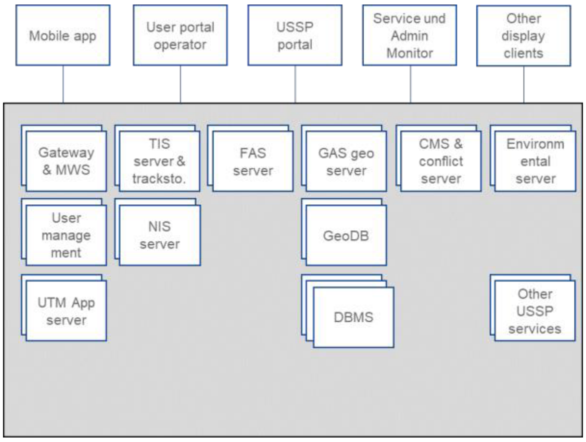

Figure 3: Components of a generic UTM system

The generic UTM contains:

- a communication gateway to receive and distribute data and messages to the outside world,
- possibly combined with a middleware server for the internal communications
- a user management server, maybe also including a P&S service for the operators or their systems
- a UTM application server that prepares, updates and maintains the contents for the display clients
- a TIS server including the maintained trackstore which is filled up with the track messages from the SCISP
- behind the TIS a NIS server that combines the track-ids with the related UAS information (registration id, serial number, callsign, network id, according to the U-space applicable standard etc.)
- a (U-)FAS server including the flight plan management
- a CMS server to compute conformance monitoring, and other conflicts (strategic conflicting) possibly in workshare with the SCISP, dedicated to more local conflicts)
- at a later stage that could be paired with a conflict resolution server that computes conflict resolutions for strategic and tactical aspects,
- a DBMS with the DBs for missions, logs, users, companies, documents, checklists, and UAS
- a geoserver for geodata provision for map drawing or geospatial computations, maybe combined with a tile server for the background maps
- behind that the geo DB, maybe separate from the other DBs to scale for more drawing performance
- an environmental server for MET data and NOTAMs (there is also potential to extend it to environmental conflict computation)
- and other service modules, implemented in background server processes, reflecting the service policy of the USSP

The attached display clients likely comprise:

- A web- and browser-based user portal for the operator
- A USSP portal and reference air situation display
- An administration portal (including system monitoring)
- A mobile app to support pilots in the field
- Other service displays according to the service profile of the USSP

Communication between the systems will apply a variety of technologies, using partly existing communications, partly new communications without a standard, and partly with usage of new communication standards. There will be a mix of LAN, Internet, and mobile telecommunication technologies. LAN communication exists between ANSP and SCISP, to some extend also with the other authorities. Between USSPs and SCISP internet websockets and HTTPS are a probable choice, and to the UAS operators besides VPN and internet also mobile communication comes into place. The contents for the communication are briefly depicted in the bowtie model of systems in figure 1. The following table provides a first non-exhaustive sketch of the foreseen links:

| **Connection** | **Contents** | **Technology** |
|---|---|---|
| ANSP->SCISP | Geodata (Shape, GeoJson) | FTP, file transfer |
| | ATC plot data in ASTERIX | UDP |
| | DARs (Json) | TCP |
| DWD->SCISP | UAS weather (grib2 format) | FTP |
| BKG->SCISP | Geodata (Shape, GeoJson) | WFS, FTP, file transfer |
| Communities/ Police->SCISP | Temp. geodata (GeoJson, KML, Shape) | Inputs in SCISP webclients |
| | | File upload |
| SCISP->USSP | Tracks (Json) | HTTPS websockets |
| | Geodata (GeoJson-> ED269) | HTTPS websockets |
| | DARs (Json) | HTTPS websockets |
| | UAS flightplans (Json) | HTTPS websockets |
| | Alerts (AIA, STCA with A/C) (Json) | HTTPS websockets |
| USSP->SCISP | Local U-space sensor plots (Json, Mavlink, | HTTPS websockets |

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| Connection | Contents | Technology |
|---|---|---|
| | CSV, other telemetry formats) | |
| | Alerts (relevant CMS, relevant local STCA) (Json) | HTTPS websockets |
| | UAS flightplans (Json) | HTTPS websockets |
| USSP->UAS operators | Traffic data (Tracks, flightplans, alerts, other U-space status data like weather and conditions) (Json) | HTTPS websockets |
| | | API access |
| | | Client displays (desktop and mobile) |
| | Warnings based on DARs | HTTPS websockets |
| | | API access |
| | | Client displays (desktop and mobile) |
| | Clearances | HTTPS websockets |
| | | API access |
| | | Client displays (desktop and mobile) |
| UAS-operators -> USSPs | Clearance requests, confirmations | HTTPS websockets |
| | | API access |
| | | Client displays (desktop and mobile) |

TAB. 1: Communication technologies in U-space systems

## 4. LUV PROCESS MODELS AND FOCAL EXAMPLES

The operational concept developed by LUV, which was described in chapter 2, creates the basis for the process models. The aim of the models is to provide a framework for the legal, technical and operational implementation of U-space airspaces, taking into account the actors involved, the process flows as well as the communication and information structures. The use of the modeling language BPMN is already established in several domains and is suitable for the description of activities. In the context of the research area of drone management, several projects and publications have already shown that this modeling language is excellently suited for the description of process steps. For example, a semi-automated framework for detecting conflicts for data minimization could be presented with BPMN [8]. Furthermore, in the CORUS project, a fundamental U-space project, first BPMN diagrams were used to describe different use cases, which could be taken up and further specified in further publications [9]. In addition, it has already been shown that the use of BPMN diagrams is also suitable for modeling U-space services from a scientific and technical point of view [10].

The Business Process Model and Notation (BPMN) modeling language can also be used to implement the process models of U-space services and use cases. The models describe a sequence of activities to be performed in order to realize a process or service relevant for a U-space under considering of a given use case.

The process models address the operation of a U-space. In addition to the life phases of a U-space, different operational phases of a U-space can be defined, which can be divided into a strategic, tactical and post flight phase (cf. Figure 4). The strategic phase describes the period in which

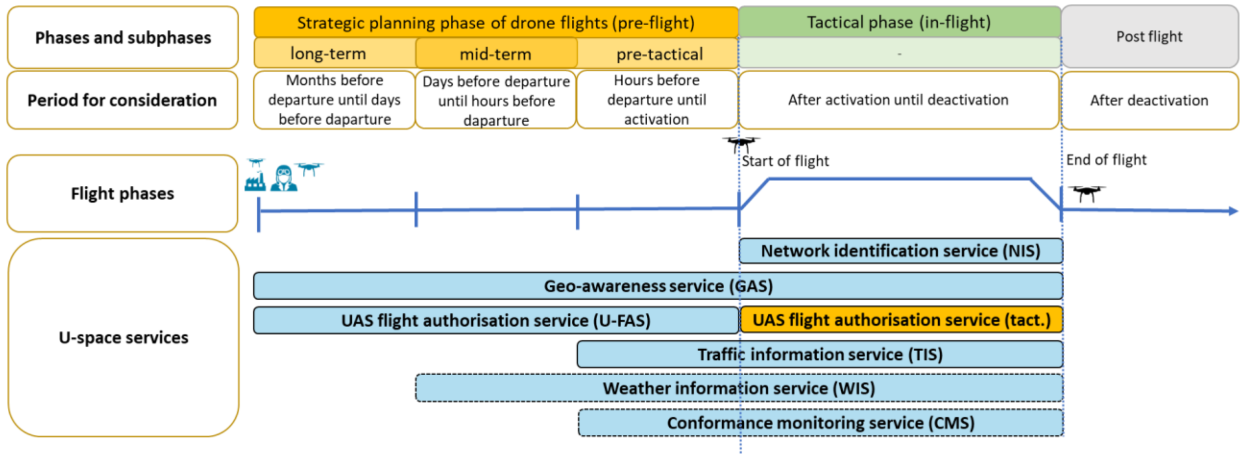

Figure 4: Operational phases of a UAS flight in a U-space

the UAS is on the ground and the planning for a UAS flight is carried out. The transition from the strategic to the tactical phase is the successful activation of a UAS flight authorization and the take-off of a UAS (mission start). When the UAS lands, the tactical phase ends and the post flight phase starts. From a UAS perspective, it is clear that the availability of U-space services is dependent on the current flight operational phase of the UAS. For example, if a UAS operator plans his UAS flight in the strategic long term phase, less U-space services will be available than in later subphases. This can have an impact on the necessary sequence of operations. Accordingly, the timing of the consideration has an impact on the processes to be modeled. In addition to the time of observation, other factors have an influence on the design of the processes, such as different triggers for an event or different requests from a user of U-space services.

Furthermore, continuously occurring processes are to be separated from the event-based ones and united in one diagram. The importance and differences of event-based and continuous processes, can be illustrated by the various U-space services. While the U-FAS can be counted among the event-based processes, the GAS service is to be assigned to the continuous processes, such as TIS, NIS, CMS and WIS. A U-FAS only reacts to incoming triggers and executes actions on them. A trigger, which can also be called an event, is, for example, the receipt of a UAS flight authorization request from a UAS operator or a change in airspace restrictions. In order for these UAS flight authorization requests to be successful and supplied with the most current data, the U-FAS relies on continuous services that update the data necessary for processing at all times. For this purpose, the GAS provides the data on current dynamic and static airspace boundaries necessary for conflict management. These processes build on SCISP processes in the background. Among the SCISP processes are again some continuous ones, and some event-based. The continuous SCISP processes, which were identified in LUV's work,  are: (1) Collection of cyclic static geodata, and its distribution to the USSPs, (2) collection of the ATM and possibly USSP sensor data, MSDF tracking, and continuous distribution to the USSPs, (3) continuous conflict detection at SCISP level for STCA conflicts among manned aircraft and UAS, and for UAS area intrusions into NFZs plus distribution of warnings and alerts, (4) UAS mission flightplan exchange among involved USSPs where needed for strategic deconfliction. Event-based SCISP processes are (1) the DAR distribution, (2) event-based temporary geodata reception, and its distribution to the USSPs.

To realize the legal, technical and operational implementation of U-space airspaces, all six U-space services of the U-space regulation, and the service processes of SCISP, as well as selected application examples are developed and transferred into process models within LUV. An example of process modeling can be given with the process of establishing a no-fly zone in U-space as well as its effects on airborne UAS.

**Establishment of a no-fly zone**:

According to U-space Regulation Art. 5 (1), dynamic NFZs are provided within the framework of the common information services, which are determined by the competent authorities. These NFZs may result in a temporary limitation for civil UAS operators of the areas of a U-space airspace where flying is not allowed. NFZs can be triggered by different events. According to LuftVO §21h para. (3) No. 11, a lateral distance of 100 meters must be maintained from accident sites and SSA operations (e.g. discovery of a bomb, fire in a building and landing of a rescue helicopter in U-space airspace) and no overflight is permitted. Major events such as G20 summit, setups of mobile ground-based obstacles such as fireworks and UAS shows require protection that needs to be considered as well.

The specific responsibility for the coverage of NFZs depends on the local distribution of competencies for the specific U-space. Therefore, it cannot be prescribed in general terms for all of the above events, but should be defined as part of the designation process. In principle, the police, public order department, fire department, and rescue squads should be integrated. All necessary information should be forwarded to the SCISP for the recording of NFZs. This includes: The entity establishing the NFZ, a unique identification number of the NFZ, a

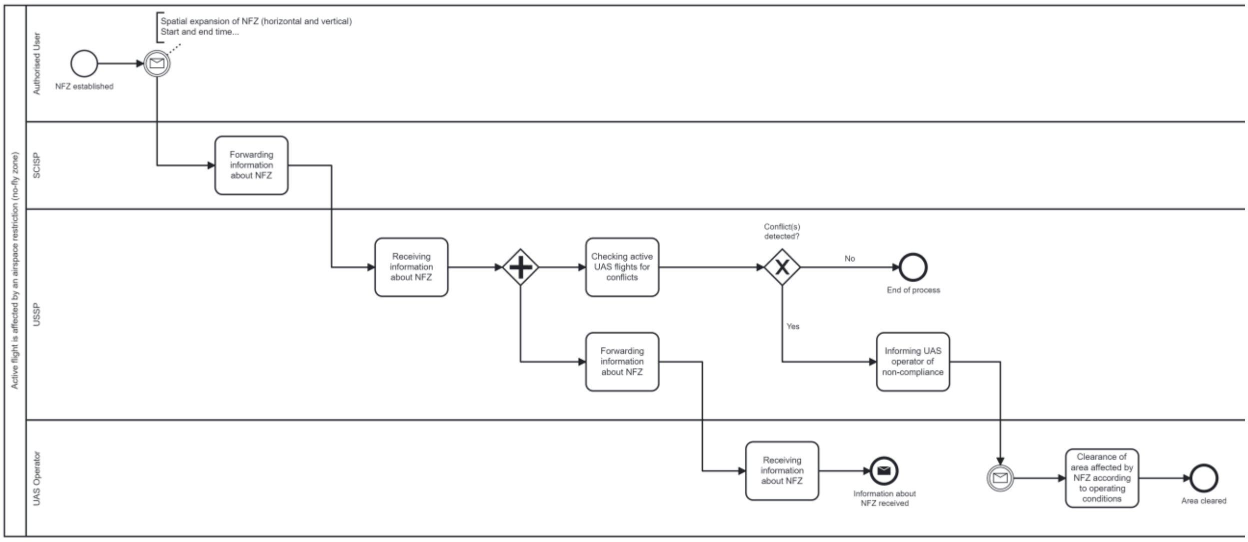

Figure 5: Active flight is affected by an airspace restriction (NFZ)

timestamp of creation, horizontal and vertical extent of the NFZ, type or reason for the NFZ, start time, end time, etc..

**Impact of a no-fly zone on active UAS flights:**

The establishment of a NFZ limits the airspace available in the U-space around the defined geographic areas of the NFZ. This can have an impact on planned and ongoing UAS flights. Figure 5 depicts the necessary actions of the U-space actors if an active UAS flight is affected as part of the establishment of a NFZ. In the first step, authorized users establishing a NFZ must forward the spatial extent of the no-fly zone to the SCISP. The SCISP immediately sends this information to all USSPs operating in this U-space. The task of each USSP is to transmit this information via the geo awareness service to all UAS operators under contract with this USSP and further to check whether the NFZ causes a conflict with flights currently taking place or in planning. If the USSP cannot identify any conflicts, the process can be terminated and no action is required. If conflicts are identified, the USSP must notify all affected UAS operators via CMS. The UAS operator must execute appropriate actions to resolve the conflict.

The example given in the context of the establishment and impact of a NFZ shows the depth level of the various process models in LUV, which are designed to describe important interfaces between actors so that a technical development of the processes can be realized.

## 5. TRAFFIC SCENARIOS AND ECONOMIC VIABILITY

In order to investigate the economic linkages and interdependencies of the actors in U-space, as well as the realization of the individual actors' strategies, possible business models are designed and mapped for them using “Business Model Canvas” (BMC) [8]. This enables the representation of different characteristics of business models and their comparison. Due to the high level of an abstract overview provided by the BMC, it is possible for the individual actors to quickly grasp the business models of the partners and thus iteratively revise and adapt their models to each other. In this way, the different perspectives on the U-space economic system are mapped and, using factors such as the costs incurred, key partners and resources required, value propositions offered, and revenue streams required, possible pricing models and concepts are developed between SCISP, USSPs, and the UAS operators.

Despite the commitment to an operations concept, the business models are considered only as examples, as there are multitudes of possibilities for use cases of U-space from an operator's perspective. Here, analyses and studies are consulted (e.g. by “Levitate Capital” [12] or “Drone Industry Insights” [13]) in order to focus on individual use-cases that represent a broad spectrum of usage. Use-cases from different segments (construction, logistics and agriculture) were chosen, which also cover a broad spectrum of flight missions (flying routes, volumes, areas). The use cases considered as examples are route inspection, property inspection (both from the inspection sector), inter-hospital transport (logistics) and health assessment and spraying (from the agriculture sector).

Possible pricing concepts for USSP services are (1) pay per time, (2) pay per used/occupied airspace, (3) pay per MTOW, (4) pay per flight, (5) pay per used services, (6) mission or other value based pricing, (7) combination of some or all of these. In the development of the pricing concepts, a focus on specific factors is deliberately avoided at the beginning in order to prevent a pre-determination. Nevertheless, it can already be said that there will not be just one factor for determining prices, but a cost function that includes various factors. The factors, their weighting and the corresponding combinations will be reflected in the cost functions of the possible pricing concepts.

For the SCISP services, probably a government-financed system development and service setup is required, which enables the USSP market. After the initial phase, fee models might be established. ANSP services were introduced decades ago in a similar manner, and today the services are paid based on time, distance, and weight of aircraft.

## 6. CONCLUSION AND FURTHER WORK

In this contribution, we have taken a detailed technical view on the systems that are relevant for a U-space to be created and the involved actors in the U-space ecosystem, identified the required functionalities, and presented the necessary data exchange in more detail. Cross-cutting aspects such as scalability, configurability, confidentiality, and reliability were also considered. Further project results will be elaborated and detailed in the second half of the LUV project until early 2023. Focus topics for the upcoming months will be

- The coexistence of event-based and continuous process models addressed in chapter 4 needs to be further examined and specified. The interaction of the U-space services, the SCISP services, and their dependencies must be analyzed and specified from a technical perspective for further development and implementation.

- The promotion of public acceptance of U-spaces: As art. 18 (f) of the European U-space Regulation clearly indicates the participation of local authorities in the designation process of U-space airspaces. LUV will elaborate exemplary procedures for municipalities to develop local strategies and designation processes that comply with the regulation.

- Some data models for the systems’ interfaces need refinement to reflect privacy needs and data protection issues.

- A feasibility and profitability assessment will be needed: U-space is not only a regulative ecosystem, but also a commercial one. The identified actors interact in multiple ways and exchange services and data. These interactions must be recognized in the business models of the single players. Thus, based on the results so far, implications for the still developing U-space market as well as dedicated business and pricing models will be examined.

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- The simulation-based evaluation of results: In order to test and qualify the preliminary project results, these processes, rules and business models will be challenged in a simulation-based evaluation phase.

- The deduction of final recommendations of the national implementation of U-space: central learnings and finding of the LUV project will be extracted and summarized. Thus, LUV will present a broad set of recommendations for the national implementation of U-spaces.

Despite the wide-ranging focus of LUV and the profound preparatory work of projects such as “U-Space Reallabor Hamburg” or UDVeo, multiple aspects of the U-space ecosystem still remain up to further research. Especially practical tests to gather further experiences and to challenge existing findings will become crucial. The importance of ongoing research is also emphasized in the German national funding program.

## 7. ABBREVIATIONS

| | |
|---|---|
| 5G | Fifth generation mobile telecommunication |
| ADS-B | Airborne dependant surveillance – broadcast mode |
| AERO DB | Aeronautical (geo-)database |
| ANSP | Air navigation service provider, the overarching notion for organizations that also provide air traffic services (ATSP) |
| API | Application programmer’s interface |
| ATM | Air traffic management |
| BKG | Bundesamt für Kartographie und Geodäsie |
| BMC | Business Model Canvas |
| BPMN | Business Process Model and Notation |
| CIS | Common information service |
| CMS | Conformance monitoring service;<br>in web design context also:<br>content management system |
| DAR | Dynamic airspace reconfiguration |
| DFS | Deutsche Flugsicherung;<br>The German ANSP |
| DIPUL | Digitale Plattform für unbemannte Luftfahrt;<br>Digital platform for unmanned aviation |
| DMZ | Demilitarized zone, network segment with two firewalls to protect an inner network segment against potential attacks from the internet |
| DSS | Data support service, an non-mandatory, possibly local additional support service like local sensing, local microweather, or additional specific traffic data like ships in ports |
| DWD | Deutscher Wetterdienst, the authorised and certified German weather service |
| FLARM | Flight alarm, an aircraft detection and collision warning technology developed originally for supporting glider flights |
| GAS | Geo-awareness service |
| HA staged cloud | A cloud system with two stages, one for (public) operation, one for (private) testing, with high availability (HA) provisions (like redundancy and switch-over) |
| HEMS | Helicopter Emergency Medical Services |
| HTTPS | Hypertext Transfer Protocol Secure |
| IFR | Instrument flight rules;<br>aircraft flying according to IFR |
| IMM-KF | Interacting multiple model Kalman filter; a Kalman filter extended to several motion/state transition models |
| Luft-VO | Luftverkehrsordnung;<br>Air traffic regulation |
| LTE | Long-term evolution mobile telecommunication |
| METEO | Meteorological data, usually wind, pressure, temperature, dew point, precipitation, cloud coverage |
| MSDF | Multisensor data fusion, complex statistical algorithms (usually combined with tracking) to fuse measured position data into a flight trajectory; often applies IMM-KF |
| NFZ | No-fly zone, geozone with restrictions for UAS flights |
| NIS | Network identification service |
| NOTAM | Notice to airmen, safety information to pilots and other air traffic personnel |
| P&S | Publish and subscribe, mechanism to book a data service either by human or computer |

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| | |
|---|---|
| SCISP | Single common information service provider |
| SSA | Safety&Security Authorities |
| STCA | Short-term conflict alert |
| TIS | Traffic information service |
| LUV | In German „Lösungen und Handlungsempfehlungen für die nationale Umsetzung der U-Space-Verordnung“, which means „Solutions and recommendations for action for the national implementation of the U-Space regulation“ |
| UAS | Unmanned aircraft system, consisting of the aircraft, the remote control system on ground, and the communication link |
| UDVEO | In German „Urbaner Drohnenverkehr effizient organisiert“, meaning „urban drone traffic efficiently organized“ |
| U-FAS | UAS flight authorization service |
| USSP | U-space service provider |
| UTM | UAS traffic management |
| VFR | Visual flight rules.<br>Aircraft flying according to VFR rules |
| VLL | Very low level airspace, usually below 500 ft above ground |
| WIS | Weather information service |

TAB 2: Abbreviations

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